ISSN 1648–6897 print
ISSN 1822–4199 online
JOURNAL OF ENVIRONMENTAL ENGINEERING AND LANDSCAPE MANAGEMENT
http:/www.vtu.lt/english/editions
2006, Vol XIV, No 4, 207–213

EVALUATION OF FLUCTUATION OF EQUIVALENT DOSE RATE DUE TO RADIONUCLIDE RADIATION IN BUILDINGS

Milda Pečiulienė, Gražina Grigaliūnaitė-Vonsevičienė, Aloyzas Girgždys

Laboratory of Nuclear Hydrophysics, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania.
E-mail: algi@fm.vtu.lt

Submitted 23 Apr 2006; accepted 25 May 2006

Abstract. Radionuclide gamma radiation in building materials twist natural gamma field, therefore, dosimetry investigation of ionizing radiation of natural radionuclides was carried out near various building constructions. It was detected that equivalent dose rate of natural radionuclides increases exponentially (this empirical dependence stays in force to 10–15 meters from a building) while approaching a building under investigation. It was measured that buildings increase ionizing radiation approximately 1,5–2 times. Wooden buildings are an exception. They change natural background to 5 %. The values of equivalent dose rate in buildings are distributed according to Gaussian distribution. The measured equivalent dose rate is 1,5 times smaller in wooden houses then in block, silicate and ceramic bricks houses.

Keywords: ionizing radiation, building materials, anthropogenic activity, natural radionuclides, dosimetry, equivalent dose rate, specific activity.

1. Introduction

External radiation is due to cosmic radiation impact, ionizing radiation of natural earth-nature radionuclides and artificial radionuclides.

Natural radionuclides in building materials make up one of the major human radiation sources [1, 2]. Parameters – to measure doses received by humans living in buildings built out of one or another building material – are quantities of natural radionuclides – specific activity in building materials [3].

From the point of view of radiation protection, natural ^{238}U, ^{232}Th chain radionuclides and mostly ^{40}K have the biggest impact upon human exposure deriving from building materials. Building materials might be contaminated with natural radionuclides through industry by-products and waste that are used during their manufacturing process and are characterized by a high natural radionuclide specific activity [4–7]. It might be phosphate-manufacturing waste, slag, soft ashes released by a thermopower station [8].

Ionizing radiation of radionuclides in building materials changes background and causes both internal and external human exposure. Data on specific activity of natural radionuclides in building materials is important because it allows to evaluate human exposure. The majority of human beings spend 80 % of their lives inside buildings. Equivalent dose rate caused by natural radiation in buildings should not be higher than 350 nSv/h. Equivalent dose rate caused by natural radiation in working places should not be higher than 450 nSv/h [6].

It is known that some building materials are very radioactive. Uranium (^{238}U-^{226}Ra) series decay chain product ^{222}Rn is the most dangerous radioactive isotope [9]. Specific activity of natural radionuclides belonging to uranium and thorium series, that are used in building materials in Lithuania, fluctuates from 10 to 100 Bq/kg (^{40}K specific activity is approximately 10 times bigger), meanwhile in wood – approximately 0,1 Bq/kg.

Building materials can have a double impact upon human health. Firstly, gamma radiation of radionuclides of ^{238}U family, ^{232}Th family and ^{40}K causes external human exposure. Secondly, ^{222}Rn and ^{220}Rn exhalation causes internal radiation because of radon and thoron decay products that access human respiratory system [10, 11]. A special attention is devoted to specific activity of ^{226}Ra (^{238}U family decay product) in building materials because radon emanation depends on it. However, not always a high value of ^{226}Ra specific activity encourages a high ^{222}Rn exhalation. In spite of these facts, reduction of doses of external gamma radiation has been recently low on an agenda. Issues of ^{222}Rn in buildings seem to be much more important. However, the only effective way of reduction of external radiation dose is an appropriate choise of building materials having a small quantity of mentioned radionuclides. Different countries have different regulations, standards and directives regulating permissible radionuclide quantities in various building materials [12–14].

