Radiation and environmental studies of the air of industrial premises of construction industry plants in the cities of Volgograd and Rostov regions

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Abstract. The article deals with the problems of ensuring radiation and environmental safety in industrial buildings. At present, the background radiation in buildings is considered as one of the main types of radiation exposure, since workers spend most of their day in the workshops of factories for the production of building structures. The article analyzes the main changes that have occurred in the system of ensuring radiation safety of workers in the construction industry with the introduction of new sanitary rules to limit the exposure of workers to natural sources of ionizing radiation. The necessity of research of radon characteristics is shown. The results of studies of the volumetric activities of radon in the air of industrial premises in the cities of the Volgograd and Rostov regions are presented. Aspects of the problem of reducing radon loads on workers in the construction industry are considered.

1. Introduction
Among the important environmental problems of the countries of the world, the problem of the presence of radon in indoor air is given priority. Radioactive derivatives of the decay of Radon make the predominant contribution to the radiation background of industrial premises of construction industry plants, as well as residential buildings. Radon causes an effective radiation dose of 1 mSv per year, i.e. not less than half of the radiation dose to workers from all natural sources [1]. According to current reports from the Scientific Committee on the Effects of Atomic Radiation at the United Nations (UNSCEAR), more than 10% of human lung cancers detected every year in the world are due to exposure to Radon. It also significantly increases the risk of cardiovascular disease and upper respiratory tract disease. In this regard, radon pollution occupies an important place in the radioecological programs of the developed countries of the world. According to the International Agency for Research on Cancer, radon is classified as a class I carcinogen. Depending on the dose, the exposure level of people over 70 years of age in Western Europe is 0.2-1.5 Sv, and the exposure level of workers in the most harmful areas exceeds the "normal" exposure level by more than 1 Sv. In this case, a small group of people's exposure can be dozens of times higher than the average [2-4]. According to the Institute of Radiological Health of Russia, thousands of residents receive 1.5 rem from the reception every year, that is, more than 100 rem in their lifetime. In just one year, the collective radiation dose from indoor spaces for the crowd is around 150,000 Sieverts [5-7].
2. Relevance and scientific significance of the issue
The concentration of radioactive natural gas radon in the air of industrial premises of construction industry plants can vary over a wide range depending on various natural and man-made factors. Consequently, the issue related to the assessment of the levels of volumetric activity of radon gas in the production shops of construction industry plants is necessary for the implementation of technical measures to control and reduce the dose load of the working population.

3. A task
The study by the method of factorial analysis of the activities of radioactive radon gas in the production workshops of the construction industry plants, built from building materials of various structures, as well as the generalization of the studied material on the distribution of radon gas in the air of the working areas of industrial premises.

4. Materials and research methods
Areas where there are rocks on the surface, the content of U and Th in which up to 100 g / t or more is usually referred to as zones of increased radioactive risk. According to the studies above, the emission of rays of radioactive gas radon is where there are faults in the rock, zones of weathering. Of the many factors in the aggregate, affecting the workers, the factors associated with the location of construction industry plants within the boundaries of tectonic disturbance zones have the greatest influence on the occurrence of oncological diseases. The release of radioactive gas radon is observed in seismically hazardous areas. Radon in the air of industrial premises of construction industry plants has a predominant effect on the exposure of the population to radioactive gas. The percentage of radon in the air of the working areas of the shops of factories producing building materials depends primarily on the quantitative content of radionuclides in the geological base under the building, building materials used in the building, and other factors. Indicators of the volume and speed of movement of radon in rooms are stochastic and depend on the natural component, on the structure of the building, the materials used in the construction and aeration. Taking into account the above factors will significantly reduce the exposure of people in the production premises of construction industry plants [3].

The greatest contribution to the gas component of natural radioactive elements is made by the radioactive families of uranium-238 and thorium-232, during the decay of which radioactive radon-222 and radon-220 are formed (Figure 1).

