



Laima PILKYTĖ

**INVESTIGATION OF CONCENTRATIONS
OF RADIONUCLIDES IN LITHUANIAN
CONSTRUCTION MATERIALS, MODELLING
AND EVALUATION OF EXPOSURE DUE TO
THESE RADIONUCLIDES**

**Summary of Doctoral Dissertation
Technological Sciences, Environmental Engineering and
Landscape Management (04T)**

Vilnius



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VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2002 – 2006.

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The dissertation will be defended at the public meeting of the Council of Scientific Field of Environmental Engineering and Landscape Management in the Senate Hall of Vilnius Gediminas Technical University at 1 p. m. on 20 October 2006.

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The summary of the doctoral dissertation was distributed on 20 September 2006.

A copy of the doctoral dissertation is available for review at the Library of Vilnius Gediminas Technical University (Saulėtekio al. 14, LT-10223 Vilnius, Lithuania).

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Laima PILKYTĖ

RADIONUKLIDŲ SAVITOJO AKTYVUMO
STATYBINĖSE MEDŽIAGOSE LIETUVOJE
EKSPERIMENTINIS TYRIMAS, JŲ SUKELTOS
APŠVITOS MODELIAVIMAS IR VERTINIMAS

Daktaro disertacijos santrauka
Technologijos mokslai, aplinkos inžinerija ir kraštotvarka (04T)

Vilnius



2006

Disertacija rengta 2002–2006 metais Vilniaus Gedimino technikos universitete.

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Disertacija bus ginama viešame Aplinkos inžinerijos ir kraštovarkos mokslo krypties tarybos posėdyje 2006 m. spalio 20 d. 13 val. Vilniaus Gedimino technikos universiteto senato posėdžių salėje.

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Disertacijos santrauka išsiuntinėta 2006 m. rugsėjo 20 d.

Disertaciją galima peržiūrėti Vilniaus Gedimino technikos universiteto bibliotekoje (Saulėtekio al. 11, LT-10223 Vilnius, Lietuva).

VGTV liedyklos „Technika“ 1300 mokslo literatūros knyga

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General characteristics of the thesis

Definition of the problem

Natural sources of radiation are the most important for exposure of humans. The principle of optimization of radiation protection requires that doses and numbers of exposed persons are as low as reasonably achievable. Identification of exposure sources and pathways is a part of optimization. UNSCEAR collects data on sources of exposure already for many years. One of the tasks of it is definition of measures of decrease of exposure. Variety of these measures is increasing. One of them – determination of relationships of exposure sources. Analysis of these relationships is an important part of investigations of impact of radiation and identification of optimized measures of radiation protection. The importance of this part depends on exposure source under investigation. Natural exposure as an important source is investigated recently more and more. Radionuclides in construction materials are one part of this kind of exposure.

Topicality of the problem

Radionuclides in construction materials are one of the most important sources of human exposure. They are ^{226}Ra and ^{232}Th and their daughters and ^{40}K . Though cases when artificial radionuclides are in construction materials were recorded the natural radionuclides are the most important taking into account magnitude of exposure. Their concentrations in construction materials might be very different. They depend on concentrations in raw materials and production technology. Importance of this problem is increasing recently because the new raw materials are used for production of construction materials. Very often it is industrial by-products. Rather high concentrations of natural radionuclides might be in these raw materials. It shows an importance of control of concentrations of radionuclides in construction materials. However, there are many different construction materials and their variety is increasing. For this reason it is important to have reliable and simple techniques of identification of construction materials which might cause higher exposure.

Exposure depends not only on concentrations of radionuclides in construction materials but also on amounts of these construction materials in buildings and their distances from exposed people. So, calculation of doses due to radionuclides in construction material is important. This importance increases when it is necessary to determine if use of construction materials with rather large concentrations (but lower than the ones preventing from use) of radionuclides is optimized.

Problem of radon exhaled from construction materials is also important. Though soil is the most important source of indoor radon in many cases, sometimes the large part of radon might be released from construction materials.

Having assessed exposure due to radionuclides in construction materials and evaluated regularities of variation of this exposure it is possible to create basis of the system of optimization of protection from this kind of exposure, i.e., to find out the measures in order to have this exposure on the optimum level. The fact that exposure due to radionuclides in construction materials affects all the people is also important. Public interest in this problem increases. Everybody has the right to know about environment. Fast and reliable ways of assessment of exposure from radionuclides in construction materials might help to solve the problem of public information on radiation and radiation protection.

Aims of the work

1. To perform measurements and assessment of concentrations of radionuclides in common construction materials.
2. To assess doses due to radionuclides in construction materials in premises of different designs.

Tasks of the work

1. To determine principles of classification of construction materials according to magnitude of exposure and identify construction materials whose radionuclides might cause the highest exposure.
2. To perform measurements of concentrations of radionuclides in samples of construction materials and determine typical concentrations in construction materials produced and used in Lithuania.
3. To evaluate construction materials as a source of radon indoors by assessment of doses of external exposure due to radon daughters.
4. To calculate and model doses of external exposure due to radionuclides in construction materials.
5. To recommend measures for optimization of protection from exposure due to radionuclides in construction materials.

Scientific novelty

Measurements of concentrations of radionuclides only in some separate construction materials have been performed until now. The whole complex of construction materials is investigated in this work. Concentrations of radionuclides in common construction materials were measured and peculiarities of exposure in premises made of different construction materials evaluated. Construction materials were classified from the point of view of

exposure. Influence of radon on absorbed dose rate was assessed. Concentrations of radionuclides in archeological samples were investigated.

