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RESEARCH ARTICLE

FORMATION OF A SET OF INITIAL DATA TO CREATE AN INFORMATION MODEL TO REDUCE THE CONCENTRATION OF RADON IN THE PREMISES

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Abstract. *The article is based on the synthesis of domestic and foreign data, shows the main sources and ways of radon in buildings, formulated the basic principles of their anti-radon protection, classifies methods and means of protection, outlines recommendations for their practical implementation in the design and construction of buildings. Today in Kazakhstan there are several laws aimed at ensuring radiation safety of the population, at the request of which epidemiological services conduct constant monitoring of facilities under construction and existing ones. According to current standards, the concentration of radon in existing buildings should not exceed 200 Bq/m^3, and during design – 100 Bq/m^3. When solving problems of anti-radon protection of buildings, the sources of radon are objects from which radon directly enters the premises, regardless of the nature of its appearance in these objects. It is necessary to understand that measures for anti-radon protection of a building, carried out at the stages of its design and construction, are more effective and require lower costs than measures to reduce radon in an already constructed building. Currently, there are no standardized methods for calculating the necessary parameters and determining the optimal type of radon protection. The procedure for this selection is heuristic and in each case is based on an analysis and qualitative assessment of a number of circumstances.*

Keywords: *radon, protection, safety, ventilation, civil engineering, activity.*

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ҒЫЛЫМИ МАҚАЛА

ҮЙ-ЖАЙЛАРДА РАДОН КОНЦЕНТРАЦИЯСЫН ТӨМЕНДЕТУ БОЙЫНША АҚПАРАТТЫҚ МОДЕЛЬ ҚҰРУ ҮШІН БАСТАПҚЫ ДЕРЕКТЕР КЕШЕНІН ҚАЛЫПТАСТЫРУ

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Аңдатпа. *Мақала отандық және шетелдік деректерді синтездеуге негізделген, радонның ғимараттарға түсуінің негізгі көздері мен жолдары көрсетілген, оларды радонға қарсы қорғаудың негізгі принциптері тұжырымдалған, қорғау әдістері мен құралдары жіктелген, ғимараттарды жобалау және салу кезінде оларды іс жүзінде енгізу бойынша ұсыныстар берілген. Бүгінгі таңда Қазақстанда халықтың радиациялық қауіпсіздігін қамтамасыз етуге бағытталған бірнеше заңдар қолданылады, олардың талабы бойынша эпидемиологиялық қызметтер салынып жатқан және жұмыс істеп тұрған объектілерге тұрақты мониторинг жүргізеді. Қолданыстағы нормалар бойынша жұмыс істеп тұрған ғимараттардағы радон концентрациясы 200 Бк/текше метрден, ал жобалау кезінде - 100 Бк/текше метрден аспауы тиіс. Ғимараттарды радонға қарсы қорғау мәселелерін шешу кезінде радонның көздері оның осы объектілерде пайда болу сипатына қарамастан, радон тікелей үй-жайларға түсетін объектілер болып табылады. Ғимаратты жобалау және салу кезеңдерінде жүргізілетін радонға қарсы қорғаныс шаралары қазірдің өзінде салынған ғимараттағы радонды азайту шараларына қарағанда тиімдірек және аз шығынды қажет ететінін түсіну қажет. Қазіргі уақытта қажетті параметрлерді есептеудің және радонға қарсы қорғаныстың оңтайлы түрін анықтаудың нормаланған әдістері жоқ. Бұл таңдау процедурасы эвристикалық болып табылады және әр жағдайда бірқатар жағдайларды талдауға және сапалы бағалауға негізделген.*

