быть выбрано более высокое значение регионального РУ, но оно не должно превышать $ОА_{Rn} < А_{реф}/К$.

Выводы

1. Несмотря на то, что в целом опыт нормирования ЭРОА дочерних продуктов радона и торона в России был положительным, в целях оптимизации защиты в ситуации облучения радоном следует установить отдельный РУ ОА радона и рассматривать облучение тороном в контексте радиационного контроля строительных материалов.

2. Для России следует установить одноуровневый РУ объемной активности радона 200 Бк/м^3 (среднегодовое значение).

3. Целесообразным и обоснованным является введение, помимо федерального, региональных референтных уровней ОА радона.

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Problems of establishing national reference level for radon

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Implementation of reference level conception for optimization of protection against radon in dwellings requires thorough consideration of a number of associated problems. With regard to both experience with regulation of indoor radon exposure in Russia and ICRP recommendations, Russian national reference level for radon should be expressed using annual radon concentration and set at level of 200 Bq/m^3.

Key words: *radon, reference level, optimization of protection*.

In accordance with the ICRP recommendations [1] in the process of optimization of protection in existing exposure situation are established the reference level (RL). Exposure to radon is existing exposure situation, because the source of radon is the natural radioactivity of the earth's crust, it exist at the time of decision making about the necessity to ensure protection and is the object on which it is impossible to affect directly. The reference level represents the level of dose or risk above which it is unacceptable to allow exposure, and below which should hold the optimization of protection. Implementation of the concept of RL in the 2007 ICRP recommendations was defined by innovation. In contrast to the level of intervention, RL does not establish a clear boundary between safe and dangerous influence, and determines an unacceptably high level of risk [2].

National RL establishes the appropriate regulatory authority. Based on data from the joint analysis of the risk of lung cancer with exposure to radon and data on dosimetry modeling of lungs, the ICRP recommended establishing of national RL of radon volume activity (VA not above than 300 Bq/m^3, which corresponds to an annual effective dose of 10 mSv [3]. In view of the same data WHO recommend reducing of the national RL to 100 Bq/m^3 [4].

Radiation Safety Standards adopted in the Russian Federation include the agreed system of action (intervention) levels. Radiation-hygienic regulation of radon exposure is based on the average value of equivalent equilibrium volume activity (EEVA) of radon progeny and thoron indoors (radon EEVA + 4,6 thoron EEVA). The ratio is a two-level and depends on the stage of the life cycle of the building on which it is applied. In operated residential and public buildings, average annual EEVA of radon progeny and thoron should not exceed 200 Bq /m^3. In the design of new buildings should be provided the average EEVA radon progeny and thoron does not exceed 100 Bq/m^3.

ICRP recommendations on the implementation of RL may require some revision of the current system of radiation safety. This paper review problems associated with the establishing of the national RL to optimize protection from radon in Russia.

Reference level selection

Selection of parameter that best characterizes the radon as a factor of exposure in dwellings is not one-valued. Exposure to radon can be characterized by several parameters, the transition between which is associated with

significant uncertainties. For the transition from radon VA to effective dose must be used coefficients, describing the shift in the equilibrium between radon and progeny, biokinetics of radon progeny in the respiratory tract, relative biological effectiveness, the radiosensitivity of organs. Many of these factors are varied, some are not well defined, and the values are periodically updated. At the same time, radon VA is a directly measured quantity. Therefore, in the case of exposure to radon convenient to set RL in size of radon VA.

From 1989 to the present time in Russia regulation of radon concentration in dwellings is carried out by radon EEVA. The advantage of using of radon EEVA in the regulation of exposure to radon is the fact that during the transition to the value of the effective dose is not required to take into account the unknown shift of the equilibrium between radon and progeny. On the other hand, the average annual radon progeny EEVA cannot be measured directly by existing facility and there is uncertainty associated with seasonal variations of intakes of radon. In practice in Russia, evaluation of levels of radon concentrations are often conducted using various methods of measuring of radon VA. The transition from the measured radon VA to radon EEVA is carried out through a fixed value of the ratio of the coefficient of equilibrium F, which is offered in the various documents to be 0.4 or 0.5. It should be noted that the using in the Russian Federation for regulation of radon EEVA instead of VA repeatedly caused the misunderstanding, and sometimes direct errors in the work of international organizations such as UNSCEAR and WHO.

Currently in Russia are imposed requirements to limit of public exposure due to thoron progeny (radon-220). However, in practice, the united s regulatory standard is used in rare cases, because the estimation of the annual thoron EEVA associated with some unsolved technical and metrological problems. Analysis of the problem of thoron shows that control of ^{232}Th concentration in construction material likely provide better protection from exposure to thoron and thoron progeny.

Thus, the comparison of the disadvantages and advantages of usage of VA, EEVA and effective dose as standardized value shows that to establish a RL is justified to use the annual average radon VA. It should specified the conditions wherein set these limit (length of stay, the coefficient of equilibrium, the values of dose coefficients and other).

