Adaptation to the russian population types of radiation risk used by ICRP

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In this paper, we calculated the nominal value of the Russian population risk coefficient using an algorithm in which the ICRP calculations conducted for the "composite" population. Increasing the intensity of mortality after irradiation used the same as the ICRP. Background intensity of all-cause mortality and intensity of mortality from cancers of different localization for the Russian population took from the WHO data for 2008. In this paper цas obtained a factor of about 1.5 times greater than that calculated for a "composite" of the population in the same approximations.

Introduction.

Equation recorded verbal description of the algorithm [1] that the ICRP used to determine the values of the coefficient of the nominal risk (nominal risk coefficient) – NRC and the weighing coefficients of the tissue (tissue weighting factor) – [2], shows that for interpopulation migration NRC there are two important components of this algorithm which are specific for each population. One is the age dependence of the intensity of mortality . It defines a survivorship function:

$$Q(t_0,t) = \exp\left(-\int_{t_0}^{t}\mu(t')dt'\right) = \frac{Q(0,t)}{Q(0,t_0)} \qquad (1)$$

which is equal to the probability for any member of a cohort of individuals who survived to age t_0, to live for at least t - t_0 years;

Another component of the algorithm is the intensity of mortality from cancer of different localization in the same population – $\mu_{cl}(t)$

ICRP determines the value of the NRC for the "composite" population, made up of the Euro-American and Asian populations. This article shows that the Russian population on both components is significantly different and estimates how this may affect the NRC value.

Features of the intensity of mortality in the Russian population, the total for all reasons

It is convenient to analyze the differences of the dependencies in different populations and their time changes if we approximate them by the Gompertz law (GL) [3]:

$$\mu(t) = \mu_0 e^{\gamma_0 t} = \mu(t_0)e^{\gamma_0 (t - t_0)} \qquad (2)$$

or, more precisely, the Makheym law:

$$\mu(t) = \mu_{00} + \mu_0 e^{\gamma_0 t} \qquad (3)$$

Two types of intensity of mortality are used in demography and epidemiology: the so-called longitudinal and transverse distribution of intensity of mortality by age, which is characterized by, respectively, the actual generation of individuals born in the same year, and the so-called conditional generation of individuals living in the same calendar period. If longitudinal of different generations coincides for many years, so transverse $\mu(t)$ also coincides cross during this period, moreover, they are identical longitudinal.

Transverse $\mu(t)$ is usually determined at the census and calculate a certain way in between them.

Longitudinal $\mu(t)$ follow directly from observations of the cohort, such as for LSS-Japanese cohort affected from the nuclear explosions in 1945. Such observations are rare and therefore the longitudinal $\mu(t)$ is obtained from the transverse received for a sufficiently long period (ten years).

Dependence on the $\mu(t)$ that the ICRP used in the calculations of the NRC (actually transverse) are given in [2] for both women and men constitute of the "composite" population in Tables A.4.12, A.4.13, A.4.16, A.4.17. The parameters for this population are given in Table 1. There are parameters for Russian and Japanese populations according to the WHO for 2008. [4]

Background intensity of mortality from all causes for men and women of these three populations and derived survival functions are shown in Fig. 1.2. As we can see, these two fundamental characteristics of the state of health for all populations are different. The worst of the characteristics observed for both genders of the Russian population, and there are more differences for men than for women. We also see that the formula (1) and (3) very well describe the observed survivorship function. Therefore, in the calculation of risks and other variables, the results of which are shown below, these approximations were used instead of incomplete evidence on the survival.

In the context of this article, it is important how the observed differences between the Russian population affect the value of the NRC.

Table 1

The values of the parameters of the formula (3) for the compared of the populations and life expectancy at birth (LE)

Population	ICRP		Japan, 2008 г.		Russia, 2008 г.	
	Men	Women	Men	Women	Men	Women
μ_{00}, year^{-1}	5,1 10^{-4}	2,7 10^{-4}	2,7 10^{-4}	3,8 10^{-4}	1,0 10^{-4}	8,3 10^{-4}
μ_0, year^{-1}	2,84 10^{-5}	1,5 10^{-5}	2,09 10^{-5}	2,62 10^{-6}	7,14 10^{-4}	3,01 10^{-5}
γ_0, year^{-1}	0,098	0,100	0,098	0,115	0,0641	0,098
LE (years)	75,7	81,3	79,5	86,2	61,8	74,2