Results of integrated investigations, evaluation and calculation of exposure due to radionuclides in construction materials are presented.

Practical value

The most important sources of exposure are natural, however, more attention is still paid to artificial sources. It affects the principle of optimization of radiation protection because there are still possibilities to decrease natural exposure. Exposure due to radionuclides in construction materials might and should be controlled. This work helps to attract attention to this problem and move towards balance between attention paid to artificial and natural sources though the border between these two types of sources is not always clear.

Aspects of calculations of activity index are analysed in this work. Results of this analysis and calculations of doses are used for creation of optimized and flexible scheme of evaluation of construction materials from the point of view of radiation protection.

Data given in this work might help to evaluate doses due to radionuclides in construction materials and increase accuracy of dosimetric control of persons in different premises.

Defended propositions

1. Construction materials might be classified from the point of view of doses due to radionuclides in these materials.
2. Absorbed dose rate indoors is related with concentrations of radionuclides in construction materials.
3. There is a statistically significant difference between absorbed dose rate in premises constructed of brick, concrete and wood, besides in ones in multifamily and detached houses.

Short content of thesis

1. Artificial and natural radionuclides in construction materials and exposure caused by them

Construction material is a natural source of exposure though sometimes determination of artificial and natural sources might be problematic because natural radionuclides might be concentrated by human activity. There are other natural sources, such a cosmic radiation, cosmogenic radionuclides, indoor and outdoor radon, natural radionuclides in soil, ^{40}K in food and radon in drinking water. Construction materials are not only a source of exposure, but they also provide shielding from radiation coming from outside. Shielding depends on density of construction material.

The main natural radionuclides in construction materials are ^{226}Ra and ^{232}Th and their daughters and ^{40}K . Variety of data collected in many countries and regions show that their concentrations in different constructions materials are very different. Due to different raw materials or different production technologies these concentrations might be different even in construction materials of the same type. Such raw materials as phosphate slag, phosphogypsum, granite, alum shale, clay, fly ash might be a reason of elevated concentrations of radionuclides in construction materials. Information about it helps to identify construction materials problematic from the point of view of radiation protection.

Construction materials are also a source of radon, usually of ^{222}Rn whose problem is dealt with in this work. Though in many cases soil is the main source of indoor radon, in some cases, particularly in premises high above the ground the exhalation of radon from construction materials is more important. Exhalation of radon from construction materials depends on concentrations of ^{226}Ra in construction materials, characteristics of construction materials, their coating. Data on exhalation rate from different materials are available.

There are data on contamination of construction materials with artificial radionuclides. Though such cases are not common they should be taken into account as probable. Facts about elevated concentrations of natural radionuclides due to raw materials coming from NORM industries have been also recorded.

Industrial by-products are more and more frequently used for production of construction materials. Radiation protection problems might arise even if crushed rocks are used for production of construction materials – there are cases when radionuclides were concentrated in fractions of crushed material of some size. Such by-products as tailings of granite and sinter, alum shale, fly ash, coal ash, by-products of processing of monazite, ilmenite and xenotime sands, iron slag, red clay and others are or were used for production of construction materials. Elevated concentrations of natural radionuclides are in many of them.

Concentrations of radionuclides in construction materials are measured by different techniques and gamma spectrometry is the most common.

Exposure due to radionuclides in construction materials is widely assessed and many data show variety of its magnitude (0.3 to 3 mSv of annual effective dose). The world weighted average dose rate indoors is $84 \text{ nGy}\cdot\text{h}^{-1}$. It is very important to identify construction materials which might cause the exposure higher than average.

It is done with the aim of optimization of this exposure. However, process of optimization as it regards exposure from radionuclides in construction

materials is rather complicated. Different approaches are used in different countries and all the three natural radionuclides are always taken into account. It is done using radium equivalent or activity index.

The basis for decision making is doses which might be caused by use of construction materials. For this reason the ways used for dose calculation are very important. Different software and models are used for this, and their results are often compared.

The last step of the whole system of protection from exposure due to radionuclides in construction materials is identification of protective measures. Though the variety of these measures is not very large there such measures as decrease of exhalation of radon from construction materials, replacement of construction materials with the ones with lower concentrations of radionuclides.

2. Experimental techniques, equipment and accessories

Measurements of concentrations of radionuclides were performed by gamma spectrometry. Different reproducible geometries of samples were used in measurements. Samples of the same type and from the same batch were taken for investigation of statistics of measurements.

Classification of construction materials was done taking into account results of measurements of concentrations of radionuclides in different types of construction materials. Such parameters important for exposure as concentrations of natural radionuclides in construction material, amount of this type of construction materials used in buildings and distance of materials from people were also taken into account.

Concentrations of indoor radon were recorded by E-PERMTM electrets and Alpha Guard ionization chambers. Dose rate indoors was measured by dose rate meters. Due attention was paid to quality assurance of measurements.

Calculations of dose rate due to natural radionuclides in construction materials were performed by Visiplan 3D ALARA planning tool which allows to describe sources of any geometry and with any radionuclide composition and to perform calculations of dose rate distribution around these sources.

3. Results and discussion

3.1. Results of gamma spectrometric measurements and classification of construction materials from radiological point of view

The large part of work was radiological investigations of construction materials – measurements of concentrations of gamma emitters. ^{226}Ra , ^{232}Th , members of their decay chains and ^{40}K were detected. In some samples the artificial ^{137}Cs was found. Concentrations of daughters of ^{222}Rn were lower than concentrations of ^{226}Ra because a part of ^{222}Rn gets out of construction

materials. These facts were taken into account when calculations of doses due to radionuclides in construction materials were performed.

