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STANDARDS FOR NATURAL RADIOACTIVE SUBSTANCES IN BUILDING MATERIALS

(K voprosu o normirovanii soderzhaniya estestvennykh radioaktivnykh veshchestv v stroitel'nykh materialakh)

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Varying amounts of naturally radioactive substances (uranium, thorium, their decay products, and K^{40}) are present in all natural materials, and thus also in materials used in the construction of dwellings. [Soviet] Sanitary Regulations No. 437-63 lay down maximum permissible concentrations of radioactive substances in building materials, namely 0.002% equilibrium uranium and thorium, or 2×10^{-11} curies g of the total Ra^{228}, Th^{228}, U^{234}, Th^{230}, Ra^{226}, Pb^{210}, and Po^{210}.

The presence of natural gamma-radiating isotopes in building materials may raise the gamma-background in dwellings, and the presence of emanating isotopes (radium and thorium) may raise the concentrations of radon and thoron and their decay products in indoor air. The establishment of norms for the concentrations of gamma-radiating isotopes in building materials has had the effect of limiting the indoor gamma-background due to these isotopes. The situation is different in the case of emanating substances. Radon and thoron concentrations in indoor air depend upon many factors, in addition to the concentrations of radium and thorium in the building materials; in some cases, high concentrations of radon and thoron may be present in dwellings constructed of materials containing low concentrations of radioactive substances.

Such a case was observed by the authors during an investigation of the gamma-background and radon and thoron concentrations in the air of dwellings in towns of the Stavropol Territory. Radon concentrations exceeding 3×10^{-12} curies/l (the maximum permissible concentration) were found in 13 of the 65 dwellings investigated. In three dwellings the concentration exceeded 1×10^{-11} curies/l. The thoron concentration was appreciably below the maximum permissible level in all cases. Radon and thoron concentrations were measured in rooms that had not been ventilated for at least 2 hours before the air samples were taken. In the majority of the houses with high radon concentration, the gamma-background

* The experimental work was carried out during an expedition led by Prof. L. A. Pertsov. Measurements were made by the authors, by G. A. Orlov, and by T. F. Kulagina, M. E. Grunis, and I. M. Tumasov, of the Stavropol and the Pyatigorsk Sanitary-Epidemiological Centers.

was very low, from 12 to 25 μr/hr, and 13 to 17 μr/hr in the street. The low gamma-background ruled out the possibility that the high concentrations of radon observed in the air of dwellings was due to the concentration of radioactive substances in the building materials.

In an attempt to find the causes for the higher concentrations of radon in dwellings, a more detailed examination was made of the build-up mechanism of this substance. The mechanism of radon liberation has been studied by several authors (Baranova, and others). The liberation of radon from rocks and soils is governed by the emanating power and diffusion factor; these can vary by more than a whole order of magnitude between various rocks. We were unable to find values of emanating powers and diffusion factors for building materials in the literature, but their values for different building materials may be assumed to vary as widely as in the case of rocks. It follows that certain materials with a comparatively low radium content may liberate larger amounts of radon than other materials with a relatively high radium content.

The build-up of radon in indoor air is governed by radon liberation and the air-change factor. Indeed, the differential equation for time-variation of the number of radon atoms in indoor air can be written in the following form

$$\frac{dN}{dt} = -\lambda N - kN + a + Vkq_{\text{our}}, \qquad (1)$$

where N is the number of radon atoms in the indoor air at the moment t; λ is the decay constant for radon; k is the air-exchange rate, the fraction of air volume exchanged in room by ventilation in unit time; a is the number of radon atoms introduced into the room in unit time by emanation from the inner surfaces (walls, floor, ceiling); q_{out} is the number of radon atoms per unit volume of outdoor air, and V is the volume of air in the room.

The quantities λN and kN are respectively the reduction in the number of radon atoms in indoor air due to radioactive decay and to ventilation; the quantities a and Vkq_{out} are respectively the number of radon atoms introduced into the room by emanation and by the ingress of outdoor air.

The solution of equation (1) has the form

$$N = \frac{a + Vkq_{\text{out}}}{\lambda + k}[1 - e^{-(\lambda+k)t}] + N_0 e^{-(\lambda+k)t}, \qquad (2)$$

where N_0 signifies the number of radon atoms in the room air at $t = 0$.