Building materials are classified into several different types: class 1 – materials for new private houses and public buildings the effective activity parameter of which does not exceed 370 Bq/kg; class 2 – materials used for road constructions and industrial buildings the effective activity parameter of which does not exceed 740 Bq/kg; class 3 – materials used for road constructions far away from living regions the effective activity parameter of which does not exceed 2800 Bq/kg [12]. The same classification system is recognized in Austria, Finland, Slovakia, Latvia, Norway, Israel and Russia. Other countries set the limit for equivalent dose rate received due to a certain building material: the limit in Sweden cannot exceed 0,5 μSv/h; in Finland – 1 mSv/year, in Slovenia – 50 μGy/h. The German rules specify that the quantity of radium in balance should be 200 Bq/kg; in Luxembourg specific activity of ^{226}Ra cannot exceed 350 Bq/kg, ^{232}Th – 250 Bq/kg and ^{40}K – 5000 Bq/kg [13, 15].

The aim of the investigation is to carry out dosimetry measurement near various building constructions and evaluate the fluctuation of equivalent dose rate due to radiation caused by natural radionuclides in buildings.

2. Investigation methods

Mobile equipment for measuring, data registration and accumulation were used in the investigation. A cross-cut profile was made for each measuring near separate building constructions. Each cross-cut profile included from 5 to 50 points remoted from each other at a 1 meter distance. The quantity of points depends on how far is a separate construction object remoted from another building that can influence equivalent dose rate changes. Buildings chosen for investigation were built of different building materials.

The equipment depicted in Fig 1 was used to carry out the measurement of gamma radiation equivalent dose rate, caused by natural radionuclides present in building materials.

Equivalent dose rate was measured with a portable radiometer SRP-08-01. The exposure dose measurement limits of this radiometer are 0 – 27000 nSv/h. Equivalent dose rate near different buildings can be measured with this equipment. The radiometer is connected to a data register from which accumulated data are transferred to a portable computer. The portable computer is connected to the Global Positioning System (GPS). The latter is a very precise radio navigation system providing information about the position of objects in space, their velocity, direction, the distance to selected points, exact time at a given moment and geographical sunrise/sunset time. GPS works in the same way in any place of the world irrespective of weather conditions, day time or season [16].

Fig 1. Measuring equipment

The following data are accumulated in the portable computer: location co-ordinates, time and readings of the radiometer. The equipment is easily transported.

A gamma spectrometric system (CANBERRA) with a semiconductor HPGe detector was used to establish the specific activity of natural radionuclides. The detector is characterized by a big resolution 2 keV. The equipment is characterized by a direct signal, wide energy interval, undelicacy of impulse amplitude for impulse count rate, high rate of impulse increasing, undelicacy for magnetic fields.

The specific activity in the building materials of the main gamma radiation sources is identified by using 24–72 hour measurement expositions. Radionuclides were identified according to the following lines: ^{40}K – 1460 keV, ^{226}Ra – 186 keV, ^{208}Tl – 583 keV. It is known that there is no radioactive balance between specific concentration of ^{232}Th and its decay product ^{208}Tl. The ratio of their specific activity is reckoned to equal to 1,6 [17].

The background was evaluated continuously during the measurement period, its level varied insignificantly. Its ^{40}K changes constituted less than 4 % of signal volume.

3. Measurement results

Dosimetry investigation was carried out near separate building constructions using the above described measurement methodology. It was detected that equivalent dose rate caused by natural radionuclides approaching a building increased exponentially.

The analyses of experimental results show that, while going away from a building, the intensity of ionizing radiation in the majority of cases decreases to 1,5 time.

Figs 2–5 show graphics of dynamics of equivalent dose rate while going away from buildings. The figures clearly illustrate the impact of anthropogenic activity upon changes of natural background.

The graph depicted in Fig 2 clearly indicates the fluctuation of equivalent dose rate going away from block buildings. 25 identical block buildings were chosen for the investigation.

Equivalent dose rate going away from block buildings changes according to the formula:

$$\dot{H} = 163 \cdot e^{-0,04x}, \quad (1)$$

where $\dot{H}$ – equivalent dose rate, nSv/h; x – distance to the building wall, m.

