

# Design-experimental assessment of radiological hazards in residential and industrial premises

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**Abstract.** Construction of residential and industrial buildings is associated with a wide application of both traditional and new structural and finishing materials. Radiological conditions in buildings are determined radiation of natural radionuclides contained in structural and finishing materials of buildings. Mostly around the world national criteria are used governing the content of natural radionuclides in building materials, based on the recommendations of international regulatory bodies. In Russia in order to justify admissibility of structural and finishing building materials in housing construction people use experimental methods. In European Union countries government suggests calculating estimation for assessment of the applicability different materials in various areas of housing and civil construction. Earlier, the authors established the fact of possible inconsistencies between Russian and European standards in different classes of materials. In order to compare the applicability of different approaches were held complex researches including experimental determination content of natural radionuclides in materials, calculation of dose rate in specific rooms and direct measurements of dose rates. As basic model authors used approach applied in the European Union countries. Experimental studies were performed using methods scintillation spectrometry and radiometry. The objects of research were premises with bearing and enclosing concrete structures faced with tiles. Experimental dose rate values were determined after deduction of the radiation background on the terrain. The conducted studies showed that the application of the computational model with the use of experimental values of the activity of natural radionuclides leads in some cases to incorrect values of dose rate in the premises, which is associated with the accepted value of the radiation background. Despite the simplicity of the proposed approach and its direct use can lead to unreliable results. So the coincidence of the calculated and experimental data is irregular. Obtained results allow to make the main conclusion about the limited application of the estimated approach to evaluation of radiological hazard in living quarters. The most reliable are the experimental approach, despite its great labor intensity. Calculate approach should be applied at the preliminary stage of rejection of materials.

## 1. Introduction

Currently in Russia and abroad accepted fundamental laws and normative documents, regulating the procedures, rules and regulations of accounting for and control of radiation and ecological factor for ensuring radiation safety of the habitat of the person are developed [1 - 4]. The most important parameters of evaluation of radiation-ecological factors in the habitat of the person are specific and effective activity of NRN in building materials and equivalent dose rate (EDR) in residential and



industrial buildings, due to the content of NRN in structural and finishing materials of buildings and structures. Both domestic, and foreign normative documents demand to minimize radiative effects on the person due to additional radiation in comparison with a natural background.

The researches conducted in the world have shown that the radiation factor of the majority of materials is in limits of the allowed sizes according to national standards [1-20]. In too time the construction industry is characterized by constantly growing volume and involvement in this process of the increasing number of suppliers of new, including artificial materials and products. This requires constant monitoring of the content of NRN in materials and EDR in residential and industrial premises. Besides, both traditional, and new materials are involved in the international market that demands harmonization of the standard and regulating approaches in Russia and abroad.

The determination of key parameter of radiation safety of construction materials demands carrying out a large number of labor-consuming, long and expensive researches and also the corresponding qualification of personnel. Of course, there is the desire and the need to use valuation calculation methods for the determination of the radiation factor for materials and premises. In Russia criteria of radiation safety are based on experimental assessment of definition of a class of construction materials [1, 2]. In EU countries, the principles of radiation security of the population are developed. The principles are based on criterion of a dose which is established taking into account national conditions. At the same time for various materials and areas of their application are used two criteria doses: 0.3 mSv/a and 1 mSv/a. The use of a particular material is determined by the activity concentration index I, which should take into account typical applications and usage of building material in the building [4]. Application of activity concentration index (I) doesn't exclude application of experimental and calculation methods of determination of activity and a dose. And the dose criterion is the main one, which is correct in principle, since it is the annual individual radiation dose that is important for an individual, and not the activity of the building materials in their environment.

In [9] an attempt was made to analyze the convergence of Russian and European safety criteria for the use of construction materials in various fields of construction. The analysis was based on the experimental data on the content of NRN in different materials. The main conclusion consists of the conducted researches that compliance of the Russian and European criteria of safety of materials is in most cases observed. A disconformity between the Russian and the European standards can be observed for a range of materials. Thus, some types of building materials, such as concrete and cinder may be used without restrictions under the Russian legislation, while only restricted use is accepted when applying the dose criterion.