Almost all modern building materials contain Rn and Tr, as well as their parent nuclides. The gas formed as a result of radioactive decay seeps through various soil inclusions, erosion of rocks, followed by mixing with other gases and can be transported over decent long distances in the earth's crust and atmosphere. Moreover, the decrease in the percentage of gases due to the course of the
processes of emanation, exhalation and natural decay on a permanent basis is compensated by the
decay of other radioactive elements present in the materials.

The dose from radioactive rocks Rn, Tr and also their derivatives decay products are influenced by
the radiation component of building materials, foundations of workshops and the water used.
Depending on the region of study, the impact of individual factors has features that depend on the
geological structure, the concentration of active radionuclides in the base rocks, groundwater,
emanation, etc. [8,9]. The measured doses in the shops of the construction industry plants were
changed depending on the stochasticity of the given characteristics.

Radon, like other derivatives of the decay products of radionuclides, penetrates into an industrial
building through almost any leaks in the building envelope (basement, basement floors and pits)
located below ground level: cracks in the floor disks, open areas of the base in the basement or
underground space, engineering communications inputs, joints between foundation blocks, beams,
foundation pads, etc [10,11].

Comparing international and Russian standards for determining standardized values: in the world it
is the International Commission on Radiological Protection (ICRP), which proposes to regulate the
volumetric activity of radon-gas in the air, while the radiation safety standards of Russia NRB-
99/2009 - the equivalent equilibrium volumetric activity (EEVA), which leads to the complication of
control and, in turn, imposes more stringent requirements on measuring instruments and measurement
techniques.

EEVA (Bq / m3) is the concentration of radon-gas in such an equilibrium mixture with the products
of radioactive decay, which has the same α-radiation value as the studied mixture. The energy of α-
radiation in an equal volume of air characterizes the total energy of α-particles of those products
retained in the lungs. Thus, it turns out that the value of EEVA allows you to characterize the impact
of radioactive gases, including radon in any mixture with its DPR [12-15]. The intake of the DPR of
radon into the body of a worker in construction industry plants is calculated as the product of EEVA
by the volume of inhaled air.

The requirements of the current radiation safety standards NRB-99/2009 to limit the exposure of
people from radon and thoron are given in Table 1.

Table 1. Requirements for limiting technogenic exposure under controlled conditions [9].

| The quantities | Values of the normalized indicator | Effective doses (ED) per year, mSv |
|----------------|-----------------------------------|-----------------------------------|
| Standards for Group A personnel working with radon (at \( t = 1700 \) h per year, \( v = 1.4 \) m³/h) | | |
| Permissible average annual volumetric activity (DOA) in air: | | |
| Rn: DOA = \( 0.10 \) A_{RaA} + \( 0.52 \) A_{RaB} + \( 0.38 \) A_{RaC} | 1200 Bq/m³ | 20 |
| Th: DOA = \( 0.91 \) A_{ThA} + 0.09 A_{ThC} | 270 Bq/m³ | 20 |
| Annual Admission Limits (AAL): | | |
| Rn: AAL = \( 0.10 P_{RaA} + 0.52 P_{RaB} + 0.38 P_{RaC} \) | 3.0 MBq | 20 |
| Th: AAL = \( 0.91 P_{ThA} + 0.09 P_{ThC} \) | 0.68 MBq | 20 |
| Standards for any worker in a working environment (at workplaces at \( t = 2000 \) h per year, \( v = 1.2 \) m³/h) | | |
| Dose limit in workplaces from all natural sources of radiation Including with mono-factorial exposure to radon isotopes: | \( ED = 5 \) mSv/year | 5 |
| average annual EEVA for Rn* | 310 Bq/m³ | 5 |
| average annual EEVA for Tn* | 68 Bq/m³ | 5 |

*The sum of the ratios of the regulated value to its permissible limit for all natural sources should not exceed one.
When assessing the quality of building materials in Russia [2] for the presence of radionuclides, they are divided into classes according to their effective specific activity (Table 2).

