

# Improving radio-ecological monitoring of potentially radon-hazardous territories

*Tatiana Lashchenova*<sup>1,3</sup>, *Lidiya Karl*<sup>1,2\*</sup>, *Albert Marenny*<sup>2</sup>, and *Sergey Kiselev*<sup>3</sup>

<sup>1</sup>Peoples' Friendship University of Russia (RUDN University), Faculty of Ecology, 6 Miklukho-Maklaya St, Moscow, 117198, Russian Federation

<sup>2</sup>State Research and Technical Center of Radiation-Chemical Safety and Hygiene FMBA Russia, 123182, Moscow, Russian Federation

<sup>3</sup>A.I. Burnasyan Federal Medical Biophysical Center FMBA, 123098, Moscow, Russian Federation

**Abstract.** Radioecological monitoring of radon-hazardous territories in residential and public buildings of the towns of Lermontov (Russia, Stavropol Region) and Baley (Russia, Transbaikal Region) made it possible to reveal that the volume activity of radon in premises on 1 floor of buildings reliably characterizes the radon inflow from the soil surface. This control parameter, which can be used to estimate the radon danger of the territory, to make decisions on the sanitary condition of the building, to estimate the potential danger to the population or personnel, to calculate the potential dose rates. Improvement of radio-ecological monitoring in potentially radon-hazardous areas is aimed at monitoring the volume activity of radon on 1 floor of buildings, the excess of which is higher than the normal values is the basis for making managerial decisions to protect the population or staff.

## 1 Introduction

According to the UN Scientific Committee, the main contribution to population radiation exposure is from natural sources of ionizing radiation. The main contribution to the population exposure dose from 50 to 90 % is made by natural radioactive gas radon (<sup>222</sup>Rn) and its decay products. Epidemiological studies have shown that <sup>222</sup>Rn, as a potential lung cancer initiator, is in second place after smoking [1,2]. The International Agency for Research on Cancer (IARC) classified <sup>222</sup>Rn as carcinogen of group 1.

During the last decade, the scientific institutes of the Federal Medical and Biological Agency of Russia (State Research and Technical Center of Radiation-Chemical Safety and Hygiene and A.I. Burnasyan Federal Medical Biophysical Center) conducted monitoring studies on the content of <sup>222</sup>Rn in residential and public buildings. These studies allowed to specify the regions where the problem is particularly acute (Altai Territory, Trans Baikal region, North Caucasus, Urals, etc.).

These areas are located in close proximity to uranium, thorium, gold and other mining sites. In buildings on such territories, due to an unfavourable combination of geological,

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\* Corresponding author: [Lidiakarl@yandex.ru](mailto:Lidiakarl@yandex.ru)

social and other factors, the concentration of  $^{222}\text{Rn}$  is tens of times higher than permitted values [3].

The purpose of this study is to improve radio-ecological monitoring of potentially radon-hazardous territories.

Studies have shown that there are a number of problems in conducting monitoring studies in potentially radon areas. These problems are connected with analytical and methodical support of control of  $^{222}\text{Rn}$  content in air, with complex analysis of received data, the volume of which needs correct interpretation for making management decisions, and other problems. There are also problems in the organization of monitoring in potentially radon-hazardous territories, due to financial indifference in the works of owners of territories and objects located on them. In this regard, the relevance of this work is undoubted, it is of great theoretical and practical importance.

Volumetric activity control of  $^{222}\text{Rn}$  in residential and public buildings is an important control parameter, and in potentially radon-hazardous areas it is a required one [4,5]. There are no regulatory documents, which would oblige officials responsible for this territory, to conduct this type of monitoring on a permanent basis. In this direction, it is necessary to implement a set of measures aimed at improving radioecological monitoring in potentially radon-hazardous areas.

Fluctuations of  $^{222}\text{Rn}$  in buildings depend on a number of factors: the content of natural radionuclides in the soil under the building, the features of the construction of the building and the ventilation condition; the type of building materials used in construction, the geological conditions in the survey area.

Any anthropogenic human activity on the territory can create or change existing inflow ways, increasing the  $^{222}\text{Rn}$  output into the atmosphere, including in residential and public, as well as industrial buildings. These routes of entry on each territory should be identified, hazard assessment should be carried out; if necessary, control and continuous monitoring should be organized; protection of the population should be carried out through preventive (preventive) or corrective actions.

