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Radiation Safety of Building Materials in Volgograd Region

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Abstract. The comfort and safety of buildings largely depends on the radiation properties of the building materials used. Therefore, an important problem for the construction industry is radiation and hygienic support of technological processes and construction. In many ways, the solution of the problem depends on the implementation of legislation in the field of population restriction from effects of natural radionuclide. The article presents the results of studies of the specific activities of natural radionuclide of building materials produced and used in the territory of the Volgograd region. Radiation monitoring in construction is necessary to ensure the radiation safety of the population.

1. Introduction

Contrary to the prevailing ideas about sources of ionizing radiation of natural origin as a natural radiation background, which has a more or less constant value throughout history, often human economic activity leads to a significant redistribution of natural radionuclide in the environment. This is most noticeable in the construction industry, extraction and processing of oil and gas, mineral resources and other mineral deposits. As a rule, production processes in these sectors of the economy are accompanied by a significant concentration of natural radionuclide with the formation of local pollution of high activity. The modern strategy of ensuring radiation safety of the population, which has been developed in the new edition of regulatory legal acts system, requires a serious review of the main practical approaches to assessing and ensuring the radiation well-being of the population.

A considerable share in the increase in anthropogenic radiation background is made by building materials and products. In buildings (where artificial sources are absent), the population is exposed to a technologically modified natural radiation background caused by natural sources of ionizing radiation: cosmic radiation and natural radionuclide (NRN) contained in the soil on which the building is built; in building materials from which the envelope buildings are made; as well as in entering the room with air, water and as a result of fuel combustion. In many developed countries of the world, high levels of exposure of the population have been found in doses significantly exceeding the allowable levels due to the use of building materials with a high content of NRN and the daughter decay products of radon that accumulate in the indoor air. The greatest reserves for decreasing the radiation exposure of the population are contained precisely in such “indisputable” forms of human activity [1-3].

The effect of increased radiation background, which is largely determined by the NRN in building materials and structures, on the population manifests itself in the form of somatic-stochastic and genetic effects, which are observed at low doses of radiation. In this case, the risk of manifestation of these effects increases with an increase in the magnitude of the increased radiation background. Thus, according to the World Health Organization, the annual radiation dose in buildings is comparable to the dose received in the process of x-ray diagnostics.

Ensuring the radiation safety of the population when exposed to natural sources of radiation is based on the basic principles: rationing, justification and optimization.



The principle of rationing is not exceeding the permissible limits of individual exposure doses to citizens from all sources of ionizing radiation.

The principle of justification is the prohibition of all activities involving the use of ionizing radiation sources, in which the benefits obtained for people and society do not exceed the risk of possible harm caused by additional radiation to the natural radiation background.

The principle of optimization is to maintain at the lowest possible and achievable level, taking into account the economic and social factors of individual radiation doses and the number of irradiated persons using any source of ionizing radiation.

The implementation of the first principle is carried out by compulsory licensing of activities related to the possible impact of ionizing radiation on people.

The second principle is implemented by automating technological processes, optimizing labor and introducing a system of control levels. Control levels are the values of dose limits and permissible levels established by the management of the institution (enterprise) and local authorities of the State Sanitary and Epidemiological Surveillance in order to minimize the radiation impact on personnel, population and environmental objects in relation to the regulated standards and based on the achieved level of radiation safety.

The third principle is implemented through state supervision over the provision of radiation safety and the established procedure of responsibility for exceeding the regulated dose limits.

Radiation safety of personnel, population and environment is considered to be ensured if the basic principles of radiation safety (justification, optimization, rationing) and radiation protection requirements are observed.

One of the fundamental provisions of the regulation of radiation protection in Russia is their compliance with the International Standards of Radiation Safety, which is confirmed by the Law of the Russian Federation "On the Radiation Safety of the Population" (1996).

It should be noted that the radiation safety requirements of the population apply to regulated natural radiation sources in industrial, communal conditions and everyday life: radon isotopes and their radioactive decay products in indoor air, gamma radiation from natural radionuclide contained in building products and materials. To ensure the safety of human life, it is necessary to differentiate between the selection of building materials in the design and construction of buildings and structures for various types of purposes. The modern strategy of ensuring radiation safety of the population, which has been developed in the new edition of regulatory legal acts system, requires a serious review of the main practical approaches to assessing and ensuring the radiation well-being of the population.