771 sample of construction materials produced and/or used in Lithuania was investigated. The results of measurements are given for different types of construction materials, e.g., stone and its products, concrete, dolomite, gypsum, etc.

Concentrations of ^{226}Ra and ^{232}Th in wood are below detection limits (accordingly, 1.5 or 1.2 $\text{Bq}\cdot\text{kg}^{-1}$). ^{137}Cs is found in some samples of wood, however, concentrations are low – the average is $(1.3\pm0.3) \text{ Bq}\cdot\text{kg}^{-1}$ (95 % confidence). ^{137}Cs in wood is because of contamination of environment with it. The dose caused by this radionuclide is small. Dose rate in the standard flat made of wood with $4.0 \text{ Bq}\cdot\text{kg}^{-1}$ of ^{137}Cs is $2.4 \text{ nGy}\cdot\text{h}^{-1}$ ($1.4 \text{ nGy}\cdot\text{h}^{-1}$ to $3.3 \text{ nGy}\cdot\text{h}^{-1}$). Calculated by Visiplan-3D.

^{137}Cs was detected in 15 samples of portlandcement (out of 141 sample) collected in Belarus in 2000-2005. Concentrations of ^{137}Cs in these samples were 0.16 to $40.0 \text{ Bq}\cdot\text{kg}^{-1}$, the average – $(7.7\pm6.4) \text{ Bq}\cdot\text{kg}^{-1}$. ^{137}Cs in portlandcement might be because of presence of this radionuclide in raw materials. Some part of this radionuclide might get into cement during its production.

Expanded clay, ceramic bricks, aluminatic cement, cinder, fire resistant concrete with cinder, granite have the highest concentrations of natural radionuclides (activity index higher than 1). It might be explained by raw materials and technology of production. However, not all the samples of, e.g., cinder or portlandcement have high concentrations.

Most problems with prognosis of possible concentrations of construction materials arise when activity index is below 1, but close to it. Such construction materials are as follows: bricks of stone mass, different ceramic bricks and slabs, some kinds of expanded clay, its gravel.

The lowest concentrations are in wood, cardboard, chalk, filler, marble, peat, quartz sand. This sand might be used for construction of premises where low dose rate is needed. Distribution of construction materials according to activity indexes is given in Fig 1. There is some small part of construction materials (1.5 %) with activity indexes higher than 1.3. The large part (79 %) of samples has activity indexes below 0.6. The distribution gives an information about the border between low and high activity indexes which is necessary in classification of construction materials from radiological point of view. It is at 0.15–0.20. A rather low border should be selected because of principle of conservatism of radiation protection. Statistical origin of results also has to be taken into account.

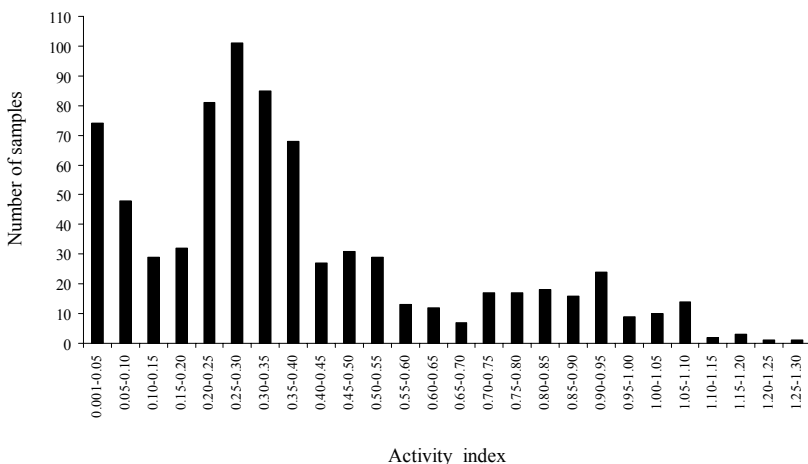


Fig 1. Distribution of construction materials according to activity indexes

Possible dose due to radionuclides in construction materials has to be taken into account in classification of construction materials from radiological point of view. Criteria used for classification were given in chapter 2.

It is possible to classify construction materials according to the second criterion – amount used, and the third one – distance from inhabitants.

On the basis of classification the priorities of evaluation of construction materials are determined (Table 1).

Table 1. Priorities of radiological evaluation of construction materials

Priority	Construction materials	Possible percentage of samples, %
High	Cement, concrete, reinforced concrete, mineral aggregate, bricks, slabs, stone, granite and gravel rubble, asphalt	75
Medium	Hardener of concrete surface, cement glue, concrete sides for streets, rims, elements used in environmental trimming	7
Low	Wood, gypsum, plaster, daub, gypsum board, glass, lime, covers, dolomite, isolation materials for tubing	18

3.2. Statistical analysis of results of gamma spectrometric investigations of construction materials

Concentrations of radionuclides are usually determined in one sample of construction materials and conclusions on suitability from the point of view of

radiation protection of the whole batch of construction materials are made using results of these measurements. However, there is always a possibility that concentrations of radionuclides in this batch might be higher than investigation levels, e.g., they might cause activity index higher than 1. This problem might be particularly important in cases when the activity indexes of investigated samples are close to 1.

Results of investigations of samples from the same batch, subsamples of the same sample and repeated investigations of the same subsample are discussed in this chapter.