In European Union countries government suggests calculating estimation for assessment of the applicability different materials in various areas of housing and civil construction. Earlier, the authors established the fact of possible inconsistencies between Russian and European standards in different classes of materials.

In order to compare the applicability of different approaches were held complex researches including experimental determination content of natural radionuclides in materials, calculation of dose rate in specific rooms and direct measurements of dose rates. As basic model authors used approach applied in the European Union countries. Experimental studies were performed using methods scintillation spectrometry and radiometry.

## **2. Techniques and objects of a research**

For the determination of radiative parameters due to the natural radioactivity of building materials used calculation-experimental method. The specific activity of radionuclide in construction materials is the parameter which determines level  $\gamma$ -background indoors. For determination of activity various methods such as are used: radiochemical, radiometric and spectrometer. The  $\gamma$ -spectrometer method is the most used as it has small labor input, high sensitivity, accuracy. This method is based on registration of the scintillation ranges of gamma radiation which emitted by a sample of construction material or a product with the following processing on the personal computer.

Experimental studies were conducted on gamma-beta-spectrometer MKS-AT1315. To process the received spectrum of NRN program «SPTR» was used. Concrete and tiles facing, used in the bearing and protecting designs inhabited and production rooms were research objects for this series of measurements generally.

The equivalent dose rate (EDR),  $\mu\text{Sv h}^{-1}$ , is controlled size in buildings and constructions. Measurements of EDR in premises of residential and public buildings, on the area, were carried out by DKS-96 and IRD-02 dosimeters-radiometers. Measurements of EDR were taken at the height of 1 m from a floor surface in the center of rooms and in 1 cm from a surface of walls and overlappings. To study the EDR was chosen as premises in residential, administrative and industrial buildings with a concrete bearing and enclosing structures in various areas of Moscow and Tverskoi and Novgorodskoi oblast. To reduce the error in each point were carried out from 5 to 10 measurements.

Settlement researches were conducted according to the European recommendations of work [4]. At the same time the following formulas, coefficients and sizes were used.

Dose conversion –  $0.7 \text{ Sv Gy}^{-1}$

Background are  $50 \text{ nGy h}^{-1} = 0.050 \mu\text{Gy h}^{-1} = 0.035 \mu\text{Sv h}^{-1}$  – the accepted value for a natural background in Europe.

The annual time spent of the person in the indoor  $t = 7000$  hours.

Dose rate indoors is calculated using the following formula (1):

$$P_{\text{pogl}} = (P_{\text{udRa}} * A_{\text{udRa}} + P_{\text{udTh}} * A_{\text{udTh}} + P_{\text{udK}} * A_{\text{udK}}) \text{ nGy h}^{-1}, \quad (1)$$

where  $P_{\text{udRa}}$ ,  $P_{\text{udTh}}$ ,  $P_{\text{udK}}$  – specific dose rate,  $\text{nGy h}^{-1}$  per Bq/kg, of radium, thorium and potassium respectively;

$A_{\text{udRa}}$ ,  $A_{\text{udTh}}$ ,  $A_{\text{udK}}$  – are the radium, thorium and potassium activity concentrations in Bq/kg.

For received conditions, the room size are  $4\text{P}5 \times 2.8$  m. Floor, ceiling and walls are of concrete. Coefficients are equal to the following values:  $P_{\text{udRa}}=0.92$ ,  $P_{\text{udTh}}=1.1$ ,  $P_{\text{udK}}=0.080$ .

### 3. Analysis and summary

Below estimated and experimental data are presented and analyzed. The data obtained for coinciding initial prerequisites for definition opportunities of practical use of recommendations of the EU and for assessment of radiological danger of construction materials. Table 1 shows experimental data about equivalent dose rate in premises of multi-storey buildings and office buildings in Moscow, Velikij Novgorod, Kimry and background values on adjoining territories.