Түйін сөздер: *радон, қорғау, қауіпсіздік, желдету, азаматтық құрылыс, қызмет.*

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НАУЧНАЯ СТАТЬЯ

ФОРМИРОВАНИЕ КОМПЛЕКСА ИСХОДНЫХ ДАННЫХ ДЛЯ СОЗДАНИЯ ИНФОРМАЦИОННОЙ МОДЕЛИ ПО СНИЖЕНИЮ КОНЦЕНТРАЦИИ РАДОНА В ПОМЕЩЕНИЯХ

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Аннотация. Статья основана на синтезе отечественных и зарубежных данных, показаны основные источники и пути поступления радона в здания, сформулированы основные принципы их противорадоновой защиты, классифицированы методы и средства защиты, изложены рекомендации по их практическому внедрению при проектировании и строительстве зданий. На сегодняшний день в Казахстане действует несколько законов, направленных на обеспечение радиационной безопасности населения, по требованию которых эпидемиологические службы ведут постоянный мониторинг строящихся и существующих объектов. По действующим нормам концентрация радона в действующих зданиях не должна превышать 200 Бк/м^3, а при проектировании - 100 Бк/м^3. При решении задач антирадоновой защиты зданий источниками радона являются объекты, из которых радон непосредственно попадает в помещения независимо от характера его появления в этих объектах. Необходимо понимать, что мероприятия по антирадоновой защите здания, проводимые на этапах его проектирования и строительства, более эффективны и требуют меньших затрат, чем мероприятия по снижению радона в уже построенном здании. В настоящее время не существует нормированных методов расчета необходимых параметров и определения оптимального типа противорадоновой защиты. Процедура этого выбора является эвристической и в каждом случае основана на анализе и качественной оценке ряда обстоятельств.

Ключевые слова: радон, защита, безопасность, вентиляция, гражданское строительство, деятельность.

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

АЛҒЫС / ҚАРЖЫЛАНДЫРУ КӨЗІ

Зерттеу жеке қаржыландыру көздерін пайдалана отырып жүргізілді.

МҮДДЕЛЕР ҚАҚТЫҒЫСЫ

Авторлар мүдделер қақтығысы жоқ деп мәлімдейді.

БЛАГОДАРНОСТИ / ИСТОЧНИК ФИНАНСИРОВАНИЯ

Исследование проводилось с использованием частных источников финансирования.

КОНФЛИКТ ИНТЕРЕСОВ

Авторы заявляют, что конфликта интересов нет.

1 INTRODUCTION

According to the sanitary rules "Sanitary and epidemiological requirements for ensuring radiation safety", when selecting sites for the construction, residential houses and social and residential buildings are assigned to the areas with a gamma background not exceeding 0.3 μSv/h, and with the density of the radon flux from the surface of the soil is not more than 80 mBq/cm^2. According to p. 320 – in the building design a radon protection system (monolithic concrete pillow, improved insulation of the basement floor, etc.) is provided for the construction of a building on site with a radon flux density of more than 80 MBq/cm^2.

The purpose of anti-radon protection of buildings is to ensure compliance with the requirements of p. 4 subpar. 29 of the sanitary rules "Sanitary and epidemiological requirements for industrial buildings and structures, according to which the average annual equivalent equilibrium volumetric activity of radon isotopes in indoor air should not exceed 100 Bq/m^3.

In order to ensure the environmental safety of construction and increase the efficiency of the use of territories, more and more attention is paid to natural radioactivity. According to numerous studies of domestic and foreign scientists, the main radiation background on the planet is created by natural radiation sources, in particular, radon, which constitutes a significant (up to 60% or more) part of the total radiation dose.

The average world dose of irradiation of people due to all natural radiation sources is about 2.4 mSv/year with a typical dose range of 1.0-13 mSv/year.

The following values of effective doses characterize the relative degree of radiation safety of the population from natural radiation sources: at a dose of less than 2 mSv/year, it is considered that the irradiation does not exceed the average dose values from natural radiation sources; from 2 to 5 mSv/year - the irradiation refers to increased; more than 5 mSv/year – to a high level.

The main contribution to the irradiation of the population by natural sources of radiation is made by the short-lived isotopes progeny in indoor air (60-70%) and external irradiation (20-30%), while the remaining ones account for up to 10% of total doses. In 1988 the Congress of the World Health Organization and the International Agency for Research on Cancer, on the basis of numerous studies, recognized that the intake of radon into the human body is dangerous and can provoke lung cancer. Taking into account the fact that on average the urban resident spends almost 80% of the time indoors, there is a need to pay serious attention to the problem of protecting the health of the population from radon exposure in buildings.

2 LITERATURE REVIEW

With the acquisition of independence, Kazakhstan, using world experience, began to create the necessary regulations to ensure radiation protection.

The regulatory framework of Kazakhstan in the field of anti-radon protection meets the requirements of the International Committee on Radiation Protection **(Tapalova, 2018)**.

Methodological recommendations on radiation hygiene, sanitary rules and sanitary standards allow determining the concentration of radon gamma background of territories and premises provide recommendations on examination and requirements for radiation safety.

In general, there is no information on the distribution of radon radiation in Kazakhstan, and fragmentary studies by specialists in deliberately dangerous areas near developed uranium deposits have shown that citizens live in territories where radon radiation doses are many times higher than permissible, however, measures have not been taken by government agencies, citizens do not know about their rights.