At present, the basic principles of radiation safety of the public and staff are defined in ICRP documents (Publication 103, Publication 126) and IAEA publications (SSG-32). They are based on establishing reference levels and applying the principle of optimization in the adoption and implementation of appropriate protective measures. In the Russian Federation, the basic requirements for ensuring radiation safety are set out in the basic regulatory documents NRB-99/2009 and OSPORB-99/2010, which are currently being reviewed in the light of international requirements. [6,7]

## **2 Materials, methods, methodology for control and assessment**

The most reliable and promising methods for measuring the volumetric activity of  $^{222}\text{Rn}$  are integral methods based on the use of track detectors to register heavy charged particles, such as alpha-particles, the separation of which occurs at the collapse of the nucleus of the  $^{222}\text{Rn}$  atom. The use of track detectors makes it possible to consider fluctuations in the excretion of  $^{222}\text{Rn}$  within a day, on this basis to reduce uncertainties in the calculation of the annual average dose to the population due to natural irradiation. The sensitivity of these methods is sufficient and meets the needs of monitoring studies.

The volumetric activity of  $^{222}\text{Rn}$  in residential and public premises has been standardised since 1989 in accordance with the requirements of the item. 5.3.3. NRB-99/2009 by the parameter of equilibrium equivalent concentration ( $\text{EEC}_{\text{Rn}}$ ). considering products of decay of subsidiary radionuclides ( $\text{EEC}_{\text{Rn}} + 4.64 \text{EEC}_{\text{Th}}$ ), the value of which should not exceed  $200 \text{Bq/m}^3$  in operated residential premises [6,7]. Average annual  $\text{EEC}_{\text{Rn}}$

value is calculated from measured  $EEC_{Rn}$  with an exposure of at least 2 months performed in cold and warm seasons.

Measurement of volumetric activity of  $^{222}Rn$  by the integral track method in industrial, residential and public premises is carried out by the method, described in the following link [8]. Fundamentals of the method, the principle and method of work with the equipment, as well as the issues of the formation of samples of premises during the examination of settlements and placement of the exposimeters in the examined premises are discussed in detail in the publication [9]. Measurement of  $^{222}Rn$  volumetric activity during screening studies on large territories is developed by the authors [10-16].

For buildings that are already in operation,  $EEC_{Rn} + 4.64 EEC_{Tn}$  should not exceed 200 Bq/m<sup>3</sup>. If this value is exceeded, radon protection measures should be taken to reduce radon inflow into buildings [6,7].

When constructing new residential and public buildings in the air of premises  $EEC_{Rn} + 4.64 EEC_{Tn}$  should not exceed 100 Bq/m<sup>3</sup>, and the effective dose rate of gamma radiation should not exceed the dose rate in the open area by more than 0.2  $\mu$ Sv/h. [3]

Radio-ecological and sanitary-hygienic assessment of industrial, residential and public premises is conducted according to the requirements of the following documents [17-21].

### 3 Results and discussion

In potentially radon-prone areas, average regional data were obtained for screening studies. Details at the district level are not always conducted, and not everywhere, so protection of the population in such conditions cannot be guaranteed.

At the control the content of  $^{222}Rn$  problems of analytical and methodical support are connected with the increase of measurement reliability and creation of methodical support, which are now actively developed with the participation of authors, and will be realized in the form of analytical methods and methodical documents for practical sanitary-hygienic application [10].

While monitoring within the framework of regional programs of  $^{222}Rn$  maintenance in residential and public buildings on potentially radon-hazardous territories one has to face the problems of processing a large volume of accumulated data, with a complex analysis of the received data, which are now being implemented using GIS-technologies [10]. FMBA of Russia is developing an information and analytical system for all types of natural sources of ionizing radiation. Application of GIS-technologies allows to carry out the complex analysis of the received data, to visualize the received results which allow to prepare visual maps on territorial distribution of the increased emission of  $^{222}Rn$  flows, and to give offers for acceptance of administrative decisions in territory, to optimize regional monitoring programs.

As part of the improvement of radio-ecological monitoring of potentially radon-hazardous territories, monitoring was carried out in the well-known radon-hazardous territories in the towns of Lermontov, Stavropol Krai and Baley, Transbaikal Krai, which are located territorially in different regions with different geological structures. For comparison, the territories in Chita were taken as background territory in relation to Baley.