The coefficient of approximation of the latter equation is considerably high ($R^2 = 0,91$). The analyses of the investigation results indicate that the influence of a building upon radiation at a distance of 10–15 meters decreases 1,6 time. Experimental investigation proved that the empirical equation for depiction of radiation fluctuation applies only at a distance to 15 meters from a building.

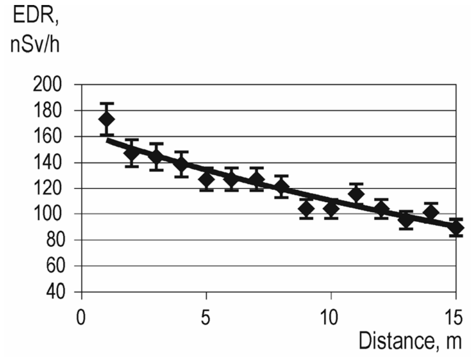

Fig 2. Equivalent dose rate (EDR) fluctuation going away from block buildings

The results of investigation of the fluctuation of radiation going away from silicate brick houses is depicted in Fig 3. 27 identical silicate brick buildings were chosen for the investigation.

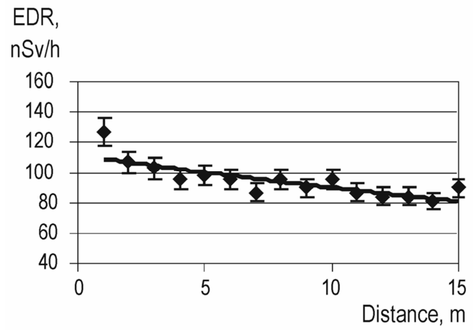

Fig 3. EDR fluctuation going away from silicate brick houses

The comparison of the results presented in Fig 2 and in Fig 3 shows that equivalent dose rate formed by gamma radiation in block houses is 1,4 time bigger than that near silicate bricks houses. This difference is predetermined by radiation of natural radionuclides present in building materials.

Using regression we arrive at an equation depicting fluctuation of equivalent dose rate going away from silicate brick houses:

$$\dot{H} = 112 \cdot e^{-0,02x}. \quad (2)$$

The coefficient of approximation of the latter equation is $R^2 = 0,70$.

After spectrometric investigation of ceramic and silicate bricks it was detected that silicate bricks contained a less quantity of radionuclides than ceramic ones (Table 1).

Table 1. Specific activity of radionuclides in samples of building materials

Building material	Number of samples	Specific activity, Bq/kg		
		^{226}Ra	^{232}Th	^{40}K
Brick (silicate)	15	32,5±8,1	14,9±4,3	749±224
Brick (ceramic)	15	68,3±10,2	36,1±4,3	980±208

Equivalent dose rates were bigger near red brick buildings (Fig 4).

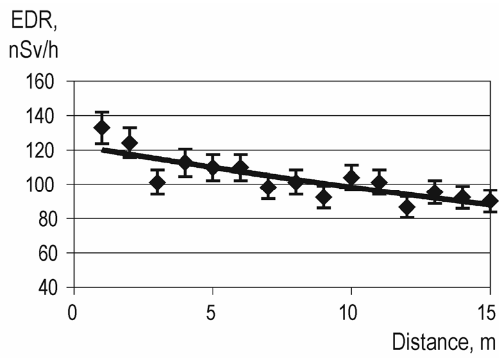

Fig 4. EDR fluctuation going away from ceramic brick houses

Going away from red brick buildings equivalent dose rate can be depicted as follows:

$$\dot{H} = 123 \cdot e^{-0,02x}. \quad (3)$$

The equation shows dependence of equivalent dose rate fluctuation upon the distance to a building. The coefficient of approximation of the equation is $R^2 = 0,71$, the latter is similar to the case of silicate brick buildings.

After measuring equivalent dose rate near wooden houses distinct fluctuation of radiation was not noticed. An average value is about 78 nSv/h. It is about 1,6 time smaller than near block buildings, and 1,3 time smaller than that near silicate brick houses.

It was found that wood contained a considerably less quantity of natural radionuclides than other building materials (Table 2), therefore, equivalent dose rate formed by wooden houses is considerably smaller and thus almost undistinguished from the natural background.