Results of investigations of samples taken in the same gravel quarry 1–2 meters from each other are given in Fig 2.

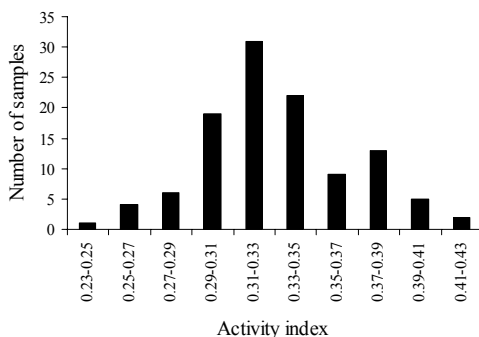


Fig 2. Distribution of activity indexes of samples of gravel taken in Senieji Trakai quarry

Results given in Fig 2 might be compared with the results received by investigation of the same batch of construction materials (final production). In all the cases distributions with some ranges are observed. Different shapes of distributions are received.

Similar distributions have been received for different subsamples of the same sample and for a number of measurements of the same subsample.

The received data were used for assessment of probability that activity indexes of construction materials exceed 1 (Table 2).

Table 2. Probabilities that activity indexes of construction materials exceed 1

Activity index received during measurements of one sample (subsample)	If one sample of the batch investigated – probability that activity index of any sample in the batch is higher than 1	If one subsample of the same sample is investigated – probability that activity index of any subsample of the same sample is higher than 1	One investigation of subsample is done – probability that activity index of the same subsample in the batch is higher than 1
0.5	0	0	0
0.6	$8.8 \cdot 10^{-8}$	0	0
0.7	$1.3 \cdot 10^{-4}$	$2.0 \cdot 10^{-9}$	0
0.8	0.017	$2.8 \cdot 10^{-4}$	0
0.9	0.17	0.062	$1.4 \cdot 10^{-8}$
0.95	0.33	0.23	$4.2 \cdot 10^{-3}$

3.3. Natural radionuclides in samples of archeological construction materials

Investigations have been performed with the aim of determination of concentrations of radionuclides in samples taken by the Institute of Lithuanian History, Department of Urban Investigations in different historical buildings.

Concentrations of radionuclides in archeological construction materials might be an indicator which shows what raw materials and production technologies were used for production. However, it is problematic to find out a direct connection between concentrations of radionuclides in construction materials and the above mentioned characteristics.

3.4. Relationship of absorbed dose rate indoors and concentrations of radionuclides in construction materials

Data received during measurements of dose rate indoors of buildings (in 4719 rooms) made of different construction materials are analyzed in this chapter. Construction materials were divided into the following categories: brick, concrete, wood and wood with external layer of brick (further – various).

A t-test indicates that there are statistically significant differences between mean values of absorbed dose rates in houses made of different construction materials between almost all the combinations of materials ($p < 0.01$). No statistically significant difference has been detected only between mean values of dose rate in houses made various construction materials.

Dose rate indoors depends not only on concentrations of radionuclides in construction materials. Geometry (i.e., amount of construction materials and size of rooms) is also an important factor. However, these parameters have not been recorded during measurements. They are difficult to describe because

houses, particularly the detached ones, are different from the point of view of construction peculiarities.

A t-test indicates that there are statistically significant difference between mean values of absorbed dose rates in apartment and detached houses made of bricks ($p < 0.01$). These differences should be due to different types of bricks used for construction.

Relationship between activity indexes of different construction materials and dose rates in premises constructed of these construction materials is given in Fig 3.

Linear approximation of the graph in Fig 3 gave the following relationship between absorbed dose rate D and activity index I :

$$D = 44 \cdot I + 105 . \quad (1)$$

If the dose rate due to cosmic exposure is subtracted and differences between detached and multifamily houses are taken into account the approximated relationship between absorbed dose rate and activity index is as follows:

$$D = 68 \cdot I + 78 . \quad (2)$$

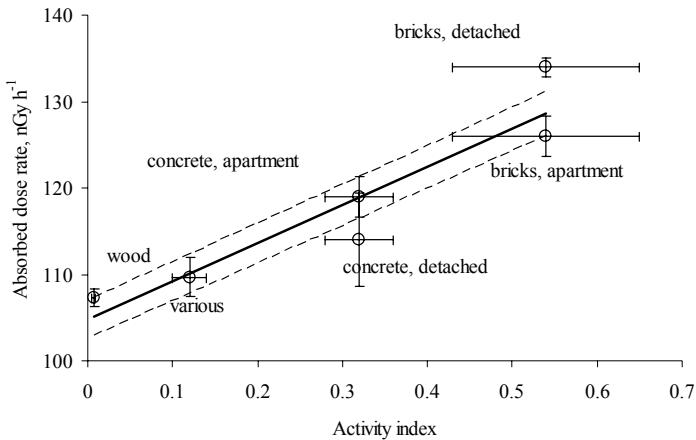


Fig 3. Relationship between activity indexes of different construction materials and dose rates. 95 % confidence intervals are given in the graph. Confidence intervals for the approximation line are given by dotted lines

The relationship given in Fig 3 might be used for direct determination of background level which is to be subtracted from readings of personal dosimeters recorded in houses made of the appropriate construction materials.

It would help to increase precision of personal dosimetry and enhance its reliability from the point of view of its users.

3.5. Absorbed dose rate indoors and indoor radon concentrations

Absorbed dose rate indoors by some degree is affected by radon daughters and this relationship is analyzed in this chapter.

