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Criteria for evaluation of building materials hazard based on their natural radioactivity in Russia and in the European Union countries

Darya Buzina[1], *Igor* Engovatov[1,*], *Lev* Alimov[1] and *Michail* Slesarev[1]

[1]Moscow State University of Civil Engineering, 129337, Yaroslavskoye Shosse 26, Moscow, Russia

Abstract. We hereby have considered the natural radioactivity of building materials as a source of radiation for the human environment. We have considered the Russian and the European evaluation criteria for ensuring radiation safety of the population. We also present an experimental research of the content of natural radionuclides in building materials. We have calculated the effective specific activity and the activity concentration index based on the results presented. We have identified discrepancies between the Russian and the European standards.

1 Introduction

Natural and artificial sources of ionizing radiation determine the radiation effect on humans both directly and through the environment, including, but not limited to the territory of residence, the buildings and the facilities, where they spend most of their life.

The natural radioactivity of the building materials used in buildings is a significant component of the human exposure, and in a series of cases can result in significant exposure doses. All building materials, as well as raw materials for their manufacturing, contain one or another quantity of natural radionuclides (NRN). The most important of them are the ^{238}U radioactive family with its progenies, the ^{232}Th radioactive family with its progenies and potassium -40 (^{40}K).

Virtually, all industrialized countries seek to reduce and limit the radiation exposure of the population by natural radioactivity of building materials, including the application of standards, evaluation criteria and scopes of application.

2 Russian criteria for evaluation

Russia has adopted the fundamental laws and elaborated the standard documents that govern the procedure and the regulations for recording and controlling the use of building materials to ensure radiation safe human environment [1, 2].

In accordance with the current legislation, the classes of building materials and the quantitative limits of the concentration of ^{226}Ra, ^{232}Th and ^{40}K natural radionuclides (NRN)

* Corresponding author: eng46@mail.ru

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for them are established using the value of the effective specific activity (A_{eff}). Materials pertaining to classes I and II may be used for building residential and industrial facilities. The quantitative values are: $A_{eff} \leq 370$ Bq/kg for class I and $A_{eff} \leq$ 740 Bq/kg for class II.

The value of the effective specific activity (A_{eff}) is calculated using the following formula [1]:

$$A_{eff} = A_{Ra} + 1.31A_{Th} + 0.085A_K, \quad (1)$$

where A_{Ra} and A_{Th} are the specific activities of ^{226}Ra and ^{232}Th radionuclides, which are in radioactive equilibrium with the rest of the members of the uranium andthorium series, and A_K is the specific activity of ^{40}K, Bq/kg.

Also, the effective dose limit of 1 mSv a year during any 5 average consecutive years, but no more than 5 mSv a year, is established for the population.

The equivalent dose rate (EDR) of the external gamma radiation and the indoor average annual equivalent equilibrium volumetric activity of radon are the values controlled inside the residential and public buildings within the territory of residence. The indoor EDR may not exceed the outdoor dose rate by more than 0.2 μSv/h. The indoor gamma radiation of radon and thoron present in the indoor air is not considered in this article.

Therefore, the Russian approach to ensuring radiation safety of the population in its environment consists in limiting the NRN concentration in the soil and building materials and the EDR of the external gamma radiation in the residential and industrial buildings. Non-exceedance of the established limits should, in principle, ensure non-exceedance of the annual dose of 1 mSv.

3 European criteria for evaluation

The international organizations, such as IAEA, ICRP and UNSCEAR show strong interests in the regulation and standardization of the radiation safety of the environment [3]. For example, the Commission of the European Communities (European Commission, EU) has issued the regulatory and methodological document “Radiation protection 112. Radiological Protection Principles concerning the Natural Radioactivity of Building Material” [4] which formulates the principles of the radiation protection and proposes to use the following radiological criteria as the basis for the controls of the building materials radioactivity:

a) Dose criterion for controls

Controls should be based on a dose criterion which is established considering overall national circumstances. Within the European Union, doses exceeding 1 mSv a year should be considered from the radiation protection point of view. These doses should be accepted only in specially stipulated exceptional cases where materials are used locally. Controls can be based on a lower dose criterion. In this case, a reasonable practicality study concerning such controls will be required. It is therefore recommended that controls be based on a dose within the range of 0.3 to 1 mSv a year. This is the excess dose to that received outdoors.

b) Level of exemption from all restrictions

Building materials should be exempted from all restrictions concerning their radioactivity if the excess gamma radiation originating from them increases the annual effective dose by more than 0.3 mSv. This is the excess gamma dose to that received outdoors.

We can present the level to be studied as the activity concentration index I. The activity concentration index must consider typical methods and volumes for use of a building material in a building.

The activity concentration index (I) is calculated using the following formula:

$$I = \frac{c_{Ra}}{300Bq/kg} + \frac{c_{Th}}{200Bq/kg} + \frac{c_K}{3000Bq/kg}, \quad (2)$$

where C_{Ra}, C_{Th}, C_K are specific activities of radionuclides ^{226}Ra, ^{232}Th and ^{40}K in a building material respectively, Bq/kg.

The coefficients 300, 200 and 3000 are references for radium, thorium and potassium respectively, which are determined on the basis of the scenarios for the use of materials to secure the dose criterion.

The activity concentration index may not exceed the following values indicated in the Table1.

