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RADIATION CONDITIONS FROM RADON DWELLINGS OF VARIOUS PURPOSE

F.I.Zuevich

Research Institute of Industrial and Marine Medicine, St. Petersburg, Russia

INTRODUCTION

A specific feature of the mechanism of pollution of air environment is continuous flow of a radon in volume of a dwelling and, owing to it decay , accumulation of affiliated products, mainly determining a dose load on the person.

The intensity of radon allocation in volume of a dwelling depends basically on geophysical properties of spread under rocks, building material and time of air exchange .This determines specific character of formation of a radiating conditions in residential and industrial dwellings.

SOURCES AND FACTORS, INFLUENCING TO INTENSITY OF ALLOCATION OF A RADON IN VOLUME OF DWELLINGS

Main sources of allocation of a radon in volume of dwellings are:

1. Massif of rocks under buildings;
2. Building materials;
3. Technical and drinking water, natural gas.

The quantity of a radon, arriving from these sources, depends on a number of the reasons, determined by geological and geophysical properties of spread under rocks and by construction and architect features of dwellings and buildings.

The allocation of a radon from a massif of spread under rocks.

Process of receipt of a radon from a massif of rocks consists of two consecutive steps: the first step is allocation of a radon in emptiness of rocks (pores, cracks) thanking the phenomenon of effect Ra-226 decay, second - distribution of allocated in thepores radon under the laws of gas diffusion or convection.

The theory of distribution of a radon in pores was in detail developed in (1,2), where for various cases of radon distribution the theoretical formulas were deduced.

In general the differential equation of distribution of volumetric activity of radon at steady conditions will have a form:

$$K\frac{\partial^2 C}{\partial^2 n} - V\frac{\partial C}{\partial n} + q\rho k - \lambda C\varepsilon = 0 \qquad (1)$$

where: K - coefficient of diffusion;
C - quantity of a radon in 1 cm³ of pore air;
V - convection velocity;
q - quantity of a radon, formed for 1 s in 1 g of rocks;
ρ - volumetric weight of rocks;
k - emanation coefficient;
λ- constant of radon decay;
ε -porosity of rocks;
t - time.

As an example we shall consider the elementary case and, in particular, diffusion distribution of a radon in infinite, homogenious layer, leaving on a surface. The change of volumetric activity of radon with depth is described by the equation:

$$C_{Rn} = \frac{q\rho k}{\lambda} * (1 - H\sqrt{\frac{\lambda}{K}}) \qquad (2)$$

And flow of radon from 1 cm² of a rock surface (exhalation)

$$E = K\frac{\partial C}{\partial x} = \frac{q\rho k}{\lambda}\sqrt{\lambda K} \qquad (3)$$

THE ACCUMULATION OF SHORT LIVED AFFILIATED PRODUCTS OF RADON IN AIR OF DWELLINGS OF VARIOUS PURPOSE

Accumulation of products of radon decay in a general case can be expressed by the following equation:

$$N_n = N_{Rn} * \lambda_1 \lambda_2 .... \lambda_{n-1} * \left(\frac{\exp(-\lambda_1 t)}{(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)*...*(\lambda_{n-1} - \lambda_1)} + \right.$$

$$\left. + ...+ \frac{\exp(-\lambda_n t)}{(\lambda_1 - \lambda_n)(\lambda_2 - \lambda_n)*...*(\lambda_{n-1} - \lambda_n)}\right\} \quad (4)$$

As the initial volumetric activity of decay products , and also the correlations between them can be different, we shall consider character of accumulation of volumetric activity of radon decay products and their potential energy directly from a radon, i.e. when the initial volumetric activity RaA, RaB and RaC is equal to zero. In this case the equation (4) became:

$$N_a = \lambda_{Rn} \frac{N_{Rn} * (1 - \exp(\lambda_a t)}{\lambda_a} \quad (5)$$

$$N_b = \frac{\lambda_{Rn} N_{Rn} * \{\lambda_a (1 - \exp(\lambda_b t) - \lambda_b (1 - \exp(\lambda_a t)\}}{\lambda_b (\lambda_a - \lambda_b)} \quad (6)$$

$$N_c = \lambda_{Rn} N_{Rn} \left(\frac{1}{\lambda_c} - \frac{\lambda_b \exp(-\lambda_a t)}{(\lambda_a - \lambda_c)(\lambda_a - \lambda_b)} - \frac{\lambda_a \exp(-\lambda_b t)}{(\lambda_c - \lambda_b)(\lambda_a - \lambda_b)} + \frac{\lambda_a \lambda_b \exp(-\lambda_c t)}{\lambda_c (\lambda_a - \lambda_c)(\lambda_c - \lambda_b)}\right) \quad (7)$$