2. Relevance of research

The main part of exposure throughout the life of a person receives from natural sources of radiation. On average, they provide more than 5/6 of the annual effective dose, and more than 50% of this value - exposure due to natural radionuclide contained in the building materials of structures. In ensuring the environmental safety of urban planning and improving the efficiency of the territory use, more and more attention is paid to natural radioactivity, although for many regions of the country it remains open. According to the International Commission on Radiological Protection and the United Nations Scientific Committee on the Effects of Atomic Radiation, the largest portion of the radiation dose (about 80% of the total) received by the population under normal conditions is associated with natural radionuclide [4]. NRNs are present in almost all environmental objects and the human body. Ionizing radiation creates a radiation background.

The most significant for radiation hygiene, control of building materials and products are natural radionuclide: ^{226}Ra , ^{232}Th , ^{40}K , ^{222}Rn . Indoors, a person is exposed to both external gamma radiation, due to the content of NRN in building materials, and internal, associated with inhalation of ^{222}Rn and its daughter decay products (DDP) contained in the air. DDP - isotopes ^{222}Rn - ^{214}Pb , ^{212}Bi , ^{212}Po in the air, including in buildings. Important effects of exposure to the natural radioactivity of building materials are reduced to two effects: gamma irradiation of the whole body and irradiation of lung tissue with decay products of ^{222}Rn and its daughter decay products. Therefore, the task of the

radiation safety of buildings is to develop methods for assessing and predicting the radiation situation in order to ensure normal working and living conditions of the population from the effects of natural radionuclide.

The radioactivity of building materials depends on many factors, among which it is necessary to note the type of rock used for production; place of rock mining; as well as the type of waste involved in the production of building materials in the form of filler or binder. Radiation contamination of building materials can be caused not only by its origin, but also by the introduction of radioactive pollutants from the environment into it. It is the radioactivity of building materials that is the main component of the technologically modified background that exists due to the redistribution of the NRN.

It is now recognized that effective doses of the population in the premises can be very high and can be reduced, and also the occurrence of significant doses during the construction of new buildings can be avoided by interfering with the existing construction practices.

The growth of requirements for environmentally friendly construction is associated not only with the creation of a comfortable living environment in the house, but also with ensuring complete safety of the home for human health.

3. Task

Investigation of specific activities of ^{226}Ra , ^{232}Th , ^{40}K of building materials, raw materials, industrial waste; evaluation of the effective specific activities of the NRN in the construction complex of the Volgograd region; reduction of radiation loads of the population.

4. Materials and research methods

The information accumulated in recent years has changed the existing perception of the immutability of the level of exposure due to natural sources of radiation and the impossibility of influencing it. It is obvious that the level of exposure is determined by the building design, used building materials and ventilation conditions, i.e. depends on the activities of people.

The intensity of terrestrial radiation varies greatly depending on the soil, minerals that make up building materials and the type of buildings. In some cases, the gamma background of the premises and the radon component of the air can be very high.

Therefore, minerals mined in the region, and especially imported (from other regions, countries) should be monitored for radiation. We also mean production waste, fuel systems, especially coal-fired, and used by construction companies in the form of additives or components in concrete, silicate and ceramic production, in road construction.

An important step in changing the activity of the end product of a building production (brick, slag concrete, panels, etc.) may be technological heating or firing of materials, as a result of which the radioactive characteristics change (for example, radon emanation coefficients). It is known that the effective specific activity of radium and radon emanation coefficient are increased during steaming of concrete or during the autoclave treatment of silicate bricks, and these parameters are significantly reduced when firing clinker of cement or ceramic bricks.

Thus, analyzing raw materials, building materials, final products you can always find the best option to reduce the radiation parameters. That is, this process of reducing radiation loads can be controlled.

Radiation background in the premises is considered as one of the main types of radiation exposure of the environment to the population, since a person spends most of his time indoors. The dispersion of the radiation background values in the premises depends on many factors, of which the following can be distinguished:

- type of the material from which the building is constructed and the structures in it;
- the geometry of the building (architectural planning solution);
- density of street buildings of various materials;
- radiation background of nearby territories and buildings.

It is known that building materials of various origins are characterized by a whole complex of physical, mechanical and technical characteristics: mechanical strength, frost resistance, water resistance, etc. The problem of radioactivity of building materials is considered from two interrelated points of view: radiation-hygienic and technological. If the first establishes permissible radiation regulations for various building materials and provides a control system, then the technological approach requires making such constructive decisions, under which these regulations will be maintained, and the radiation doses will be as low as it is achievable, taking into account acceptable technical and economic indicators in this region.