The study of regularities of  $^{222}Rn$  volume activity distribution according to  $EEC_{Rn}$  in the buildings of Baley, Chita and Lermontov towns (5239 measurements) and revealed that distribution of values in all premises for all three territories is lognormal, the median was used as an average value. In the background area for the Transbaikal region in Chita,  $EEC_{Rn}$  values are significantly lower than 200 Bq/m<sup>3</sup>, the median is 27 Bq/m<sup>3</sup>.

In Baley and Lermontov, the average geometric and median values do not exceed 200 Bq/m<sup>3</sup>, and are 109 Bq/m<sup>3</sup> and 126 Bq/m<sup>3</sup> respectively. At the same time, in Baley,  $EEC_{Rn}$  values exceed the standard value of 200 Bq/m<sup>3</sup> in 30% of the total number of

measurements; and in Lermontov, the excess is 35% of the total volume of measurements, respectively. Maximum values in Baley and Lermontov exceed  $200 \text{ Bq/m}^3$  by 10 times.

Statistical processing of data showed that premises with  $\text{EEC}_{\text{Rn}}$  excess above  $200 \text{ Bq/m}^3$  are mainly located on the first floors of buildings.

Our study of the patterns of distribution and accumulation of  $^{222}\text{Rn}$  in buildings, showed that the main source of income to the premises on the first floors is the soil under the building. The first floors of buildings experience the largest anthropogenic burden, the magnitude of which depends on the content of natural radionuclides in the soil under the building and violations associated with the peculiarities of the construction of buildings, ventilation and other violations.

The measurements were made and it was found that the gas content of  $^{222}\text{Rn}$  in the premises on the ground floors in Baley exceeds 28 %, and in Lermontov 35 % of the total number of measurements. We carried out statistical processing of the received data on the ground floors in Baley and Lermontov. The results are presented in the table 1.

**Table 1.** Parameters of distribution of  $\text{EEC}_{\text{Rn}}$  values exceeding  $200 \text{ Bq/m}^3$  on the first floors of buildings in Baley and Lermontov towns..

Distribution parameter	Baley	Lermontov
N	254	694
Arithmetic mean, $\text{Bq/m}^3$	505	479
Geometric mean, $\text{Bq/m}^3$	421	427
Standard geometrical deviation	1,8	1,6
Median, $\text{Bq/m}^3$	365	422
Max, $\text{Bq/m}^3$	2087	1980
Excesses, % of total excesses	64	60

According to the table, the number of premises with excesses from the total number of measurements on the ground floors are: in Baley town - 64%, in Lermontov town - 60%. Median on the first floors is -  $365 \text{ Bq/m}^3$ (Baley), and  $422 \text{ Bq/m}^3$ (Lermontov), that is above  $200 \text{ Bq/m}^3$  almost in 2 times. Maximum  $\text{EEC}_{\text{Rn}}$  values are  $2087 \text{ Bq/m}^3$  in Baley and  $1980 \text{ Bq/m}^3$  in Lermontov.

In order to find out what influences increased  $\text{EEC}_{\text{Rn}}$  values in premises on the first floors, a study was carried out to identify the dependence of radon volume activity on various factors and revealed the following. A multivariate data analysis was carried out in the program "Statistica", for the analysis of data array the method of multivariate classification cluster analysis was used, which allows to identify homogeneous data groups on radon volume activity. All data were divided into groups (clusters) by the method of single linkage, using the calculation of similarity method Manhattan distances.

It was found out that the main criteria for assessing the potential radon danger of the territory is the volume activity of radon on 1 floor of buildings, which reliably characterizes the flow of radon from the soil surface, regardless of the source of inflow. These are control parameters by which one can estimate the radon hazard of the territory, make decisions about the sanitary condition of the building, estimate the potential danger for the population or staff, calculate the potential dose rates.

## 4 Conclusions

Improvement of radio-ecological monitoring in potentially radon-hazardous territories is aimed at control of radon volume activity on 1 floor of buildings, exceeding of which is higher than standard values is the basis for making managerial decisions to protect the population or personnel.

For optimization of radio-ecological monitoring it is necessary to introduce in practice modern analytical methods allowing to control the content of  $^{222}\text{Rn}$  in residential and public buildings on large territories; to carry out development of methodical documents for sanitary and hygienic application; development of information-analytical systems with application of GIS-technologies for acceptance for optimization of regional monitoring programs of territories on the radiation factor.

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