Results of measurements indoor radon concentrations on different floors of multifamily houses are presented in Fig 4.

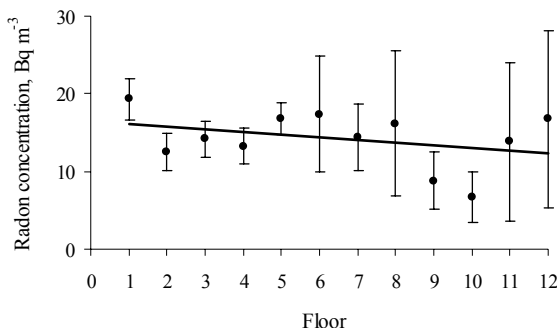


Fig 4. Averages of indoor radon concentrations on different floors (with 95 % of confidence). Linear approximation is shown

The proposition is made that contribution of other sources than soil is (10-15) Bq·m⁻³ of indoor radon. Construction materials should be the most important among these other sources.

Linear approximation of relationship between absorbed dose rate and indoor radon concentrations shows that dose rate decreases with increase of indoor radon concentrations the polynomial approximation was also done. Dose rate caused by cosmic radiation on different floors was subtracted.

This relationship might be due to impact of other factors on dose rate indoors and small influence of radon daughters on dose rate when concentrations of these daughters are low.

Analysis of results received from continuous measurements in the same premises indicate that there is the direct relationship between absorbed dose rate and indoor radon concentrations.

Different slopes of approximation line were received in different premises. It might be related with geometry of source – dimensions of premises, distributions and concentrations of aerosols with radon daughters indoors.

It is evident that the relationship between absorbed dose rate and indoor radon concentrations is not simple and not always a direct correlation is observed.

3.6. Modelling of exposure due to radionuclides in construction materials

Calculations of doses due to radionuclides in construction materials were done by Visiplan-3D ALARA planning tool. Typical concentrations of radionuclides in concrete were used. The fact that a part of radon is exhaled from construction materials and concentrations of its daughters in construction materials are lower was taken into account. The typical most common living flat of two rooms and kitchen was used for modelling. The scheme of the flat is given Fig 5.

Distributions of dose rate on other planes were also received. One of such distributions is given in Fig 6.

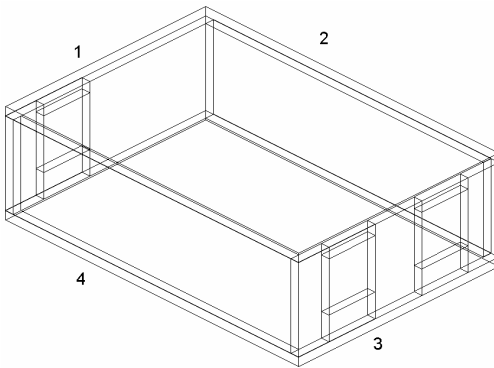


Fig 5. Scheme of model premises

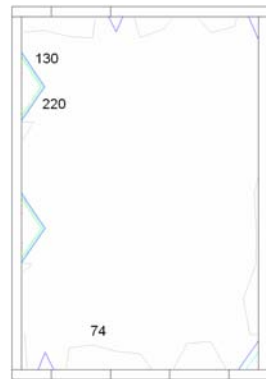


Fig 6. Distribution of dose rate ($\text{nGy}\cdot\text{h}^{-1}$) on the horizontal plane at a height of 1.25 m above the floor

Distributions show that the largest variations of dose rate are at 1 m and closer to construction materials – walls, floor and ceiling.

Relationships between dose rate and density of construction materials, thickness of floor, impact of different radionuclides and different construction elements, influence of internal walls and plaster on the walls were also analysed. Dose coefficients for construction materials of different densities were assessed.

Results of this model were compared with results received in other models. Comparison shows that these results are rather similar. The largest differences are received for ^{226}Ra . Its reason might be the fact that lower concentrations of

radon daughters were used in this model and it is more realistic because part of radon is exhaled from construction materials.

Flexibility of Visiplan-3D and its applicability for assessment of doses due to construction materials was illustrated by calculations of possible doses due to radionuclides in ceramic sink.

It is evident that calculations of doses due to radionuclides in construction materials is an effective tool of evaluation of construction materials from the point of view of radiation protection and its optimization.

Conclusions

1. Taking into account factors, which are important for exposure due to radionuclides in construction materials, construction materials produced and used in Lithuania were classified into 8 classes according to 3 criteria: concentrations of radionuclides, amounts used and places where they are used.
2. It is determined that concentrations of radionuclides in construction materials produced and used in Lithuania are in wide range: ^{226}Ra – $0.6 \text{ Bq}\cdot\text{kg}^{-1}$ to $1030 \text{ Bq}\cdot\text{kg}^{-1}$, ^{232}Th – $0.2 \text{ Bq}\cdot\text{kg}^{-1}$ to $426 \text{ Bq}\cdot\text{kg}^{-1}$, ^{40}K – $1.1 \text{ Bq}\cdot\text{kg}^{-1}$ to $4690 \text{ Bq}\cdot\text{kg}^{-1}$.
3. It is determined that activity indexes of construction materials produced and used in Lithuania most commonly are in the range of 0.25–0.55, but in some cases it might be as high as 3.78.
4. It is found what in case the concentration of ^{137}Cs is the highest recorded in construction materials produced and used in Lithuania, the dose due to this radionuclide is appr. 0.8% of the total dose due to radionuclides in construction materials.
5. It is determined that absorbed dose rate indoors depends on concentrations of radionuclides in construction materials. In case the activity index is equal to 1, annual effective dose due to such construction materials would be (0.3–0.6) mSv.
6. Concentrations of indoor radon, their variations and impact on absorbed dose rate indoors were determined.
7. By modelling the distribution of absorbed dose rate indoors the impact of parameters of premises was evaluated.