Table 2. Specific activity of ^{40}K, ^{226}Ra and ^{232}Th in wood

Number of samples	Specific activity, Bq/kg		
	^{40}K	^{226}Ra	^{232}Th
18	38,4±11,9	5,2±1,6	2,3±0,7

Fig 5 presents fluctuation of equivalent dose rate going away from a wooden building.

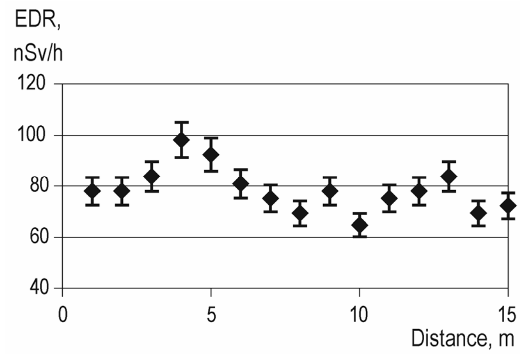

Fig 5. EDR fluctuation going away from wooden houses

Going away from wooden buildings equivalent dose rate can be depicted as follows:

$$\dot{H} = 85 \cdot e^{-0,01x} . \quad (4)$$

The coefficient of approximation of the equation is very small ($R^2 = 0,22$) and therefore applies exceptionally to separate cases.

It is important to note that the provided empirical equation applies only to a distance of 10–15 meters to the buildings under investigation. Coefficients of exponential distribution degree of equivalent dose rate caused by natural radionuclides fluctuate from –0,04 to –0,01, depending on the type of a building. It is found that, while building a house, a human increases ionizing radiation approximately 1,5 time, sometimes even 2 times. An exceptional case are wooden houses that change the natural background only by 5 %.

It was investigated what ionizing radiation was spread by separate construction objects. Fig 6 shows isolines of equivalent dose rate fluctuations caused by ionizing radiation near the only remained wall of an already missing building. The investigation was performed using the computer programme Surfer.

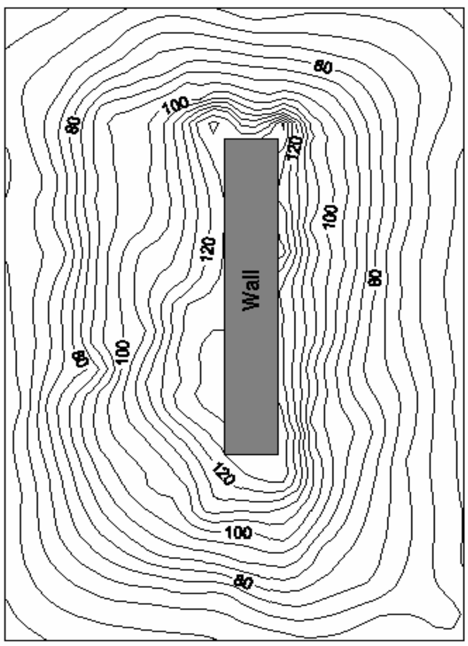

Fig 6. EDR (nSv/h) fluctuation of ionizing radiation going away from silicate brick wall

The building was built from white silicate bricks. It was noticed that the biggest equivalent dose rate caused by natural radionuclides was detected near the wall, i e 110–120 nSv/h, the smallest one – at a 10 meter distance from the wall, i e about 64 nSv/h.

Table 3 presents the following building materials which were also investigated radiologically: cement, concrete, insulating and decoration materials.

Major natural radionuclides were identified. Their specific activities differ in different building materials. 15 different building materials were chosen for investigation.

Table 3. Specific activity of ^{40}K, ^{226}Ra and ^{232}Th in some building materials

Building materials	Specific activity, Bq/kg		
	^{40}K	^{226}Ra	^{232}Th
Cement	38,4±11,9	5,2±1,6	2,3±0,7
Sand	238±29	13,9±3,9	5,6±1,4
Gypsum	215±25	1,9±0,9	0,9±0,4
Expanded clay	961±231	52,7±18,4	22,7±7,5
Concrete	543±101	47,2±9,2	34,7±8,1
Sawdust	38±12	8,6±2,3	3,2±1,2

The biggest part (about 80 %) of building material radiation is made up of ^{40}K radiation. Radiation of the latter influences mainly external irradiance. The value range of this radionuclide specific activity is very wide. The smallest value of ^{40}K specific activity was identified in cement, the biggest one – in expanded clay.

