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ABOUT SOME ISSUES OF RADON MEASUREMENT TECHNIQUES

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Abstact. *The article examines the validity of measuring radon in units of activity – becquerels, and shows that such an approach in the methodology, recommended by the International Commission on Radiation Protection (ICRP) and currently widely used, leads to a false fourfold increase of radon concentration estimations.*

Key words*: Radon concentration measurement, Becquerel, Radon decay.*

The noble radioactive gas radon, which is a product of the decay of radium, is quite widespread and has a significant impact on living nature. High concentrations of radon are observed in mine workings and groundwater outlets, and are often used for medical purposes.

According to the currently accepted and recommended by International Commission of Radiation Protection (ISRP) methodology, radon is quantified through its activity in becquerels.

Becquerel is a measure (unit) of the number of decays of the corresponding substance per 1 second. Usually, we are talking about the number of decays per second (or rate) in a specific volume, for example, a cubic meter or a liter. Moreover, when measuring radon activity, it is usually assumed and declared that all decays belong specifically to radon, although control of this aspect is not provided, and is hardly possible due to the fact that the number of decays itself does not provide information about their genetic origin or nature, since it does not document the source, but although it is assumed that it is radon itself. Such a statement can be confirmed or refuted solely by spectral (energy) analysis of subatomic particles, generated in decay, which goes too far beyond the scope of simply calculating the rate of decay, in other words, its activity.

On the other hand, it is well known that the decay of the radon atomic nucleus is a cascade process, involving the sequential generation of four alpha particles, four electrons and four gamma quanta (see Table).

Table1. Cascade decay of radon ^{222}Rn

Element	Type of decay	Energy, MeV	Half-life
222Rn	α	5,49	3,9235 days
218Po	α	6,0	3,11 min
214 Pb	β	0,67, 0,73	26,8 min
	γ	0,352, 0,30, 0,24	
214Bi	β	1,54, 1,51, 3,27	19,9 min
	γ	0,61, 1,76, 1.12	
214Po	α	7,69	164,3 mks
210Pb	β	0,06, 0,02	22,3 years
	γ	0,044	
210 Bi	β	1,16	5,012 days
	γ	0,27, 0,30	
210 Po	α	5,3	138,376 days
206Pb	Stab.		

If we assume that the main, most energy-intensive processes of the cascade decay of radon, associated with the generation of alpha particles, are the ones that generate the above mentioned becquerels, then it turns out that only one of the decays, the very first of them, belongs to radon itself, and the other three belongs to its progenies, namely polonium Po218, polonium Po214 and polonium Po210, that is, not all alpha particles that create impulses in activity registration devices genetically belongs to the decay of radon itself.

Moreover, if we abandon the calculation of becquerels and switch to methods of deposition of alpha particles on activated carbon, the result will also be identical – only one out of every four alpha particles will be responsible for the activity of radon itself and, accordingly, for its concentration in the environment.

So, in principle, it is impossible to talk about the activity of radon in becquerels, since this falsely quadruples the radon concentration as a result.

If, in addition to this, the decays associated with the emission of β and γ will be also taken into account in becquerels, this will cause an even greater increase in the Radon activity index. This circumstance can cause serious errors in estimates of the number of radon decayed nucleus and, accordingly, the energy of radiation exposure on biological objects and the accumulation of decay products in them.

Meanwhile, it seems that correct calculation of both the absorbed dose and the amount of decay products accumulated (incorporated) by the body is possible only on the basis of solving the well-known radioactive decay equation.

The radiation decay equation is

$$dN/dt = -\lambda N \text{ (1)},$$
$$N(t) = Noexp(-\lambda t) \text{ (2)},$$

where $d\big(N(t)\big) = d(No(exp\ exp\ (-\lambda t)\ ) = -\lambda No(exp\ exp\ (\lambda t)\ dt$ (3),

where N_0 is the number of radioactive nuclei at time t=0, and λ is the decay constant (probability) for radon 222Rn, determined from the expression $T_{1/2}$=ln2/λ, or λ= ln2/$T_{1/2}$, and all calculations in these expressions should be conducted in SI units for avoid of obtaining incorrect values:

ln2=0,69314718056, (dimensionless quantity),
$T_{1/2}$ = 3,8235 (half-life in days),
$T_{1/2}$ = (3,8235 x24 x60 x 60) = 330350.4 (half-life in seconds).
Then λ=0,69314718056 / (3,8235 x24 x60 x 60) = 0,69314718056/330350,4 = 0,00000209821
or $\lambda \approx 2{,}1 \times 10^{-6} c^{-1}$.

In addition, from the same equation shall be obtained an estimation of the decay rate or, in other words, the activity at radon constant concentration N_{oconst}:

$$\mu = \frac{dN}{dt} = \lambda Noconst \qquad (4).$$

Thus, the connection between the two most important constants of radiation decay is established – the probability of decay λ and its activity μ at a known concentration of radioactive nuclei N_0, or, vice versa, the concentration of radon nuclei

$$No = \mu/\lambda \qquad (5).$$

From the above mentioned it follows that the currently used method for assessing the radon concentration by becquerels is incorrect and unable to provide an adequate representation of its prevalence in the natural environment and, accordingly, the danger for living organisms.

The simplest approximate way to avoid this situation during determining the radon concentration is to divide the recorded radon activity in becquerels by 4, i.e. on the number of α-particles, generated by the cascade decay of 1 radon nucleus, but this is only possible in case of energy discrimination of becquerels, associated with other types of decays – β and γ.

Another, more realistic method for estimating radon concentration may be the well-known method of accumulation of α-particles on activated carbon, of course, modified to take into account the cascade decay of radon with the generation of four (4) α-particles and dividing the result by 4.

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