Recommendations

1. Classification of construction materials from radiological point of view is not enough for assessment of possible exposure due to radionuclides in construction materials – measurements of these concentrations are also needed.

2. Dose rate measurements indoors should be performed not closer than 1 m from walls, floor and ceiling.
3. Assessment of construction materials from the point of view of radiation protection when not only activity index but, if necessary, dose calculations are used, is an effective tool of optimization of radiation protection which helps to apply the system of radiation protection requirements more flexibly.
4. Doses due to radionuclides in construction materials might be decreased by control of concentrations of radionuclides in these materials. One of possible ways is replacement of construction materials with the ones with lower concentrations of radionuclides.
5. Doses due to radon released from construction materials might be decreased by improving ventilation and covering internal surfaces (most often, walls) with radon proof coating.

Publications on the topic of the thesis

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Laima Pilkytė was born on May 11, 1963. She graduated from Vilnius University, Faculty of Physics, worked at the Institute of Electrography as an engineer. Since 1997 she works at the Radiation Protection Centre as an engineer-radiologist. In 2002-2006 – a PhD student at the Faculty of Environmental Protection of Vilnius Gediminas Technical University. Laima Pilkytė was on training at Danish National Riso Laboratory (in 1999), Swedish Radiation Protection Institute (in 2001), Institute for Transuranium elements of Joint Research Center of European Commission (in 2003).

RADIONUKLIDŲ SAVITOJO AKTYVUMO STATYBINĖSE MEDŽIAGOSE LIETUVOJE MATAVIMAS, JŲ SUKELTOS APŠVITOS MODELIAVIMAS IR ĮVERTINIMAS

Temos aktualumas

Vienas svarbiausių žmogaus apšvitos šaltinių yra radionuklidai statybinėse medžiagose. Tai yra gamtinės kilmės radionuklidai – ^{226}Ra , ^{232}Th ir jų skilimo produktai bei ^{40}K . Nors yra užregistruota atvejų, kai į statybines medžiagas patenka ir dirbtinės kilmės radionuklidai (pavyzdžiui, netyčia išlydžius į metalo laužą patekusį jonizuojančiosios spinduliuotės šaltinį ir iš gauto metalo pagaminus gelžbetonio konstrukcijas), didžiausią įtaką apšvitai turi gamtiniai radionuklidai.

Gamtinės kilmės radionuklidų savitieji aktyvumai statybinėse medžiagose gali būti įvairūs. Jie priklauso nuo šių radionuklidų aktyvumų statybinių medžiagų žaliavose ir gamybos technologijos. Paskutiniuoju metu šios

problemos aktualumas ėmė didėti, nes statybinių medžiagų gamybai, siekiant, kad jos įgautų tam tikrų savybių, imama naudoti naujos žaliavos, neretai pramonės atliekos. Šiose žaliavose gali būti, palyginti, dideli gamtinės kilmės radionuklidų savitieji aktyvumai. Kartais į statybines medžiagas dideli gamtinės kilmės radionuklidų kiekiai patenka statybinių medžiagų gamybai naudojant medžiagas, atsiradusias pramonėje, kurioje naudojamos arba perdirbamos gamtinės kilmės radioaktyviosios medžiagos. Todėl yra svarbu kontroliuoti radionuklidų savituosius aktyvumus statybinėse medžiagose. Tačiau statybinių medžiagų asortimentas yra didelis, ir jis nuolat plečiasi, todėl labai svarbu kuo paprastesniais būdais identifikuoti statybines medžiagas, kuriose radionuklidų jonizuojančioji spinduliuotė gali sukelti didelę žmonių apšvitą. Apšvita priklauso ir nuo šių medžiagų kiekių pastatuose, jų išdėstymo žmogaus atžvilgiu. Todėl didelę reikšmę turi apšvitos nuo statybinių medžiagų dozių skaičiavimas. Šis aspektas ypatingą reikšmę įgyja tada, kai būtina įvertinti ar radiacinės saugos požiūriu optimalu naudoti statybines medžiagas, kuriose aptikti, palyginti, dideli radionuklidų savitieji aktyvumai, tačiau šie aktyvumai dar nėra tokie, kokie leistų daryti vienareikšmę išvadą apie statybinių medžiagų tinkamumą ar netinkamumą jas naudoti.

Įvertinus apšvitą nuo statybinėse medžiagose esančių radionuklidų jonizuojančiosios spinduliuotės bei šios apšvitos kitimo ir formavimosi dėsninumus, galima sukurti apsaugos nuo šios apšvitos optimizavimo sistemos pagrindus, t.y. numatyti priemones, kurių būtina imtis, kad apšvita nuo statybinėse medžiagose esančių radionuklidų jonizuojančiosios spinduliuotės būtų optimaliai maža.

Darbo tikslai

1. Išmatuoti ir įvertinti radionuklidų savituosius aktyvumus tipinėse statybinėse medžiagose.
2. Nustatyti radionuklidų, esančių statybinėse medžiagose, jonizuojančiosios spinduliuotės sukeltas apšvitos dozes įvairių konstrukcijų patalpose.