Radon concentration level selection

Obviously, the optimization of public protection from radon cannot be achieved if the national RL is set higher than the maximum levels of radon in dwellings. Conversely, if the radon VA exceeds RL in a large number of dwellings reduction costs of radiation will not be economically justified. Therefore, a national RL of radon VA must be established based on the analysis of real levels of radon in dwellings in the country. For example, as the value of radon VA for RL can be used 90-th percentile of the distribution of radon VA in dwellings. For this purpose, the distribution parameters must be defined during the random national radon survey.

To date nationwide representative random radon survey are not conducted. However, on the basis of radiation-hygienic passports of the Russian regions can be estimated regional average value of radon VA in urban-type houses as 52 Bq/m3, geometric standard deviation (GSD) of 1.6 (2009) [5]. In a first approximation, this value may be used as the average value of radon VA in Russia. To reestablish the lognormal distribution structure is necessary to adopt some value for GSD of radon VA. In our opinion, a good estimation of the GSD can be 2.7. In this approach, the 90-percentile for urban-type houses corresponds to radon VA 160 Bq/m^3, taking into account other types of buildings, this value is about 200 Bq/m^3. The approach is demonstrated in the figure.

In Russia since establishing of radon EEVA limit for designing a buildings (<100 Bq/m^3) were built many new residential and public buildings. Reduced of requirements for radiation protection of the population, compared with the achieved level is not reasonable. Because in Russia is possible to establish a single-level (for new and for constructed buildings) RL equal to the average annual values of radon VA 200 Bq/m^3, which at once corresponds to the reached limiting level of the public exposure and 90 percentile of radon distribution in dwellings.

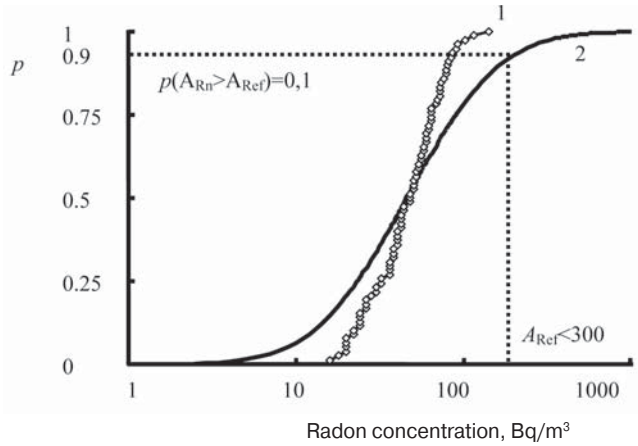

Fig. The basic approach to the choice of values for radon VA for RL. 1 – integral distribution of average radon VA in subjects of the Russian Federation, GSD = 1.6; 2 – model distribution of radon VA in dwellings, GSD = 2.7.

Problems of RL implementation

Implementation of RL instead of strong limit, obviously, can cause difficulties in the implementation of the principles of radiation safety in cases where radon VA is slightly below or above the RL. For the practical implementation of the concept of RL in addition to the numerical value of the reference level Aref, as an additional monitoring tool can be establish a coefficient K. If conditions VARn> Aref/K are satisfied, so the corrective actions to reduce radon levels are required. In fact, this threshold will be playing the role of the action level or intervention level. On conditions that VARn <Aref /K no action to reduce the levels of radon VA in the room should not be carried out. When Aref /K<VARn <Aref/K the decision to conduct corrective actions should be taken on the basis of optimization principle taking into account the number of persons exposed to radiation, their age, complexity and cost of the technical implementation of measures to reduce the radon VA and so on. Numerical value of K may be in the range of 1.5 – 2.0.

The factors that determine the intake and accumulation of radon in buildings are regional that necessary take into

account in the process of optimization of protection against radon. For such a large country as Russia, is characterized by the presence of several climatic zones, areas with substantially difference in radon potential and application of various building technologies. Consequently, the average for the subjects of the Russian radon EEVA varies considerably. Therefore, in Russia suggests reasonable implementation of regional RL of radon VA in additional to the federal. One of the effective approaches to optimization of protection against radon at the regional level is considered as regional RL, values of radon VA corresponding to the 90 percentile of radon VA in the group of buildings, that demonstrate best protection practice, which was achieved in this region. Taking into account economic and social factors can be selected a higher value of regional RL, but it should not exceed VARn<Aref/K.

Summary

1) Despite the fact that the experience of regulation of radon and thoron EEVA in Russia was positive in general, in order to optimize protection in situations of exposure to radon, a separate RL for radon concentration should be established. Exposure to thoron should be treated in the context of radiation control of building materials.

2) A unique RL should be established in Russia equal to annual average radon concentration of 200 Bq/m3.

3) It is appropriate and reasonable to establish regional RL in Russia in addition to the federal RL.

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