**Table 1.** The average value of the equivalent dose rate.

| The location of measurement       | The average value EDR the indoor, $\mu\text{Sv h}^{-1}$ | The average value EDR the outdoor, $\mu\text{Sv h}^{-1}$ |
|-----------------------------------|---------------------------------------------------------|----------------------------------------------------------|
| Moscow, Dmitrovskoe shosse        | 0.13                                                    | 0.14                                                     |
| Moscow, Yaroslavskoye Shosse      | 0.15                                                    | 0.17                                                     |
| Moscow, Central'nyj okrug         | 0.15                                                    | 0.15                                                     |
| Moscow, Yugo-zapadnyj okrug       | 0.14                                                    | 0.13                                                     |
| Moscow, Zapadnyj okrug            | 0.18                                                    | 0.17                                                     |
| Sergiev Posad, Moskovskaya oblast | 0.17                                                    | 0.18                                                     |
| Kimry, Tverskaya oblast           | 0.11                                                    | 0.13                                                     |
| Velikij Novgorod                  | 0.14                                                    | 0.13                                                     |

Analysis of the results presented in the table 1 shows, that all residential and industrial premises satisfy the Russian standards (The indoor EDR may not exceed the outdoor dose rate by more than  $0.2 \mu\text{Sv/h}$ ). Within an error of measurements of EDR indoor and outdoor are the same. In some cases it is possible to speak about shielding of external radiation (a radiation background) walls, a ceiling and floors of the premises.

For the authenticity of the conditions of comparison have been measured specific and effective specific activity of NRN in the concrete applied in the construction of residential and industrial premises. The relevant data are presented in table 2. Also in table 2 shows typical values for the concrete used in construction of the European countries.

**Table 2.** The values specific activities and effective specific activity NRN of the concrete and raw materials for their production.

| Material                       | Country     | $^{226}\text{Ra}$ ,<br>Bq/kg | $^{232}\text{Th}$ ,<br>Bq/kg | $^{40}\text{K}$ ,<br>Bq/kg | $A_{\text{eff}}$ ,<br>Bq/kg |
|--------------------------------|-------------|------------------------------|------------------------------|----------------------------|-----------------------------|
| Concrete panel                 | Belarus     | 11                           | 10                           | 320                        | 53                          |
| Concrete overlapping           | RF          | 10                           | 7                            | 315                        | 46                          |
| Concrete base                  | RF          | 10                           | 7                            | 456                        | 58                          |
| Concrete the protecting design | RF          | 9                            | 8                            | 502                        | 48                          |
| Concrete panel                 | RF          | 53                           | 59                           | 826                        | 204                         |
| Crushed granite                | RF          | 61                           | 52                           | 746                        | 196                         |
| Limestone                      | RF          | 12                           | 3                            | 57                         | 20                          |
| Sand                           | RF          | 14                           | 3                            | 234                        | 39                          |
| Concrete                       | UK          | 19                           | 11                           | 183                        | 50                          |
| Concrete                       | Spain       | 30                           | 32                           | 204                        | 90                          |
| Concrete                       | Finland     | 53                           | 38                           | 838                        | 178                         |
| Tile will keramogranit         | RF          | 56                           | 33                           | 538                        | 145                         |
| Tile ceramic                   | RF          | 57                           | 73                           | 468                        | 194                         |
| Tile ceramic                   | RF          | 56                           | 49                           | 532                        | 168                         |
| Tile ceramic                   | Spain       | 61                           | 66                           | 600                        | 201                         |
| Tile ceramic                   | Netherlands | 67                           | 46                           | 310                        | 155                         |

These tables 2 show that all materials belong to the first class (use without restrictions) according to Russian standards.

In table 3 an example of compiling the results of the estimation of the parameters of radiological hazards in the premises based on the method [4] using the experimental values of the content of NRN and EDR. We used the room in the estimated model with bearing and enclosing concrete structures.