The analysis of the values of specific activity of ^{226}Ra in building materials showed that they widely fluctuated. The smallest value of ^{226}Ra specific activity was identified in gypsum, a 10 times higher one – in sand and the biggest one – in expanded clay.

According to measurement results, specific activity of ^{232}Th in building materials under investigation is the least one from that of all the other identified radionuclides.

A conclusion is drawn that specific activity of natural radionuclides depends on the mining location.

As it was mentioned, ionizing radiation spread by buildings depends mainly on the type of a building material. Comparative dosimetry measurements were carried out in buildings built of different building materials. Block buildings, ceramic (red) brick houses and silicate (white) brick houses were built in 1970–1980, wooden ones – in 1954–1968. 25 block houses, 18 ceramic brick houses, 27 silicate brick houses and 14 wooden houses were chosen for the experiment (Fig 7).

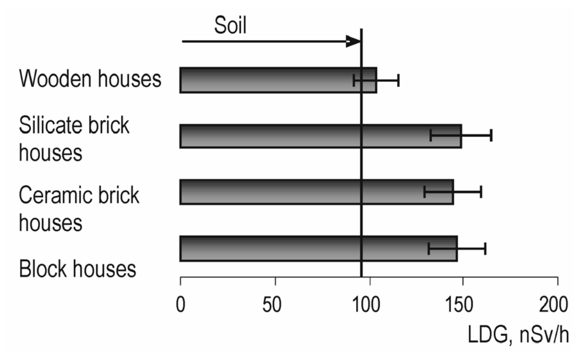

Fig 7. EDR fluctuation in different houses

An approximate value is about 147 nSv/h in a block house, in a ceramic (red) brick house – about 144 nSv/h, in a silicate (white) brick house – about 149 nSv/h, in a wooden house – about 104 nSv/h. The measurement results show that gamma radiation in a wooden house is 0,7 times less than in a silicate brick house, consequently, a person in a wooden house receives a less dose than in a silicate brick house.

Figs 8–11 depict the statistical data of equivalent dose rate measurements. Dependencies found while analysing equivalent dose rate fluctuation in different buildings (block buildings, ceramic brick houses, silicate brick houses and wooden houses) are close to one mode Gaussian distribution.

The analysis of experimental results showed that the highest equivalent dose rate was in block houses, ceramic brick houses and silicate brick houses. Equivalent dose rate in wooden houses is 1,5 time less. It is due to building material radio isotropic content.

The analysis of the results of multifold experiments showed that building floor does not have much influence on equivalent dose rate fluctuation. That is determined by the amount of radioactive substances except the case of basement where the soil influence is the strongest.