The quantity of accumulated radon decay products , expressed in potential energy units of alpha-decay, is equal in MeV l^{-1}

$$E = E_a + E_b + E_c = 13{,}68 * N_a + 7{,}68 * N_b + 7{,}68 * N_c \quad (8)$$

where N_a, N_b and N_c are calculated under the formulas (5, 6, 7).
The change of potential energy in time in relative units will be equal

$$\phi = \frac{E}{E_{eqv}} = \frac{13{,}68 * N_a + 7{,}68 * N_b + 7{,}68 N_c}{E_{eqv}} \quad (9)$$

The analysis of decay curve "ϕ" shows, that with rather good approximation the change in ϕ can be expressed by the following dependence:

$$\phi = 1 - \exp(-\lambda_e * t) \quad (10)$$

Where λ_e - empirical constant, s^{-1};
t - time of a radon presence of in volume of a dwelling, s.
Then the equation of accumulation of potential energy or equivalent equilibrium volumetric activity (EEVA) of a radon in a dwelling will have a form:

$$E = C_{Rn} * [1 - \exp(-\lambda_e * t)] \quad (11)$$

In dwellings, in which radon continually arrives, the change of volumetric activity is recorded by an equation:

$$v\frac{\partial C_{Rn}}{\partial w}+\lambda_{Rn}C_{Rn}=Q_w \quad (12)$$

where C_{Rn} - volumetric activity of a radon in a point "w" of a dwelling, Bq m^{-3};
v - speed of air movement in a dwelling, m / s;
λ_{Rn} - constant of radon decay , s^{-1};
Qw - volumetric density of radon flow, Bq m^{-3} s^{-1}.

Using a boundary condition $C_{Rn} = C_{Rn}o$ at x=0, the solution of equation (12) at constant ventilation mode can be recorded in the following form

$$C_{Rn} = C_{Rn}o * \exp(-\lambda_{Rn} * t) + (Qw / \lambda_{Rn}) * [1 - \exp(-\lambda_{Rn} * t) \quad (13)$$

Taking into account, that the time of air exchange in a dwelling cannot be more than two hours, $\lambda_{Rn} * t << 1$, the equation 13 can be recorded with sufficient for practical purposes accuracy:

$$C_{Rn} = C_{Rn}o + Qw * t \quad (14)$$

Thus, the equation of accumulation of potential energy can be submitted as

$$E = C_{Rn}o * [1 - \exp(-\lambda_{Rn} * t)] + Qw * t * [1 - \exp(-0{,}5 * \lambda_{Rn} * t)] \quad (15)$$

PARAMETERS, DESCRIBING A RADIATION CONDITIONS UNDER THE FACTOR "RADON" IN A DWELLING

In the basis of acceptance of the decisions is incorporated criterion not excess mean year EER of a radon equal 100 Bq m^{-3} for new housing accommodation and 200 Bq m^{-3} for existing. For valuation of these values, long-term measurements of a radon by extent till 6 months (measurements in current two seasons) and subsequent recalculation on EEVA of radon with accepted shift of balance equal 0,5 are recommended. I shall not be go in critics of this rule, but I offer, as alternate, following approach to valuation and forecast of a radiating conditions in dwellings of various purpose at different stages of its development from designing before delivery it in operation and while in service.

CRITERION of DECISIONS ACCEPTANCE

<u>Stage of designing and organization of the use of land.</u>

Parameter	Radon safe	Additional researches needed	Radon remedial measures needed
1. Content Ra-226 in soil, Bq kg^{-1}	< 20	$20 < A_{Rn} < 50$	>50
2. Diffusion coefficient, cm^{2}s^{-1}	> 0,01	> 0,002	> 0,002
3. Volumetric Rn activity kBq m^{-3}	< 10	$10 < C_{Rn} < 40$	> 40
4. The relation C_{Rn} (1 m)/C_{Rn} (0,1 m)	1,2	1,1-1,0	>1,05
5. Exhalation, Bq m^{-2} h^{-1}	< 75	75 - 150	> 150

The exhalation of radon from a surface can be determined experimentally or by calculation using gradient of volumetric activity in soil pore air. Unfortunately, the estimates are rather complex and possible only on computers. The account of an exhalation of a radon is carried out under the formula (3), and we receive factor of diffusion from the solution of equation:

$$K=\frac{H1*H2*\lambda_{Rn}}{2*\ln(1-B(1-\exp(-H2*\sqrt{\frac{\lambda_{Rn}}{K}})))} \quad (16)$$

<u>Stage of a reception of a new living accommodation and valuation of existing.</u>

The accumulation EEVA of radon in a dwelling is well described by equation (15), from which it is clear, that determining parameter is specific volumetric flow of a radon in a dwelling. Taking into