In place of the number of radon atoms, we now consider the activity due to radon per unit volume, $C = \frac{N\lambda}{V}$; the activity of radon added to indoor air from the internal surfaces (walls, floor, ceiling) per unit time is designated by $A = a\lambda$:

$$C = \frac{A + VkC_{\text{out}}}{(\lambda + k)V}[1 - e^{-(\lambda+k)t}] + C_0 e^{-(\lambda+k)t}. \qquad (3)$$

From (3) it follows that the time necessary for the establishment of radon-concentration equilibrium in the room is not governed by the quantity λ (as erroneously assumed by Hultquist), but the quantity $\lambda + k$.

With an air-exchange rate of 1 per hour, the equilibrium concentration is established in just a few hours. The radon-concentration equilibrium indoor is

$$C_{eq.} = \frac{A + VkC_{out}}{(\lambda + k)V}. \quad (4)$$

According to the 1962 building standards and regulations, the air-exchange rate in dwellings should not be less than 1 per hr (more correctly, 3 m^3 of air per hour per 1 m^2 of floor area). For this, or comparable values of the air-exchange rate, we may say that $\lambda \ll k$, and the quantity λ in the denominator of formula (4) can be neglected. For radon, $\lambda = 2.1 \times 10^{-6}$ sec^{-1}, and for an air-exchange rate of 1 per hr, $k = 2.8 \times 10^{-4}$ sec^{-1}. Under these conditions, the formula becomes

$$C_{eq} = \frac{A}{kV} + C_{out}. \quad (5)$$

From (5) it is seen that the radon concentration indoors is always higher than that outdoors, the difference being directly proportional to the radon emanation from the internal surfaces (walls, floor, ceiling), and inversely proportional to the air-exchange rate.

Assuming the specific radon liberation Q to be the same for all the internal surfaces (walls, floor, ceiling), formula (5) can be written as

$$C_{eq} = \frac{QS}{kV} + C_{out}, \quad (6)$$

where S — the total surface area of the walls, floor and ceiling.

If the quantities C_{eq} and C_{out} are expressed in curies/liter, Q in curies/sec/m^2, S in m^2, V in m^3, and K in complete air changes per hour, the formula becomes

$$C_{eq} = 3.6\frac{QS}{kV} + C_{out} \text{ curies/l}). \quad (7)$$

The same procedure can be applied to thoron concentration in indoor air, with the difference that λ in formula (4) cannot be neglected since it has a value $\lambda = 1.35 \times 10^{-2}$ sec^{-1}.

To assess the level to which the build-up of radon in a room may reach, a knowledge of the specific radon liberation is necessary. If this is calculated on the assumption that all the radon formed in the walls leaves them (50% into the room and 50% through the outside face of the walls), it leads to the conclusion that the maximum permissible concentration of radon will be reached (with normal air exchange) even when the radium content of the building materials is considerably lower than the Clark [abundance ratio] one. However, this assessment of radon liberation appears to be much too high.

According to Bykovskii, the specific radon liberation from soils varies from 2×10^{-15} to 1.7×17^{-12} curies/sec·m^2, with an average value of 4.5×10^{-13} curies/sec·m^2. These values were used in establishing a criterion for evaluating the specific radon liberation by walls, floor, and ceiling. The calculation was made for a room 5m × 4m, and 3m high.

Outdoor radon concentration was taken to be 1×10^{-13} curies/liter, and air-exchange rates of 0.1, 1 and 10 per hour were used. The calculation results are listed in Table 1.

TABLE 1. Calculated indoor radon concentrations due to emanation from walls, floor, and ceiling, curies/liter

K, hr^{-1}	Q, curies/sec·m^2		
	$1.7 \cdot 10^{-12}$	$4.5 \cdot 10^{-13}$	2.10^{-15}
0.1	89.0	24,000	0.20
1	9.7	2.60	0.11
10	1.1	0.35	0.11

TABLE 2. Calculated indoor radon concentrations due to emanation from the soil under the floor, curies/liter

K, hr^{-1}	Q, curies/sec·m^2		
	$1.7 \cdot 10^{-12}$	$4.5 \cdot 10^{-13}$	2.10^{-15}
0.1	19.0	5.1	0.12
1	2.1	0.64	0.10
10	0.3	0.15	0.10

Radon concentrations in the same room, calculated on the assumption that all the emanation comes through the floor, are listed in Table 2. The table represents a case in which the liberation of radon by the building materials is small, while the floor is a poor barrier against the radon liberated by the soil.