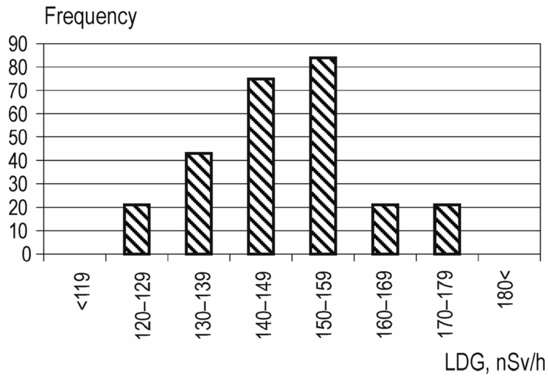

Fig 8. Frequency of EDR in block houses

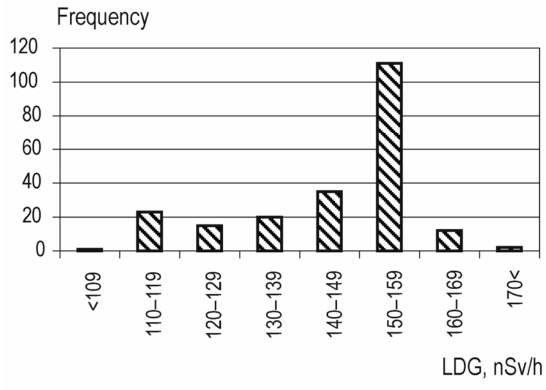

Fig 9. Frequency of EDR in ceramic brick houses

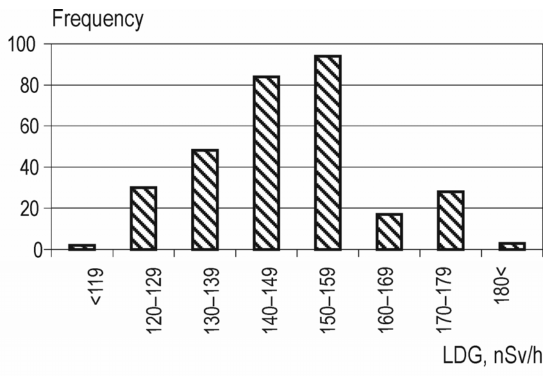

Fig 10. Frequency of EDR in silicate brick houses

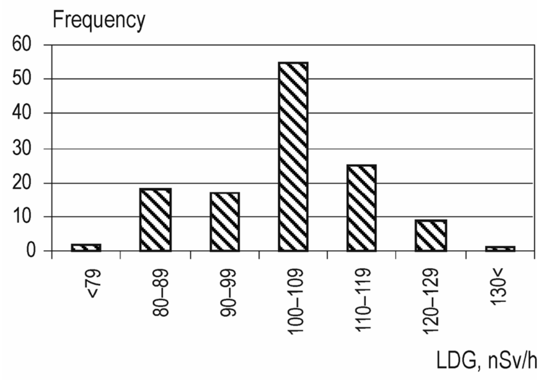

Fig 11. Frequency of EDR in wooden houses

Regarding different building floors, equivalent dose rate of ionizing radiation fluctuates from 79 to 130 nSv/h. The highest equivalent dose rate of natural radionuclides was found in the basement because basements usually are not ventilated, and natural inert gas, such as radon and its split products, accumulates and mainly influences additional irradiance [18]. The ratio of internal and external irradiance equals to 1,4. The ratio depends mainly on the type of a building material and the width of building walls because building materials are not only the source of ionizing radiation but also a screen protecting a person from the influence of cosmic radiation.

After measuring specific activity of the main gamma radiators ^{40}K, ^{226}Ra and ^{232}Th in silicate bricks, their input for radiation was found (for ^{40}K – about 17 nSv/h, for ^{226}Ra – 9 nSv/h, for ^{232}Th – 9 nSv/h) [19].

4. Conclusions

1. It is found that equivalent dose rate of natural radionuclides increases exponentially approaching a building. The results of dosimetry investigation performed near different types of buildings show that at a distance of 10–15 meters the impact of a building upon radiation decreases approximately 1,6 time in the case of block buildings, 1,3 time in the case of silicate bricks houses and 1,4 time in the case of ceramic bricks houses.

2. The results of the investigation show that the diversity of values of equivalent dose rate caused by ionizing radiation depends upon the quantity of radionuclides in building materials. Spectrometric analysis of most often used building materials shows that the least specific activity of natural radionuclides is found in wood (e g ^{40}K – 38±12 Bq/kg), the biggest one – in expanded clay (e g ^{40}K – 961±231 Bq/kg), therefore, in order to avoid additional irradiance it is necessary to consider the use of specific building materials in constructing various buildings (particularly dwelling-houses).

3. Distinct ionizing radiation fluctuation was not noticed near wooden buildings. In the case of wooden buildings equivalent dose rate is 1,6 time smaller than that near precast concrete buildings, and about 1,3 time smaller than that near silicate brick buildings, because the values of specific activity of natural radionuclides found in wood are considerably smaller than those found in

other three types of building materials under investigation.

4. The results of comparative dosimetry measurements in houses of different building materials show that the values of equivalent dose rate in buildings are distributed according to Gaussian distribution. The measured equivalent dose rate in wooden houses is 1,5 time smaller than that in block, silicate and ceramic brick houses.

