

Environmental and Hygiene Requirements for Ensuring Radiation Safety During the Construction and Reconstruction of Buildings in The Russian Federation

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Abstract: The levels of natural background radiation in certain territories of the Russian Federation differ significantly from each other and can vary widely. Most of the population receives radiation doses from natural sources of ionizing radiation from 2 to 4 mSv/year, but in some areas their radiation levels exceed 10 mSv/year. The population of the Russian Federation receives the main collective dose of radiation from natural radiation while living and working in enclosed residential, public and industrial buildings. In them, the levels of ionizing radiation in buildings, as a rule, depend on the level of the radiation background of the territory, which is determined by the geological, geochemical features of the area and its terrain, as well as on the type of building, radioactivity of the building materials used, emanation and exhalation of radon and daughter products of its decay into rooms from the ground and building materials used. The average annual individual doses of ionizing radiation in buildings, with the exception of certain territories, are small, but they can in isolated cases cause somatic and genetic effects in humans. To reduce the likelihood of such consequences in the Russian Federation, a system of legal and organizational provision of radiation safety of the population during the construction and reconstruction of buildings was developed, environmental and hygienic requirements for it were determined.

Keywords: Average annual individual doses, Ionizing radiation, Natural sources, Restriction of exposure of the population.

INTRODUCTION

Ensuring the radiation safety of the population, including from natural sources of ionizing radiation, is one of the priorities in the Russian Federation. The levels of natural background radiation in individual territories of the Russian Federation differ significantly from each other, but they are relatively constant in the same territory for a long period of time. The main reasons for the heterogeneity of the radiation background of territories are their geological and geochemical features. Relatively safe levels of the effective dose of gamma radiation in an open area are considered to be levels in the range of 0.05-0.15 mSv/h, which is typical for most territories of the Russian Federation [1-3].

The average total individual radiation dose from natural sources of ionizing radiation of the majority of the population ranges from 2-4 mSv/year. The exposure of 10.2% of the population is about 5 mSv/year, and the exposure of 0.78% exceeds 10 mSv/year [1, 2].

The levels of ionizing radiation inside buildings are directly related to the natural radiation background of the territory and its individual components, but they are usually noticeably higher than in open areas.

Prerequisites for an increase in the levels of ionizing radiation in buildings are increased levels of natural radionuclides contained in the soil and mineral building materials, the release of radon and short-lived daughter products of its decay from the soil, building materials, drinking water and natural household gas. Sanitary products, decorative and finishing materials with a high content of natural radionuclides can be additional sources of ionizing radiation in buildings. In rare cases, buildings can be contaminated with technogenic radionuclides, due to contamination of residential areas as a result of local or global radiation accidents [1-3].

People in buildings are exposed to external and internal radiation. The main sources of external radiation are cosmic radiation, gamma radiation of terrigenous radionuclides and natural radionuclides contained in building materials. The population receives internal exposure due to the inhalation of radon and short-lived daughter products of its decay, emanated from soil and building materials, drinking water and natural household gas. Moreover, the level of internal exposure to radon and its daughter products of decay is more than 50% of the annual radiation dose of the population due to natural sources. When inhaling vapors of radioactive gases, as well as dust particles with radionuclides sorbed on their surface, the epithelium of the nasopharyngeal mucosa, trachea, bronchi, alveoli are irradiated with alpha particles, which causes microburns of tissues and can lead to the development of lung cancer. At the same time, more

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than 95% of the human radiation dose is caused by inhalation not of radon itself, but of its short-lived daughter decay products - isotopes ^{210}Po , ^{214}Bi and ^{214}Pb [1, 2, 4, 5].