It will be seen from Tables 1 and 2 that, if the ventilation is poor or if there is a high liberation of radon, the indoor radon concentration may approach the maximum permissible level, or even exceed it. This is also possible in houses constructed of materials with a low content of radioactive substances, but with a poor barrier against radon liberated by the soil.

Thus, the concentration of radioactive substances in building materials is not a reliable index of the possible radon concentration in the building. We therefore regard it as desirable to introduce standards for the specific radon liberation by walls, floor, and ceiling, in addition to the standards governing the concentration in the building materials of substances emitting gamma rays. The maximum permissible specific radon liberation can be derived from the maximum permissible concentration of radon in dwellings (3×10^{-12} curies/liter) and the minimum air-exchange rate (1 per hour). Substituting these values in (7), we obtain the maximum permissible level of specific radon liberation. For present purposes, it is also necessary to define the ratio of the surface area of the walls, the floor, and the ceiling, to the volume of the room. This quantity does not vary markedly for actual dwellings, and the maximum specific radon liberation may be based on its mean or maximum value. For example,

if S:V = 1.61, the maximum permissible level of specific radon liberation is 5×10^{-13} curies/sec· m^2. Methods for the experimental determination of the specific radon liberation by soils and rocks have been described by Bykhovskii. If these techniques are modernized, they may be applied to building materials.

Materials can be tested to check their suitability for housing construction, even if no dwellings have been built from the materials in question. This can be done in the following manner. The materials are used to build a mock-up of a wall, floor, or ceiling, which is then finished in a suitable manner (with plaster, oil paint, or whitewash). Measurements of specific radon liberation are then made on the mock-up. Some building materials are suitable only if finished with oil paint or some other finish that inhibits the liberation of radon. It must be remembered that complying with a standard for the maximum permissible level of radon liberation will not ensure that the radon concentration in a dwelling will be below the maximum permissible level, unless the standard for air-change factor is likewise respected.

Further development of methods for determining specific radon liberation, and the actual carrying out of such measurements will allow a body of data to be collected on the levels of radon liberation by various types of building materials, and on the source of radon in the different cases (liberation by walls, or diffusion from the soil through the floor). Investigations of this kind will make it possible to detail measures that will have the effect of restricting radon concentration in dwellings to an agreed permissible level.

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This paper does not provide information on the uranium and thorium contents of the building materials used in the construction of the dwellings investigated by the authors. The paper likewise lacks data on experimental measurements of specific radon liberation by walls and soils. Nevertheless, the question raised in the paper of the need for such measurements deserves attention; the investigations envisaged will lead to the establishment of more precise regulations for building materials. It may also be assumed that such investigations would lead to more reliable measures being taken to limit radon concentration in buildings. The feasibility of the establishment of norms for specific radon liberation can only be decided on, when a large body of experimental data has been collected.

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EXPERIMENTAL CHANGE IN THE PROCEDURE FOR IDENTIFICATION OF BACTERIAL CARRIERS AMONG WORKERS AT FOOD ENTERPRISES
(Opyt izmeneniya poryadka obsledovaniya rabotnikov pishchevykh ob''ektov na bakterionositel'stvo)

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Instructions currently in force for the detection of typhoid and paratyphoid carriers call for bacteriological examinations of all persons entering employment at food enterprises, nursery schools and medical institutions. These employees must undergo further examinations at annual intervals, as well as after illness or contact with a sick person.

Examinations of such persons constitute about 30—35% of the bacteriological analyses for pathogenic intestinal bacteria performed by laboratories of sanitary-epidemiological centers. In recent years the incidence of typhoid and paratyphoid bacteria in these analyses has not exceeded 0.006—0.008% for the entire USSR. It is especially low in the regular annual examinations.

The large volume of this work and the negligible numbers of carriers detected indicate a need for a more efficient procedure.

As a first step, the institution of stricter criteria for the selection of persons for mandatory bacteriological examination would seem to offer a method of increasing efficiency. Such a procedure was tested in Kiev in 1965.

The city was divided into a control area (4 districts) and an experimental area (5 districts), the number of persons undergoing examinations annually being similar for each area. In the control area workers were examined in full accordance with the instructions in force, while modifications were introduced in the experimental area. Mandatory examinations were performed of workers who had suffered from an acute febrile disease in the period July—October, irrespective of the diagnosis (influenza, tonsillitis, etc.), and of the personnel of enterprises and institutions servicing areas where there was a high incidence of any intestinal infection. No other regular annual examinations were performed, except

* Participants in the work included bacteriologists, epidemiologists, and health physicians from nine districts of the city of Kiev.