Hygienic assessment of building materials can be established by the value of the effective specific activity (A_{eff}). The value of natural radionuclide A_{eff} is used in the regulation and control of radioactivity of building materials and determines the dose rate of gamma radiation in buildings. The dose rate of gamma radiation is proportional to the weighted average A_{eff} of natural radionuclide in building materials used in the construction of buildings [5]. Therefore, it can be changed only by influencing the range of building materials used, for example, by refusing to use materials with the highest content of natural radionuclide in housing construction. This can be achieved by rationing A_{eff} in materials mined at individual fields.

The regulation and control of the A_{eff} value is a method to reduce this component of human exposure. The radiation safety standards RSS-99/2009 [6] are aimed at limiting the exposure of the population from natural radionuclide contained in building structures and air of industrial, social and residential premises. The regulatory documents contain requirements for limiting exposure of the population in residential and public buildings: standards and levels of intervention for gamma-radiation dose rate and average annual volume activity of the daughter products of radon isotopes in the air of the designed (under construction) and existing buildings; radioactivity standards for building materials and products used in various types of construction; criteria for evaluating construction sites based on gamma-radiation dose rate and radon flow from the ground surface.

Qualitative and quantitative analysis of the specific activity of NRN in the samples was performed on a scintillation gamma spectrometer. The values of specific activities K^{40} , Ra^{226} , Th^{232} were experimentally obtained, and the calculations of the effective specific activities of the NRN were performed. The value of the effective specific activity of natural radionuclide A_{eff} is used in the regulation and control of the radioactivity of building materials. According to regulatory documents [6, 7]:

$$A_{\text{eff}} = A_{\text{Ra}} + 1.31A_{\text{Th}} + 0.09A_{\text{K}} \quad (1)$$

where A_{Ra} and A_{Th} are the specific activities of ^{226}Ra and ^{232}Th in the material, which are in equilibrium with other members of the uranium and thorium series, A_{K} is the specific activity of ^{40}K in the material (Bq/kg).

Effective specific activity of natural radionuclide in building materials (crushed stone, gravel, sand, rubble and sawn stone, cement and brick raw materials, etc.) mined at their deposits or being a by-product of industry, as well as industrial waste used for the manufacture of building materials (ashes, slags, etc.), and finished products should not exceed:

- for materials used in construction and reconstruction of residential and public buildings, such building materials can be used for all types of construction without restrictions (Class I) - $A_{\text{eff}} \leq 370$ Bq/kg;

- for materials used in road construction within the territory of settlements and areas of prospective development, as well as in the construction of industrial buildings (Class II). When using these materials for the construction of industrial buildings in the premises, sufficient air exchange should be ensured (at least three times per hour) - $A_{\text{eff}} \leq 740$ Bq/kg;

- for materials used in road construction outside settlements (Class III) - $A_{\text{eff}} \leq 1500$ Bq/kg. Materials of class III within settlements are suitable only for the construction of underground structures in which people are not allowed to stay (sewer pipelines, collectors, etc.) provided that they are covered with a layer of soil of at least 0.5 m or low-level radioactive material.

At $1.5 \text{ kBq/kg} < A_{\text{eff}} \leq 4.0 \text{ kBq/kg}$ (class IV), the use of materials is decided in each case separately on the basis of the sanitary-epidemiological conclusion of the Federal executive body authorized to exercise state sanitary-epidemiological supervision.

At $A_{\text{eff}} > 4.0 \text{ kBq/kg}$ materials should not be used in construction.

This classification makes it possible to correctly assess all types of building materials, including industrial waste with different specific activity of natural radionuclide, without taking into account the degree of population exposure. It should be borne in mind that the standards do not apply to raw materials, but to finished products - building materials (cement, aggregate, crushed stone, concrete, and others). Therefore, in cases where the raw materials in the manufacturing process of building materials are subjected to processing, which can change the total specific activity of radionuclide (washing, firing, etc.), the product must meet the standards.

The permissible content of natural radionuclide in mineral raw materials and materials, products using them (products made of ceramics and porcelain stoneware, natural and artificial stone, etc.), as well as requirements for ensuring radiation safety when handling them, are established in the sanitary regulations for limiting population exposure due to natural sources of radiation.