References

1. European Commission. Radiation Protection No 96. "Enhanced radioactivity of building materials". 1999.
2. European Commission. Radiation Protection No 112. "Radiological protection principles concerning the natural radioactivity of building materials". 1999.
3. Kumar, A.; Kumar, M.; Singh, S. Natural activities of U-238, Th-232, K-40 in some Indian building materials. *Radiation measurements*, 36(1–6), 2003, p 465–470.
4. Lu Xinwei. Radioactive analysis of cement and its products collected from Shaanxi, China. *Health Physics*, 88(1), 2005, p 84–86.
5. United Nations Scientific Committee on the Effects of Atomic Radiation. UNSCEAR, 1988. Effects and risk of ionizing radiation. UNSCEAR report, New York, 1988, p 647.
6. Lietuvos higienos norma HN73–1997. Pagrindinės radiacinės saugos normos. Lietuvos Respublikos sveikatos apsaugos ministerija. Vilnius, 1997. 198 p.
7. Nero, A. V.; Nazaroff, W. W. Characterizing the source of radon indoors. *Radiation Protection Dosimetry*, No 7, 1984, p 23–39.
8. Harley, N. H. Back to Background: Natural Radiation and Radioactivity exposed. The 1999 Lauriston S. Taylor Lecture. *Health Physics*, Vol 79 (1), 2000, p 121–128.
9. Keller, G.; Hoffmann, B.; Feigenspan, T. Radon permeability and radon exalation of building materials. *Journal of Environmental Radioactivity*, 272, 2001, p 85–89.
10. Siotis, I.; Wrixon, A. D. Radiological consequences of the use of fly ash in building materials in Greece. *Radiation Protection Dosimetry*, Vol 7, No 1(4), 1983, p 101–105.
11. Morkūnas, G.; Mastauskas, A. Radono įtaka patalpų oro kokybei Lietuvoje. Iš: Sveikata ir aplinka. Vilnius, 1996, p. 76–81.
12. Construction and decoration materials used in Moscow region radioactivity database (http://www.clor.waw. pl/Z-2/Eng-Building.htm)
13. Louzi, A.; Proukakis, C; Petropoulos, N. P.; Anagnostakis, M. J.; Simopoulos, S. E.; Angelopoulos, M. G. Measurements of natural radioactivity in Greek building materials. In: Proceedings of the 1st Mediterranean Congress on Radiation Protection, 5–7 April 1994, Athens, p 240–244.
14. Butkus, D.; Morkūnas, G.; Pilkytė, L. Ionizing radiation in buildings: situation and dealing with problems. *Journal of Environmental Engineering and Landscape Management*, Vol XIII, No 2, 2005, p 103a–107a.
15. Thomas, R. H. Ionizing radiation exposure measurements at commercial jet aircraft altitudes. *Radiation Protection Dosimetry*, Vol 48(1), 1993, p 51–57.
16. Pečiulienė, M.; Jasaitis, D.; Grigaliūnaitė-Vonsevičienė, G.; Girgždys, A. Equivalent dose rate of ionizing radiation above water reservoirs in Vilnius. *Journal of Environmental Engineering and Landscape Management*, Vol 12, No 2, 2004, p 53–57.
17. Aycik, G. A.; Erkan, A. Radioactivity measurements of coals and ashes from coal-fired power plants in the Southwestern part of Turkey. *Journal of Environmental Radioactivity*, No 35, 1997, p 23–35.
18. Jasaitis, D.; Pečiulienė, M.; Girgždys, A. The variations of radon and its short-term decay products in living rooms. In: The 6th International Conference on Environmental Engineering, Selected papers, Vol 1, 2005, p 114–117.
19. Bogdevičienė, V.; Pečiulienė, M; Girgždys, A. Changes of natural ionizing radiation in anthropogenic objects. *Journal of Environmental Engineering and Landscape Management*, Vol XIII, No 3, 2005, p 103–107.