The majority of the rural population of the country in the cold season, and the urban population throughout the year spend a significant part of the time (up to 80-90%) indoors and receives the main collective dose of radiation from natural sources. Currently, the ambient dose rate of gamma radiation in enclosed spaces varies in wooden buildings from 0.06 to 0.21 mSv/h, in stone buildings – from 0.06 to 0.20 mSv/h, in multi-storey buildings – 0.04 - 0.20 mSv/h [6]. However, in some localities of the Zabaikalsky and Khabarovsk Territories, the Evreisky Autonomous Okrug, Irkutsk and Chelyabinsk regions, it reaches 0.22 - 0.30 mSv/h [2]. The average levels of the effective equilibrium volume activity (EEVA) of radon in the air of buildings in individual territories range from 6 to 172 Bq/m³, and its average value in the whole country is about 31 Bq/m³ [2, 6]. The radiation doses of the population in most buildings are small, nevertheless they are sufficient for the occurrence of individual cases of stochastic effects among the population.

In this connection, the Russian Federation has developed a system for limiting the effects of ionizing radiation on humans, containing environmental and hygienic requirements for ensuring radiation safety during the construction and reconstruction of buildings.

The System of Limiting the Doses of Exposure of the Population During the Construction and Reconstruction of Buildings

Interest in studying the patterns and levels of exposure of the population from natural sources in residential, public and industrial buildings in the

Russian Federation arose when the first information about the possible negative effects of small doses of ionizing radiation on humans appeared. And although this issue has not yet been fully resolved, the International Commission on Radiation Protection (ICRP) has proposed the concept of linear non-threshold action of ionizing radiation, according to which any arbitrarily small dose of ionizing radiation can cause somatic-stochastic and genetic effects in humans body. Currently, this concept is accepted by most of the scientific community, since it is sufficiently confirmed by the data of many epidemiological studies [7, 8].

Since 2001, information on the levels of exposure of the population of the Russian Federation due to natural sources of ionizing radiation (Block – № 4-DOS) has been collected annually in the Russian Federation within the framework of the Unified governmental system of control and accounting on the individual doses of the citizens (ISDCR) [9]. This system made it possible to create a Federal data bank on the doses of exposure of the population to natural sources, to identify areas with elevated levels of natural radiation, to establish the most significant factors of exposure of the population of the Russian Federation in buildings. This system has a hierarchical structure, which makes it possible for the research to cover the entire territory of the country (Figure 1).

The accumulated data made it possible to develop measures to reduce the levels of natural radiation exposure of people in buildings to realistically possible values, taking into account the peculiarities of the natural distribution of natural radionuclides in environmental objects of a particular territory. These measures gradually transformed into a coherent system of legal, organizational and restrictive measures, including recommendations for limiting the

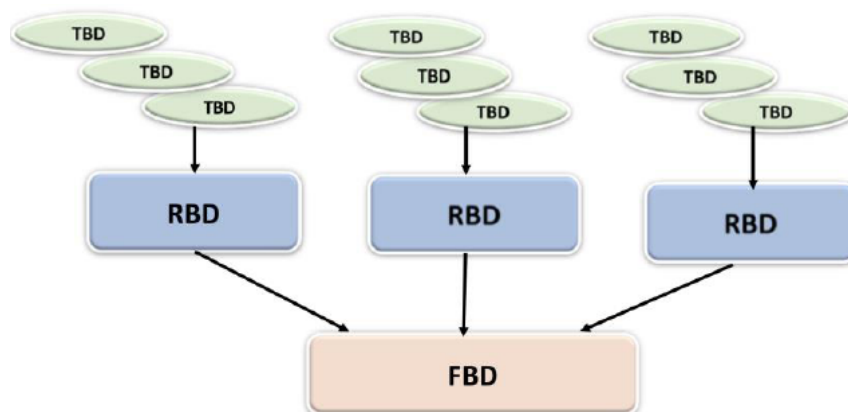


Figure 1: Scheme of collecting information in the Federal Data Bank on the doses of exposure of the population to natural sources. (FBD – federal database; RBD – regional database; TBD - territorial database).

effective dose of gamma radiation, the level of radon and short-lived daughter products of its decay in buildings, the content of natural radionuclides in building materials, sanitary and technological devices, as well as recommendations for the design, construction and reconstruction of buildings [10-15].

This system contains both preventive and corrective measures to ensure the reduction of public exposure levels in buildings, and includes:

- radiation monitoring of the territory of future development at the stage of allotment of land for construction or around the reconstructed building;
- radiation monitoring of buildings before reconstruction;
- radiation control of building materials;
- radiation monitoring of commissioned buildings after construction and reconstruction.