**Table 3.** Assessment of parameters of radiological hazards in the indoor by NRN.

| Country                                            | $^{226}\text{Ra}$ | $^{232}\text{Th}$ | $^{40}\text{K}$ | $A_{\text{eff}}$ | I    | Dose rate indoors, $\text{Ppogl}$ , $\mu\text{Sv h}^{-1}$ design [4] | Annual effective dose, mSv (the exposure time 7000 hours) design [4] | Annual effective dose, mSv without background 50 nSv $\text{h}^{-1}$ (35 nSv $\text{h}^{-1}$ ), the exposure time 7000 hours, design [4] | Annual effective dose, mSv without experimental background 130-180 nSv $\text{h}^{-1}$ , design [4] | Annual effective dose, mSv on experimental data indoors |
|----------------------------------------------------|-------------------|-------------------|-----------------|------------------|------|----------------------------------------------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|---------------------------------------------------------|
| <b>Bearing and enclosing structures - concrete</b> |                   |                   |                 |                  |      |                                                                      |                                                                      |                                                                                                                                          |                                                                                                     |                                                         |
| Radiation protection 112 [4]                       | 80                | 70                | 800             | 243              | 0.88 | 0.15                                                                 | 1.1                                                                  | 0.81                                                                                                                                     | 0.81                                                                                                |                                                         |
| RF                                                 | 20                | 13                | 322             | 66               | 0.24 | 0.04                                                                 | 0.3                                                                  | 0.0                                                                                                                                      | -                                                                                                   | 0.28                                                    |
| RF                                                 | 27                | 6                 | 56              | 40               | 0.14 | 0.03                                                                 | 0.2                                                                  | -0.1                                                                                                                                     | -                                                                                                   | 0.21                                                    |
| RF                                                 | 22                | 32                | 839             | 139              | 0.51 | 0.09                                                                 | 0.6                                                                  | 0.4                                                                                                                                      | -                                                                                                   | 0.63                                                    |
| RF                                                 | 53                | 59                | 826             | 204              | 0.75 | 0.13                                                                 | 0.9                                                                  | 0.6                                                                                                                                      | 0                                                                                                   | 0.91                                                    |
| Europe                                             | 40                | 30                | 400             | 115              | 0.42 | 0.07                                                                 | 0.5                                                                  | 0.3                                                                                                                                      | -                                                                                                   | 0.49                                                    |

The analysis of the received results doesn't allow to claim about reliable convergence of data of radiological hazards of building materials by NRN. Both coincidence and full discrepancy is observed. And it is obvious that coincidence of results is observed for materials with the high content of NRN. In practice the actual content of NRN in concrete of the bearing and enclosing concrete structures can change over a wide range. The specific and effective activity of NRN in concrete for receiving the most correct data has to be equal or more values presented to in the table 4.

**Table 4.** The maintenance of NRN in concrete at which calculated values of the absorbed dose indoors can coincide with experimental data.

| Material | $^{226}\text{Ra}$ , Bq/kg | $^{232}\text{Th}$ , Bq/kg | $^{40}\text{K}$ , Bq/kg | $A_{\text{eff}}$ , Bq/kg |
|----------|---------------------------|---------------------------|-------------------------|--------------------------|
| Concrete | 70                        | 75                        | 800                     | 240                      |

At such specific activities we will receive that dose rate from concrete is  $0.12 \mu\text{Sv h}^{-1}$ . This corresponds to experimental data.

In design model very low value of a background the outdoor is accepted. The real background surpasses the accepted value several times including in the European countries. In design model the possible contribution to the absorbed dose not only  $^{222}\text{Rn}$ , but also the radiation of technogenic radionuclide  $^{137}\text{Cs}$  is not considered.

#### 4. Conclusion

- The conducted researches have shown objectivity of use of dose criterion for ensuring radiological safety of use of construction materials in buildings and constructions of inhabited and production appointment.
- Need of harmonization of approaches to assessment of radiological danger in Russia and the countries of Europe is confirmed, considering use volumes in the national markets.

- At the same time the received results allow to make a conclusion about limited uses of the European approach based on estimates of radiological hazard in living quarters.
- Obtained results allow to make the main conclusion about the limited application of the estimated approach to evaluation of radiological hazard in living quarters.
- The calculation method can be used as selection of materials, estimated at a preliminary stage.

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