An analysis of scientific sources shows that in many developed countries there is currently quite extensive information on the accumulation of radon, its distribution, diffusion, and emanation in residential and office premises.

Specialists in the field of radiation hygiene draw attention to the effects of radon in the environment as an etiological factor of respiratory diseases, including lung cancer, especially in non-smokers **(Grzywa-Celińska, 2020; Lorenzo-González, 2019; Al, 2018)**.

The concentration of radon in the premises is directly related to its concentration in the soils under houses and used building and decorative materials **(Pacheco-Torgal, 2012; Gandolfo, 2017; Singh, 2016)**.

What are the methods and recommendations for radon protection?

Foreign researchers suggest using various insulating materials to protect against radon. Moisture-proof or waterproof insulation laid over the entire surface of basement floors and walls in contact with the soil can prevent radon from entering buildings from the soil. These types of insulation can be considered as one of the most effective radon reduction systems in new homes **(Hůlka, 2001; Zhuk, 2019; Finne, 2019; Arvela, 2014; Jiránek, 2004; Gaskin, 2021; Rahman, 2009)**.

The methods developed in the UK are mainly based on passive radon barriers, which are inexpensive and easy to install **(Scivyer, 2001)**.

Japanese experts have tested a membrane permeability method for removing radon from the air using a hollow fiber module **(Iida, 2001)**.

In multi-storey buildings, the main source of radon intake is Ra-226 in building materials. At low air exchange rates, radon concentrations may exceed control levels. An increase in uncontrolled infiltration of fresh air while maintaining a normal ventilation regime (the duration of periods of active and passive ventilation) has a certain potential to reduce the concentration of radon in the room. Technically, such a corrective measure can be implemented by installing additional air ducts in enclosing structures, channels in window frames, etc. **(Singh, 2016; Tejado-Ramos, 2024)**.

Thus. It can be concluded that radon protection methods are scattered and insufficiently developed in terms of efficiency and effectiveness in the situation, the relevance of developing such methods increases with the widespread introduction of energy efficiency requirements in building construction. It is necessary to understand that measures for anti-radon protection of a building, carried out at the stages of its design and construction, are more effective and require less costs than measures to reduce radon in an already built building.

3 MATERIALS AND METHODS

When solving tasks of anti-radon protection of buildings, radon sources are objects from which radon directly enters the premises regardless of the nature of its appearance in these objects. The presence of radon in the air of a room may be due to its intake from the following sources:

– soils under the building;
– fencing structures made with the use of building materials from rocks;
– outside air;
– water from the building water supply system;
– fuel burned in the building.

Mechanisms and ways of radon entering the building. The average world values of volumetric activity (concentration) of radon in the outside air at a height of 1 m from the surface of the earth are from 7 to 12 Bq/m^3 (background value). In areas with saturated radon soils, this value can reach 50 Bq/m^3. There are areas where the radon activity in the outdoor air reaches 150 or more Bq/m^3. With the construction of the building site area is isolated from the surrounding space, therefore radon released from the underlying ground under the building can not be freely dispersed in the atmosphere, penetrates the building, and its concentration in the air of the premises becomes higher than in the outside air.

The inflow of soil radon into the premises is conditioned by its convective (along with air) transport through cracks, cracks, cavities and openings in the enclosing structures of the building, as well as diffusion transfer through the enclosing structures.

The main ways of radon entering the building are shown in **Figure 1**.

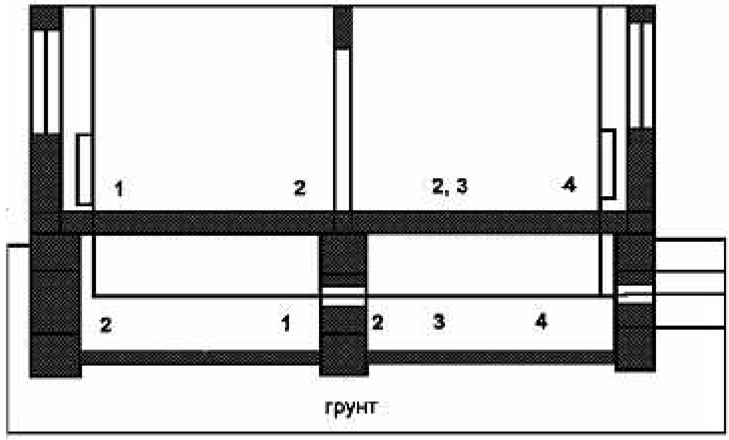

Figure 1 – The main ways of radon entering the building: 1 – isolation from the materials of enclosing structures; 2 – seams and joints between elements of enclosing structures; 3 – cracks and voids in the enclosing structures; 4 – openings for building utilities in the underground part of the building and basement floor (author's material).