Radiation Monitoring of the Territory

Radiation monitoring of the territory of future development at the stage of allotment of land for construction or around the reconstructed building includes measuring the ambient dose rate of gamma radiation and determining the density of radon flux from the ground.

Determination of the level of gamma radiation is carried out in order to:

- estimates of the intensity of gamma radiation in the controlled area;
- identification of local areas or individual points with increased natural gamma radiation inherent in this area;
- identification of local sources of ionizing radiation or local areas of contamination of the territory with technogenic radionuclides.

If the intensity of gamma radiation at the site of the planned development does not exceed 0.3 mSv/h for residential and public buildings and 0.6 mSv/h for industrial buildings, it is considered that there are no local radiation anomalies in the surveyed area and the land plot is suitable for construction [11, 13, 15].

On the territory of settlements, in most cases, the presence of anomalous zones is due to the filling of individual sections with granite rubble, the location of large natural stones near the surface of the earth, the remnants of construction debris. In some cases, anomalies may be associated with the presence of

radioactive contamination of the soil by gamma-emitting radionuclides of technogenic origin. When radiation anomalies are detected, the boundaries of their localization on the soil surface are determined, their causes are established and, if possible, eliminated. If it is impossible to eliminate the radiation anomaly in the building project, a system for reducing gamma radiation levels inside buildings should be provided.

Determination of the radon flux density (RFD) from the ground surface is carried out in order to control the potential radon hazard of the territory. In the areas of the planned development, the RFD is measured within the contour of the projected building. If the PPR on the surveyed site allocated for the construction of residential and public buildings does not exceed 80 mBq / (m²· s), and for industrial buildings 250 mBq / (m²· s), then it is considered that this area is not radon-hazardous and the construction of buildings on it is possible without special radon-protective measures. If the RFD exceeds these values, then the final decision on the possibility of construction of a building is made, taking into account repeated measurements at the level of laying the sole of the foundation. The development of engineering and construction radon protection measures to reduce radon intake into buildings from the soil is carried out by design and specialized scientific organizations, taking into account the radon hazard of the territory, the effectiveness of radon protection characteristics of the structures of the underground part of the building provided for in the project. The control of RFD from the ground surface on land plots adjacent to buildings, taking into account the large dilution of the emitted radon by atmospheric air, is not carried out.

Additionally, the content of natural radionuclides in the soil is monitored on land plots allocated for construction, if it is planned to move soil during construction and further use for backfilling. At the same time, the soil is treated as a building material. If there is a suspicion on contamination of the soil with artificial radionuclides as a result of radiation accidents or emissions of industrial enterprises, the soil is monitored for the content of these radionuclides in it. At the same time, the specific activity of technogenic radionuclides should not exceed the values established by legislation [2, 15].

Currently, in many regions of the Russian Federation, maps of the potential radon hazard of certain territories, geological maps of geochemical anomalies, pollution of certain territories with technogenic radionuclides due to radiation accidents, and others have been compiled. They help to identify

possible problem areas more quickly, to make a more optimal layout of settlements, to determine areas of future construction, to develop recommendations on radiation protection of buildings.

Radiation Monitoring of Buildings before Reconstruction

Radiation monitoring of buildings before reconstruction is carried out to identify possible radiation contamination and anomalies that occurred during their construction or during their operation. This is especially important for buildings built before the introduction of the radiation control system in the country. At this stage, the ambient dose rate of gamma radiation in buildings and the emission of radon isotopes in the air are monitored. If the measured values exceed the established standards, then the reconstruction project of the building should provide for measures to reduce the levels of gamma radiation and (or) radon emission.