Darbo uždaviniai

1. Nustatyti statybinių medžiagų klasifikavimo pagal apšvitą principus ir identifikuoti statybines medžiagas, kuriose esančių radionuklidų jonizuojančioji spinduliuotė gali sukelti didžiausią apšvitą.
2. Išmatuoti radionuklidų savituosius aktyvumus parinktose statybinėse medžiagose ir nustatyti tipinius radionuklidų savituosius aktyvumus Lietuvoje gaminamose ir naudojamose statybinėse medžiagose.
3. Įvertinti statybines medžiagas kaip radono patalpose šaltinį, nustatant išorinės apšvitos dėl radono skilimo produktų jonizuojančiosios spinduliuotės dozes patalpose.

4. Apskaičiuoti ir sumodeliuoti išorinės apšvitos nuo statybinėse medžiagose esančių radionuklidų jonizuojančiosios spinduliuotės dozes.
5. Rekomenduoti priemones žmonių apšvitai patalpose nuo statybinėse medžiagose esančių radionuklidų jonizuojančiosios spinduliuotės optimizuoti.

Darbo mokslinis naujumas

Iki šiol Lietuvoje radionuklidų savitieji aktyvumai buvo nustatomi tik tai atskirose statybinėse medžiagose. Šiame darbe išnagrinėtos ne jų visuma, nustatant radionuklidų savituosius aktyvumus mūsų šalyse gaminamose ir naudojamose tipinėse statybinėse medžiagose bei įvertinant apšvitos ypatumus iš įvairių statybinių medžiagų pastatytuose namuose. Pirmą kartą statybinės medžiagos suklasifikuotos apšvitos, kurią gali lemti jose esančių radionuklidų jonizuojančioji spinduliuotė, požiūriu. Nustatyta radono įtaka sugertosios dozės galiai patalpose. Ištirti radionuklidų savitieji aktyvumai archeologinių statybinių medžiagų bandiniuose. Darbe pateikiami kompleksinių radionuklidų savitųjų aktyvumų tipinėse statybinėse medžiagose ir iš tų statybinių medžiagų pastatytų namų patalpose apšvitos tyrimo, vertinimo, mažinimo ir modeliavimo rezultatai.

Praktinė darbo reikšmė

Pagrindinis žmogaus apšvitos šaltinis yra gamtinė spinduliuotė. Tačiau šiuo metu didesnis dėmesys yra skiriamas apsaugai nuo žmogaus sukurtų šaltinių, ypač atominės energetikos ir radioaktyviųjų atliekų. Tuo pažeidžiamas radiacinės saugos optimizavimo principas, kadangi rezervų mažinti gamtinę apšvitą dar yra labai daug. Statybinėse medžiagose esančių radionuklidų jonizuojančiosios spinduliuotės sukelta apšvita irgi gali ir turi būti kontroliuojama. Šiuo darbu atkreipiamas dėmesys į minėtą problemą.

Pažymėtina, kad ne visada yra aiški riba tarp gamtinės ir dirbtinės kilmės apšvitų. Statybinėse medžiagose esančių radionuklidų jonizuojančiosios spinduliuotės sukelta apšvita gali būti laikoma ir dirbtine, nes radionuklidų kiekis jose priklauso nuo žmogaus veiklos – technologinių procesų, žaliavų, gamtinės kilmės radionuklidai statybinėse medžiagose yra koncentruojami.

Darbe išanalizuoti statybinių medžiagų radionuklidų aktyvumo rodiklio, naudojamo įvertinti statybinių medžiagų tinkamumui radiacinės saugos požiūriu, nustatymo aspektai. Šios analizės ir atlikto apšvitos dozių modeliavimo rezultatai panaudoti kuriant optimizuotą ir lanksčią statybinių medžiagų įvertinimo radiacinės saugos požiūriu schemą.

Darbe pateikiami duomenys gali padėti įvertinti apšvitos nuo įvairiose statybinėse medžiagose esančių radionuklidų jonizuojančiosios spinduliuotės dozes, o tai padidintų žmonių, dirbančių patalpose, pastatytose iš įvairių medžiagų, matuojamų dozių tikslumą.

Ginamieji teiginiai

1. Statybinės medžiagos gali būti klasifikuojamos pagal radionuklidų, esančių jose, jonizuojančiosios spinduliuotės sukeltas apšvitos dozes.
2. Sugertosios dozės galia patalpose siejasi su radionuklidų, esančių statybinėse medžiagose, savitaisiais aktyvumais.
3. Egzistuoja statistiškai patikimas skirtumas tarp sugertosios dozės galios ore pastatuose, pastatytuose iš plytų, betono bei medžio, o taip pat daugiabučiuose ir individualiuose namuose.

Darbo apimtis ir struktūra

1 skyriuje išdėstyta gamtinės ir dirbtinės kilmės radionuklidų statybinėse medžiagose sukliamos gyventojų apšvitos patalpose tyrimų apžvalga, aptartas apšvitos modeliavimas ir mažinimas. 2 skyriuje aprašyti gama spektrometrinių tyrimų, radono tūrinio aktyvumo ir sugertosios dozės galios matavimo metodai. 3 skyriuje pateikti statybinių medžiagų klasifikavimo ir gama spektrometrinių tyrimų rezultatai, sugertosios dozės galios ore ryšys su radono tūriniais aktyvumais patalpose ir su patalpų statybinėse medžiagose esančių radionuklidų savitaisiais aktyvumais, išorinės apšvitos modeliavimo rezultatai.