Table 2. Norms of effective specific activity ($A_{\text{eff}}$) of natural radionuclides in building materials.

| Category | $A_{\text{eff}}$, Bq/kg | Permitted types of construction |
|----------|------------------------|--------------------------------|
| I        | $\leq 370$             | All types, including the construction of residential and public buildings. |
| II       | $\leq 740$             | Industrial and road construction. |
| III      | $\leq 1500$            | Road construction outside settlements, within settlements, construction of underground structures covered with soil more than 0.5 m thick, where the presence of people is excluded. |
| IV       | 1500–4000              | Foundations of roads, dams, etc., located outside settlements, provided that they are covered with low-level material with a thickness of more than 0.5 m. |
| V        | $>4000$                | Should not be used by building contractors. Intra-industry use is acceptable. |

In accordance with modern regulatory requirements, at the stage of pre-design surveys, an expert assessment of the potential radon hazard of the site is carried out on the basis of a set of qualitatively and quantitatively determined factors. The most significant factors to consider when doing this include:

- EEVA of radon in buildings operated on the considered site or near the site under consideration;
- flux density (exhalation) of radon on the soil surface;
- characteristics of the geological structure of the sections;
- specific activity of radium in rock layers of geological sections;
- the coefficient of radon emanation in the rocks of the geological section.

The data on the registered values of the integral EEVA of radon more than 100 Bq/m$^3$ in rooms operated near the investigated building site serve as the basis for classifying the site as potentially radon-hazardous.

The quantity characterizing the radon hazard is the radon\(^{[11]}\) flux density (RFD). It indicates the intensity of the release of gas to the surface of their land or building structures capable of emitting.

5. Results and its discussion
The stochastic component in the concentration and flux of radioactive gases, including radon, depends on the geophysical characteristics of the construction site, the structure of the building, building materials and the quality of the aeration systems of the construction industry plants. Correct consideration of all factors will significantly reduce the exposure of people in the production shops of construction industry plants. Investigations of the volumetric activities of radon in 17 shops of construction industry plants in the cities of Rostov and Volgograd regions in the winter period were carried out. The results of the studies performed in the working zones of the factories of concrete goods in Rostov-on-Don, Volgograd, which have enclosing structures made of various [11] building materials, are presented in table 3.

The volumetric activity of radon in rooms, caused by radon and its DPR, varies for different shops from 15.9 Bq / m$^3$ to 82.5 Bq / m$^3$. The highest levels are set for block shops, the lowest for shops with enclosing panels. The variability of the volumetric activities of radon determines the formation of effective doses of irradiation of the population. The carried out radon studies have an important social
orientation - reducing the doses of radioactive exposure of the working population from the controlled radon component.

**Table 3.** Indicators of the volumetric activity of radon and daughter decay products in the shops of the construction industry plants in the cities of Rostov and Volgograd regions.

| №  | Workshop construction material          | Number of measurements | Average value. Bq/m³ |
|----|----------------------------------------|------------------------|----------------------|
| 1  | Panels                                 | 5                      | 29.5                 |
| 2  | Ceramic brick                          | 3                      | 32.2                 |
| 3  | Silicate brick                         | 3                      | 32.9                 |
| 4  | Reinforced concrete                    | 3                      | 33.1                 |
| 5  | Autoclave blocks                       | 3                      | 34.4                 |

**6. Conclusions**

The problem of ensuring the radon safety of industrial buildings in the construction industry should be solved in an integrated manner, taking into account all the factors that determine the flow of radon into the internal volume of workshops. Radon exposure refers to the situation of industrial exposure, the source is the unchanged concentrations of natural radionuclides in the foundations of production workshops of construction industry plants. The production activity of workers can create new or change the existing paths of radioactive radon gas intake, increasing or decreasing its percentage inside the production premises of factories producing building materials and ready-mixed concrete compared to the background in open areas. Radon gas pathways can be controlled by preventive or corrective measures. It is precisely the controllability of radon exposure in the working areas of factories that is put at the forefront of regulating the exposure situation, the development of strategies and tactics of which is the subject of recommendations and requirements of independent international organizations on radiation safety.

Only a systematic approach to the design, construction, operation of buildings and structures producing structures and products for the construction industry will allow creating environmentally friendly, favorable conditions in the workshops of factories, as well as predicting the development of urban areas for industrial purposes, taking into account the optimal terms of their operation.

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