5. Results and discussion

Effective specific radioactivity is practically the only controlled parameter in determining the environmental safety of building materials. The value of the effective specific activity of natural radionuclide characterizes the dose rate of gamma radiation generated by large masses of material with a uniform distribution of radionuclide. The coefficients in the above expression were calculated for an infinite space with a uniform distribution of radionuclide and gamma-ray spectra (4π -geometry) [8]. Calculations of the gamma-radiation dose rate for a semi-infinite space (2π -geometry), performed by the Monte-Carlo method, gave the values of these coefficients close to those used in the above ratio.

The problem of radioactivity of building materials is considered from two interrelated points of view: radiation hygienic and technological. If the first establishes permissible radiation regulations for various building materials and provides a control system, then the technological approach requires the adoption of such constructive decisions, under which these regulations will be maintained, and the radiation doses will be as low as it is achievable, taking into account acceptable technical and economic indicators in this region.

Table 1 presents the concentration of specific activities of the NRN in building materials of the Russian Federation [9].

Table 1. Specific activities of NRN in building materials of the Russian Federation

Type of building material	A_{eff} , Bq/kg
Russian soil	118
Clay	102.2
Sand	40.3
Crushed stone of dolomite and limestone	22.4
Crushed granite	126.6
Lightweight concrete	55.5
Heavy concrete	70.3

The concentration of the averaged effective specific activity of the NRN varies in Russia in the range from 22.4 to 126.6 Bq/kg, which does not exceed the value for building materials of class I.

The Laboratory of Radiation Control of the Institute of Architecture and Civil Engineering of Volgograd State Technical University (IACE of VSTU) conducted research on the content of natural radionuclide in building materials and production wastes. Table 2 shows part of the results of large-scale studies of the effective specific activity of the NRN building materials produced in the Volgograd region [9].

Table 2. Volume and results of studies of the effective specific activity of NRN in the building materials produced in the Volgograd region

Material	Number of samples	A _{eff} , Bq/kg
Binding material		
Cement M500-D20, M500-D0	10	73.3-41.8
Gypsum G-4, G-6, G-8	11	21.6-35.6
Lime	8	91.5-96.0
Wall materials and products		
Ceramic	18	77.8-166.5
Silicate	16	20.8-45.4
Asbestos-cement products		
Asbestos	3	77.9
Asbestos	3	66.3
Concrete and reinforced concrete		
Concrete V-15, V-20, V-30, V-40	31	31.4-134.9
Porous aggregates for concrete		
Expanded clay	33	88.8-200.8
Ceramic materials and products		
Ceramic facing tile	7	224.3-237.6
Mettlach ceramic tile	3	166.1
Glazed floor tile	3	243.2
Extruded tile	3	196.9
Ridge tile	3	154.4
Ceramic sanitary ware	5	186.5
Ceramic pipes	3	211.4

The specific effective activity of finished building materials and products produced on the territory of the Volgograd region varies from 20.8 Bq/kg to 243.2 Bq/kg, which corresponds to the sanitary standards for the content of radioactive nuclides in building materials of class I according to radiation characteristics.

Due to the considerable variability of natural radioactivity [10, 11], the range of individual doses of population exposure even within the same territory reaches one order or more. This creates serious problems related both to the control of natural radiation exposure of people and the possibilities of reducing their exposure. Building materials of local production according to the results of research can be used in all types of construction, including housing.

6. Conclusion

Building materials are characterized by a large range of variation in the NRN activity. This is an important fact, indicating the possibility of controlling the radiation quality of building materials and products by eliminating or reducing the share of highly radioactive raw materials in them. Positive experience convincingly refutes the statement about impossibility of influence on the level of irradiation of the population caused by natural sources.

Solving the problem of obtaining environmentally friendly building materials using natural and technogenic raw materials can be achieved through a systematic approach involving the implementation of a set of measures, including chemical binding of natural and man-made radionuclide in stable slightly soluble compounds and removal from the raw materials or blocking them in the structure of the material.

To control the quality of raw materials during construction work, it is necessary to conduct its radiation and hygienic assessment. Therefore, the control of building materials and building sites should be carried out in the aggregate and not rely on the assessment of only one indicator. All types

of construction control should be aimed at achieving its maximum quality; ensuring non-exceedance of radiation hygienic standards and human safety.

The development of scientific ideas in the field of radiation safety of the population, their practical implementation within the framework of the national radiation protection system will provide a solution to the problem of limiting public exposure from natural sources of radiation and will optimize the system of public protection and reduce radiation risks.

The strategy of ensuring radiation protection of the population is to extend the radiation safety requirements to all sources of ionizing radiation, taking into account the importance of individual types of radiation and their contribution to the total effective dose.

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