Išvados

1. Išanalizavus faktorius, nuo kurių priklauso apšvita nuo statybinėse medžiagose esančių gamtinės kilmės radionuklidų jonizuojančiosios spinduliuotės, Lietuvoje naudojamos statybinės medžiagos radiologiniu požiūriu buvo suklasifikuotos į aštuonias klases pagal tris požymius: 1) juose esančių radionuklidų savituosius aktyvumus, 2) kiekius, kuriais jos naudojamos, 3) vietas, kur jos naudojamos, žmogaus atžvilgiu.
2. Nustatyta, kad gamtinės kilmės radionuklidų savitieji aktyvumai Lietuvoje gaminamose ir naudojamosiose statybinėse medžiagose kinta plačiose ribose: ^{226}Ra – nuo $0,6 \text{ Bq}\cdot\text{kg}^{-1}$ iki $1030 \text{ Bq}\cdot\text{kg}^{-1}$, ^{232}Th – nuo $0,2 \text{ Bq}\cdot\text{kg}^{-1}$ iki $426 \text{ Bq}\cdot\text{kg}^{-1}$, ^{40}K – nuo $1,1 \text{ Bq}\cdot\text{kg}^{-1}$ iki $4690 \text{ Bq}\cdot\text{kg}^{-1}$.
3. Nustatyta, kad gamtinės kilmės radionuklidų Lietuvoje gaminamose ir naudojamosiose statybinėse medžiagose aktyvumo rodikliai daugiausiai kinta nuo 0,25 iki 0,55, tačiau atskirais atvejais gali siekti 3,78.
4. Įsitikinta, kad Lietuvoje gaminamose ir naudojamosiose statybinėse medžiagose esant didžiausiam vienintelio aptikto dirbtinės kilmės radionuklido ^{137}Cs savitajam aktyvumui, užregistruotam medžio bandiniuose, šio radionuklido jonizuojančioji spinduliuotė lemtų apie 0,8 % dozės, kurią lemia gamtinių radionuklidų, esančių statybinėse medžiagose, jonizuojančioji spinduliuotė.
5. Nustatyta, kad sugertosios dozės galia įvairių pastatų patalpose priklauso nuo radionuklidų savitųjų aktyvumų statybinėse medžiagose. Mūsų šalyje

metinė efektinė dozė patalpose, pastatytose iš statybinių medžiagų su aktyvumo rodikliu, lygiu 1, būtų 0,3–0,5 mSv.

6. Nustatyti ^{222}Rn turiniai aktyvumai ir jų kaita patalpų ore bei įtaka sugertosios dozės galiai rodo, kad sugertosios dozės galia priklauso ir nuo patalpų charakteristikų. Dozės koeficientai įvairioms patalpoms gali skirtis iki 30 kartų. Radono skilimo produktų metinė efektinė dozė spinduliuotės patalpose įtaka sugertosios dozės galiai neviršija kelių procentų.
7. Modeliuojant sugertosios dozės galios kaitą ore, įvertinta patalpos parametrų (statybinių medžiagų tankio, patalpos konstrukcinių elementų storio, patalpos dydžio, apdailos medžiagų, vidinių pertvarų) įtaka gyventojų apšvitai.

Rekomendacijos

1. Vien klasifikavimu įvertinti galimos apšvitos nuo statybinėse medžiagose esančių gamtinės kilmės radionuklidų jonizuojančiosios spinduliuotės negalima – būtini šių radionuklidų savitųjų aktyvumų statybinėse medžiagose matavimai.
2. Dozės galios matavimai patalpose turėtų būti atliekami ne arčiau, kaip 1 m atstumais nuo sienų, grindų ir lubų.
3. Statybinių medžiagų tinkamumo radiacinės saugos požiūriu įvertinimas, kai naudojamos ne tik jų radionuklidų aktyvumo rodikliai, bet ir, esant būtinybei, atliekant galimų apšvitos dozių skaičiavimus, yra efektyvus radiacinės saugos optimizavimo būdas, padedantis lanksčiau taikyti radiacinės saugos reikalavimų sistemą.
4. Apšvita nuo statybinėse medžiagose esančių radionuklidų jonizuojančiosios spinduliuotės gali būti sumažinta kontroliuojant radionuklidų savituosius aktyvumus šiose medžiagose. Vienas iš tokios kontrolės būdų yra pakeisti statybines medžiagas medžiagomis, kuriose yra mažesni radionuklidų savitieji aktyvumai.
5. Apšvita nuo radono, išsiskyrusio iš statybinių medžiagų, gali būti mažinama gerinant patalpų vėdinimą ir padengiant vidinius patalpų paviršius (paprastai sienas) radonui nepralaidžia danga.

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Laima Pilkytė

INVESTIGATION OF CONCENTRATIONS OF RADIONUCLIDES IN
LITHUANIAN CONSTRUCTION MATERIALS, MODELLING AND
EVALUATION OF EXPOSURE DUE TO THESE RADIONUCLIDES

Summary of Doctoral Dissertation

Technological Sciences, Environmental Engineering and Landscape Management (04T)

Laima Pilkytė

RADIONUKLIDŲ SAVITOJO AKTYVUMO STATYBINĖSE MEDŽIAGOSE
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Daktaro disertacijos santrauka

Technologijos mokslai, aplinkos inžinerija ir kraštovaizdis (04T)

2006 09 13. 1,5 sp. l. Tiražas 100 egz.

Leido Vilniaus Gedimino technikos universiteto

leidykla „Technika“, Saulėtekio al. 11, LT-10223 Vilnius

Spausdino UAB „Biznio mašinų kompanija“,

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