It is necessary to understand that the measures for anti-radon protection of the building, carried out at the stages of its design and construction, are more effective and require fewer expenses than measures to reduce radon in the already constructed building.

At present, there are no normalized methods for calculating the required parameters and determining the optimal type of anti-radon protection. The procedure for this choice is heuristic and in each case is based on the analysis and qualitative assessment of a number of circumstances. The effectiveness of a solution of anti-radon protection depends on how in each specific case these circumstances and the types of technical solutions used combine.

The most effective combination of several technical solutions of anti-radon protection in one construction. When choosing technical solutions for anti-radon protection, it is recommended to consider the following factors and circumstances:

The intensity of radon emissions in the construction site. The higher the intensity of radon emissions from the ground at the construction site and the lower the allowable radon content in the building's premises, the higher the effectiveness of anti-radon protection.

Depth of the building. The greater the depth of the building, the higher the probability of increased radon supply through the floor and the basement walls.

Characteristics of the geological section. In the case where the upper layers of the geological section are composed of dense, low gas permeability rocks, their removal during excavation can lead to an increase in radon load on the underground part of the building.

Ground water level. With a high level of groundwater and the need for a drainage system, it, having the properties of a collector of soil gas, can have both a positive and negative impact on the radon situation at the base of the building.

The purpose of the premises of the basement floor and the characteristics of its ventilation system. At the device of poorly ventilated cellars and undergrounds the radon-insulating ability of their floor and overlapping should be raised.

The layout of the openings for input-output of utility communications in the underground enclosing structures of the building. The dispersal and large number of such openings increases the likelihood of radon penetrating them through the building.

Quality of construction works. The radon-insulating ability of the enclosing structures depends critically on the quality of the construction work. The use of poor-quality materials and the violation of their technology can lead to zero effectiveness of anti-radon protection.

Recommendations for design

Ventilation of premises – The possibility of reducing the concentration of radon in indoor air due to their ventilation by external air is limited by the maximum permissible (or economically justified) magnitude of the air exchange rate. Therefore, ventilation should be considered only as an auxiliary tool, complementary to other solutions. The intensification of ventilation leads to an increase in energy consumption for heating the building.

The best is a well-balanced system of supply and exhaust ventilation, providing the hygienic reasons for the air exchange in the rooms and the minimum pressure difference between the basement and upper rooms.

Impregnation – The sealing impregnating compound is a suspension or emulsion on bitumen, latex, polymer, etc. basis. Impregnations are recommended to reduce the radon permeability of finely dispersed materials such as clay and sand in unexploited subterranean buildings with a slight deeper penetration.

Coating – Coatings can be used in the insulation device on the outer or inner surface of the enclosing structure, as well as between its elements.

Membrane – Radon-insulating membranes are used in the construction of foundation slabs, walls and floors of cellars of monolithic reinforced concrete or prefabricated reinforced concrete elements to prevent radon transport through pores, cracks, joints and air cavities in these structures.

When the membrane is installed, it is important to ensure its continuity within the protected area of the structure and the possibility of elastoplastic deformation during the movements of the supporting structure.

4 RESULTS AND DISCUSSIONS

Barrier – The anti-radon barrier is made in the form of a solid, monolithic reinforced concrete slab, which can serve as the foundation of the house, the floor or the ceiling of the basement. The effectiveness of the barrier is greatly enhanced by creating the possibility for a free exit (natural drawing) of radon from the ground beneath the building to the surrounding space. For this purpose, a device is recommended under the barrier of the radon collector in the form of a layer of coarse-grained, freely conductive gas of piling and a pipe serving for the discharge of radon from the piling into the atmosphere **(Figure 2)**.