Table. 1. The values of the activity concentration index for different uses of building materials

Dose criterion	0.3 mSv a year	1mSv a year
Basic structural and finishing materials, e.g. concrete	$I \leq 0.5$	$I \leq 1$
Materials with restricted use: curbs, framing and others	$I \leq 2$	$I \leq 6$

The activity concentration index must be used only as a tool for identifying the materials which has to be focused on. Any final decision on restriction of the use of a material must be based on a separate dose evaluation. Such evaluation must be based on the situation considering direct use of such material.

Normally, changes in the activity concentration are needed only when there are substantial grounds to suspect that the dose criterion for controls could be exceeded.

The manufacturer or the seller is liable for ensuring quality showing that a material complies with the radiological requirements established by the state. However, other approaches can be applied to the controls as well. For example, the builder or the designer of a building can be liable for the compliance of a new building with the radiological requirements.

Materials should be exempt from all elements of controls concerning their radioactivity, if it is shown that the dose criterion for the exemption from restrictions has not been exceeded.

Exempt materials to be used for building without any restrictions concerning their radioactivity must be allowed to enter the consumer market.

4 Analysis and summary

Therefore, the European approach contemplates more varied approaches to the evaluation of the potential hazard and the scopes of application of building materials for their use. 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.

For this purpose, it is of undoubted practical interest to carry out comparative evaluations of the radiological hazard of building materials and raw materials for their fabrication, using Russian and European approaches.

The studies of the content of NRN in building materials have been and are carried out both in the RF [5-10] and abroad [11-20]. As the result of the studies carried out, wide qualitative and quantitative material concerning the NRN content in the building materials used and in the raw materials for their fabrication has been obtained.

As the result of the studies, it has been established that in most of the cases, the NRN content is much less than the reference values given in the formula (2). At the same time, it is established that the NRN concentration of some materials and raw materials for their manufacturing can considerably exceed the average typical values.

Table 2 shows the experimental results of determination of the NRN in building materials of the RF and several foreign countries, as well as data concerning the effective specific activity A_{eff} for them, using the Russian approach (formula) and the activity concentration index **I**, using the European approach (formula 2) for the typical and maximum values.

Table 2. Typical and maximum values of the natural radioactivity of building materials

Material	Country	Typical activity, Bq/kg					Maximum activity, Bq/kg				
		^{226}Ra	^{232}Th	^{40}K	A_{eff}	I	^{226}Ra	^{232}Th	^{40}K	A_{eff}	I
Concrete	Russia	27	6	56	40	0.14	53	59	826	204	0.75
	USA	26	18	296	76	0.28	89	118	1147	346	1.27
	Europe	40	30	400	115	0.42	240	190	1600	631	2.28
Light concrete	RF	20	15	62	45	0.16	35	13	162	66	0.24
	Europe	60	40	430	151	0.54	2600	190	1600	2991	10.15
Red brick	RF	11	60	43	93	0.35	55	62	783	206	0.75
	Europe	39	41	560	143	0.52	200	200	2000	640	2.33
	Saudi Arabia	27	21	279	80	0.29	39	27	213	93	0.34
Grey brick	RF	11	60	43	92	0.35	55	62	783	206	0.75
	USA	91	73	596	239	0.86	178	144	1184	472	1.71
	Europe	10	10	330	53	0.19	59	67	670	206	0.76
	India	0	26	152	48	0.18	3	48	412	103	0.39
	Egypt	29	50	167	110	0.40	65	89	376	214	0.79
	Saudi Arabia	15	9	114	38	0.14	32	19	171	72	0.26
Cinder	RF	62	88	367	210	0.77	679	112	577	877	3.02
	USA	706	15	940	809	2.74	3145	7	1850	3321	11.14
	Europe	180	100	650	369	1.32	1100	300	1500	1625	5.67

Material	Country	Typical activity, Bq/kg					Maximum activity, Bq/kg				
		^{226}Ra	^{232}Th	^{40}K	A_{eff}	I	^{226}Ra	^{232}Th	^{40}K	A_{eff}	I
Natural stones (granite, marble, etc.)	RF	22	22	472	93	0.34	105	119	103	269	0.98
	Europe	60	60	640	196	0.71	500	310	4000	1263	4.55
	India	74	0	65	80	0.27	82	112	1908	399	1.47
	Egypt	18	24	350	81	0.30	65	60	920	226	0.82
	Saudi Arabia	21	18	276	69	0.25	45	35	821	165	0.60
Plaster	RF	12	2	6	15	0.05	12	9	138	36	0.13
	Europe	10	10	80	30	0.11	1034	43	37	1093	3.67
	India	8	0	27	10	0.04	233	9	22	247	0.83
	Egypt	39	25	226	92	0.33	32	55	116	114	0.42
	Saudi Arabia	29	55	65	106	0.39	58	72	97	160	0.58

Conclusion

The analysis of the table allows us to make the following conclusions:

- Most of the materials comply with both ours and European criteria and can be used without any restrictions.
- A disconformity between the Russian and the European standards can be observed in different classes 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.
- The dose criterion is more objective, since the annual individual radiation dose is much more important for an individual the human, than the activity of the building materials in their environment.
- Even though complex controls mean considerable financial and time expenses, a great quantitative increase in the nomenclature of building materials and the use of varied natural raw materials, industrial waste and artificial additives do not discard the current task of computational and experimental study of the natural radioactivity of different types of building materials.
- For uninterrupted circulation of building materials on the global market, it is needed to harmonize standard approaches and regulations for the radiation purity of the product (material, raw materials, building).

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