STATINIUOSE ESANČIŲ RADIONUKLIDŲ SUKELTOS SPINDULIUOTĖS LYGIAVERTĖS DOZĖS GALIOS KITIMO ĮVERTINIMAS

M. Pečiulienė, G. Grigaliūnaitė-Vonsevičienė, A. Girgždys

S a n t r a u k a

Statybinėse medžiagose esančių radionuklidų gama spinduliuotė iškreipia natūralų gama lauką, todėl šalia įvairių statybinių konstrukcijų ir jose buvo atlikti dozimetriniai gamtinės kilmės radionuklidų jonizuojančiosios spinduliuotės tyrimai. Nustatyta, kad gamtinių radionuklidų spinduliuotės lygiavertės dozės galia artėjant prie pastato didėja eksponentiškai (ši empirinė priklausomybė galioja iki 10–15 m nuo tiriamojo objekto). Pastatytieji pastatai padidina jonizuojančiąją spinduliuotę vidutiniškai apie 1,5–2 kartus, išimtis – mediniai pastatai, kurie natūralų foną pakeičia iki 5 %. Nustatyta, kad patalpose lygiavertės dozės galios reikšmės pasiskirsčiusios pagal normalųjį skirstinį. Mediniuose pastatuose išmatuotosios dozės vertės yra apie 1,5 karto mažesnės nei išmatuotosios blokiniuose, keraminių plytų bei silikatinių plytų pastatuose.

Reikšminiai žodžiai: jonizuojančioji spinduliuotė, statybinės medžiagos, antropogeninė veikla, gamtinės kilmės radionuklidai, dozimetrija, lygiavertės dozės galia, savitasis aktyvumas.

ОПРЕДЕЛЕНИЕ ИЗМЕНЕНИЯ МОЩНОСТИ ЭКВИВАЛЕНТНОЙ ДОЗЫ ИЗ-ЗА ИЗЛУЧЕНИЯ РАДИОНУКЛИДОВ, НАХОДЯЩИХСЯ В СТРОИТЕЛЬНЫХ КОНСТРУКЦИЯХ

М. Пячулене, Г. Григалюнайте-Вонсявичене, А. Гиргждис

Р е з ю м е

Гамма-излучение радионуклидов изменяет в строительных материалах естественное гамма-поле. Были проведены дозиметрические испытания ионизирующего излучения, выделяемого радионуклидами натурального происхождения вблизи различных строительных конструкций. Установлено, что мощность эквивалентной дозы натуральных радионуклидов при приближении к постройке экспоненто увеличивается (эта эмпирическая зависимость может быть до 10–15 м от испытуемого объекта). Установлено, что строительные конструкции увеличивают ионизирующее излучение в среднем до 1,5–2 раз, за исключением деревянных строений, которые изменяют естественный фон до 5 %. В помещениях значения мощности эквивалентной дозы устанавливаются согласно нормальному распределению. Измеренные в деревянных строениях значения мощности в 1,5 раза меньше, чем в строениях из блочных плит, керамического или силикатного кирпича.

Ключевые слова: ионизирующее излучение, строительные материалы, антропогенное действие, радионуклиды натурального происхождения, дозиметрия, удельная активность.

Milda PEČIULIENĖ. Dr, Dept of Physics, Vilnius Gediminas Technical University (VGTU).

Doctor of Science (Technological Sciences), VGTU, 2006. Master of ecology, VGTU, 2000. Publications: co-author of 7 research papers. Research interests: environmental physics, natural radioactivity, anthropogenic impact.

Gražina GRIGALIŪNAITĖ-VONSEVIČIENĖ. Dr, Dept of Physics, Vilnius Gediminas Technical University (VGTU).

Doctor of Physics, VGTU, 2001. Master of Physics, Vilnius Pedagogical University, 1997. Research interests: semiconductor physics, environmental physics.

Aloyzas GIRGŽDYS. Dr, head of Laboratory of Nuclear Hydrophysics, Vilnius Gediminas Technical University (VGTU).

Doctor of Science (environmental physics), Moscow Institute of Atmospheric Physics, 1985. First degree in Physics, Vilnius University (VU), 1970. Publications: author of 1 monograph, over 170 research papers. Research interests: environmental physics, aerosol physics.