Radiation Control of Building Materials and Sanitary Devices

Currently, in the Russian Federation, all construction materials and their components manufactured using mineral raw materials and industrial waste containing natural radionuclides are subject to radiation control by the manufacturer during their production. Depending on the radiological characteristics of the deposits of the main components of building materials used in the production of these products, the content of natural radionuclides in them can vary in a wide range. At the same time, they determine the effective specific activity of natural radionuclides (^{226}Ra , ^{232}Th , ^{40}K). For the construction and reconstruction of residential and public buildings, only construction materials are allowed, the effective specific activity of which does not exceed 370 Bq/kg and 740 Bq/kg for industrial buildings. It is allowed to use ceramic and granite tiles, facing products made of natural and artificial stone for the exterior and interior cladding of buildings, the effective specific activity of natural radionuclides in which does not exceed 740 Bq/kg. Wood products containing technogenic radionuclides are allowed to be used in construction if the permissible specific activity of ^{137}Cs in them does not exceed 300 Bq/kg [13, 14].

In addition to building materials, sanitary products, decorative and finishing products made of porcelain stoneware, natural and artificial stone, clay, earthenware and porcelain and other materials containing natural radionuclides are monitored for the content of natural radionuclides [2]. They control the effective specific activity of natural radionuclides, and

also determine the content of natural radionuclides in the aqueous extract [10]. The effective specific activity of natural radionuclides in them should not exceed 740 Bq/kg, and the content of natural radionuclides in the aqueous extract should not exceed 1.76 Bq. Compliance of these requirements reduces the risk of radiation exposure to the population to a minimum.

Radiation Monitoring of Buildings after Construction or Reconstruction

All newly constructed and reconstructed buildings are subject to radiation control. The ambient dose rate of gamma radiation and the average annual dose of radon isotopes in indoor air are monitored in buildings. This control makes it possible to determine the overall level of gamma radiation in the building and to identify local radiation anomalies in the building's enclosing structures, if any occurred during construction or were not eliminated during the reconstruction of buildings [12].

The dose rate of gamma radiation in newly constructed and reconstructed residential and public buildings should not exceed the ambient dose rate in an open area by more than 0.2 mSv/h and for industrial buildings - 0.6 mSv/h. When local radiation anomalies are detected in the structures of buildings, measures are taken to eliminate them. The average annual EEVA of radon and thoron daughter products in indoor air in newly constructed residential and public buildings should not exceed 100 Bq/m³, and in industrial buildings - 150 Bq/m³. At higher values of the volumetric activity of radon in the premises, protective measures should be carried out aimed at reducing the intake of radon into the air of the premises and improving the ventilation of the building.

Great attention in the design, construction and reconstruction of buildings is paid to ventilation and sealing of the basements of the building, the quality of construction work. Wall cladding, sealing cracks in the floor and walls helps to reduce the radon content in buildings. Radon emission from the walls decreases by about 10 times when the walls are lined with plastic materials made of polyamide, polyvinyl chloride or when the walls are covered with a layer of paint, wallpapering. If it is impossible to reduce the power values of the ambient equivalent of the dose of gamma radiation and/or the EEVA of the daughter products of radon and thoron in the indoor air to a standard level without violating the integrity of the building, the issue of converting the building or part of it from residential to non-residential is considered. If it is impossible to repurpose it due to the high level of radiation hazard, the building is subject to demolition [16-19].

CONCLUSIONS

In residential, public and industrial buildings, ionizing radiation acts on the population, its level of exposure depends on the level of the radiation background of the earth that has developed in the territory of their residence and work, the radioactivity of the building materials used, the emanation and exhalation of radon and its daughter products of decay into rooms from soil and building materials. Although the levels of ionizing radiation in buildings, with the exception of certain territories and buildings, are small, they can in isolated cases induce the development of somatic-stochastic and genetic effects in humans. To reduce the likelihood of such consequences in the Russian Federation, a system has been developed to limit the effects of ionizing radiation on humans and environmental and hygienic requirements for ensuring radiation safety during the construction and reconstruction of buildings have been defined. It implies carrying out preventive and corrective measures at the stages of allotment of land for construction, manufacture of building materials, quality control of the building being erected or reconstructed. The current system of radiation limitation in residential, public and industrial buildings in the Russian Federation makes it possible to apply radiation protection measures to the population in a timely manner and significantly reduce the risk of exposure to natural radionuclides.

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