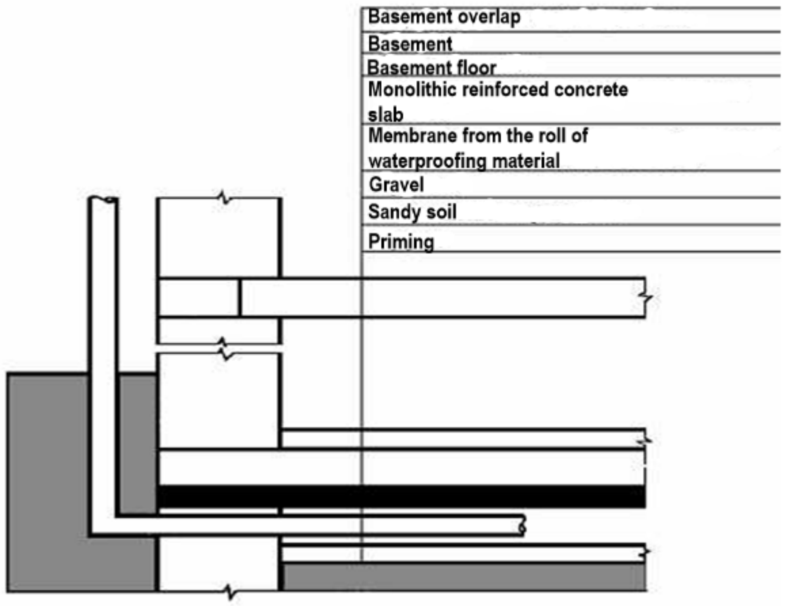

Figure 2 – Radon collector, membrane, barrier (author's material)

Depending on the area of the house, pipes in the gravel layer can be laid along the axes of the protected area or along the foundations.

Depression of the soil base – The greatest effect of anti-radon protection of the building is achieved with a depression (creating a low-pressure zone) of the basement floor basement.

Depression is provided when the radon collector is supplemented with a special system of forced exhaust ventilation, which is completely unrelated to the ventilation of the premises.

When using forced drawing, the effective operation of the protection system is ensured by installing one underground pipe at a rate of 100-120 Bq/m^3 of protected area and using a low-pressure fan with a capacity of 150 to 250 Bq/m^3. Fans should have a sealed enclosure and be located in the vertical part of the pipes as close as possible to the point of release of soil gas into the atmosphere.

It is recommended to mount the fan with removable fasteners and flexible hermetic connection of the housing with the pipe. Installation of fans in the basement and other premises of the building, except for the attic, is not allowed.

The soil is ventilated due to a natural stack effect and wind interaction with the exhaust pipe on the roof of the building. If the activity of radon in the building exceeds the permissible levels, an exhaust fan located in the attic can easily be installed on the existing air duct system in the building. If the results of the study show that in an erected building an elevated level of radon is unlikely, or it will be decided not to install a soil ventilation system, then after installing the pipes to connect the air ducts to the foundation plate, their necks are carefully sealed. In this case, it is desirable that the construction of the building allows, if necessary, quickly and economically to install the entire system of exhaust or discharge ducts.

One of the most effective is the method of removing radon from under the floors of the first floor. Air from under the slabs is diverted by means of special ventilation ducts outside the buildings. At the same time, depending on the construction of the building, various air discharge schemes are used (by placement of ventilation ducts and air ducts). Reducing the concentration of radon in buildings allows the use of radon wells. The radon well is a well dug to a depth of 4 m at a distance of 10-60 m from the house. A powerful fan is installed in the well, which removes radon from the soil outside. Radon wells can reduce the level of radon concentration by 92% within 60 m from the well provided high soil permeability. Reducing the concentration of radon allows the application of the radon-collecting system under the foundation and the sealing of the foundation and overlap.

The principle of the radon-collecting system is as follows. In the space under the foundation with the help of a centrifugal fan, air pressure is reduced compared to the rooms. At the same time radon released from the soil is released into the atmosphere. The commissioning of the radon-collecting system, consisting of five air intakes, allows reducing radon concentrations in the premises of the first floor by 10 or more times.

5 CONCLUSIONS

In the presence of high radon concentrations in soils in order to exclude or limit radon intake from the technical underground, cellar or basement of the building, special anti-radon measures are necessary, including:

- ventilation of basement premises;
- screening of the basement using special materials (impregnation, coating);
- application of radon-insulating membranes and anti-radon barriers;
- organization of radon collectors;
- creation of a zone of low pressure (depression) of the ground basement of the basement floor;
- sealing joints, joints and openings;
- application of radon suppression systems;
- sealing cracks, cracks, communication openings of floor slabs of the first floor with the use of self-adhesive, plastic, elastic, foaming, etc. materials;
- the device of special vapor barrier insulation above the basement, etc.

The above examples clearly demonstrate that the use of these or those measures effectively reduces the radon and thoron content in indoor air. The choice of concrete measures is largely determined by the amount of funding for repair and construction and ventilation.

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