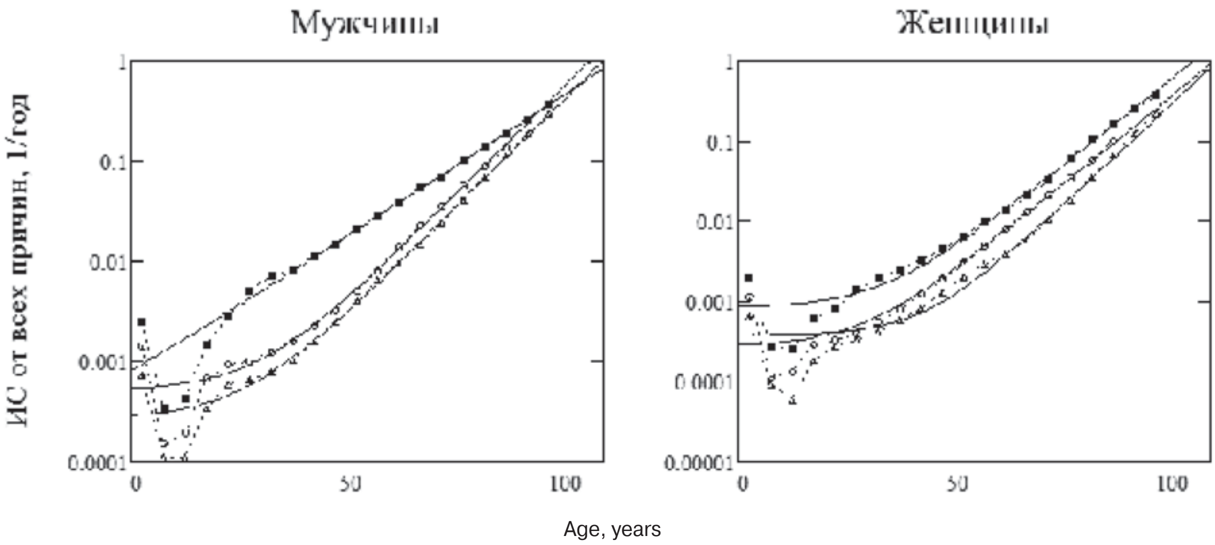

Fig. 1. Background intensity of mortality from all causes for the Euro-American population, ICRP [2] (circles), Japan (triangles) and the population of Russia (squares) from the database of the WHO [4] for 2008
Line – calculation by formulas (1) and (3) at the parameter values given in table 1.

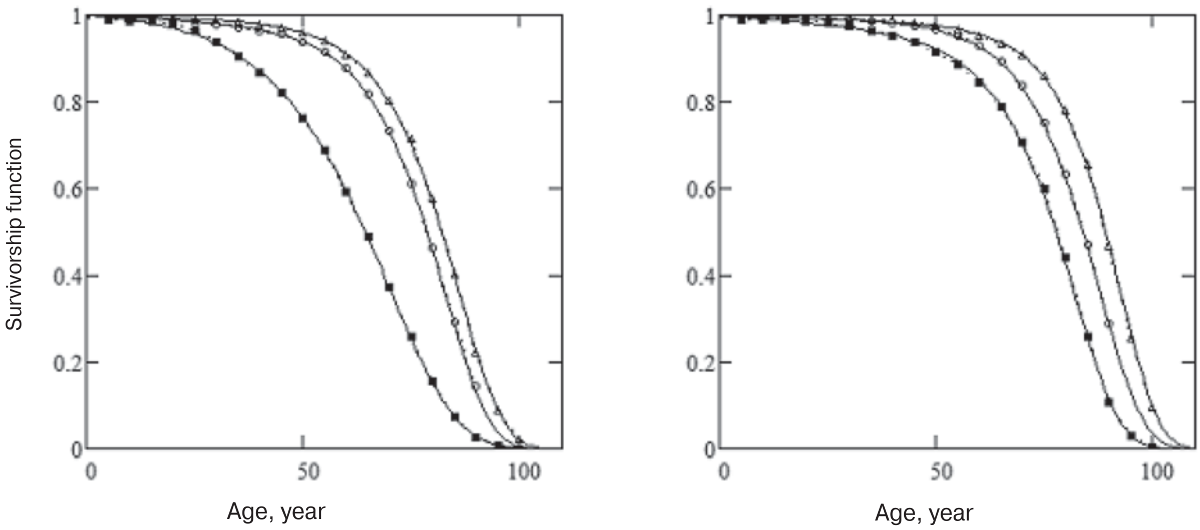

Fig. 2. Survival functions calculated from the intensity of mortality shown in Figure 1. The notations are the same

Estimates of the nominal risk coefficient

The main part of the definition of verbal description of the algorithm, which ICRP used to determine the values of NRC (mentioned in the introduction), is given [1]:

$$K_R(t_{\min},t_{\max}) = \int_{t_{\min}}^{t_{\max}} Q(t_{\min},t_0)\int_{t_0}^{\infty}\Delta\mu_r\left(t_0,t\right)\cdot$$

$$\cdot Q(t_0,t)dtdt_0 \,/\, E\left(t_0\right)\cdot\int_{t_{\min}}^{t_{\max}} Q(t_0,t)dt_0 \qquad (4)$$

Where $E(t_0)$ – instant dose at the age;

$\Delta\mu(t_0, t)$ - angle – additional intensity of mortality due to exposure at the age of , depending on the attained age , which is considered to be equal to the intensity of mortality of radiogenic cancer, i.e.:

$$\Delta\mu_r\left(t_0,t\right) \approx \Delta\mu_{r.}\left(t_0,t\right)$$

ICRP integration intervals equal to: for workers – t_{min} = 18 and t_{max} = 65, and for the entire population – t_{min} = 0 years and t_{max} = 90 years.

As a basis of the relationship $\Delta\mu(t_0, t)$ ICRP took data for the previously mentioned LSS-cohort divided by :

$$\Delta\mu_r\left(t_0,t\right) = \frac{E\left(t_0\right)\cdot\psi\left(t_0,t\right)}{DDREF} \qquad (5)$$

Further, for numerical estimates of the value of the NRC in [1] we used the function , constructed according to table A. 4.9 [2]:

$$\psi(t_0,t) = 1,32\cdot 10^{-9}\cdot\exp\left(-0,0274\cdot t_0\right)\cdot$$

$$\cdot\, t^{3,63}\quad (t > t_0) \qquad (6)$$

In these formulas, the coefficients correspond to the case when the age is expressed in years, and the dose in Sv. We did not consider the few percent difference between the pre-exponential factor for men and women. As a result, we obtained the "composite" ICRP population NRC value equal to 0.0366 for men and 0.0423 for women. The average value of 0.415 significantly less than 0.0503 for mortality from solid cancers in Table A.4.2 in [2]. This was expected, since in [1] the goal was to find only the relative dependence of the radiation risk from exposure age. Therefore, we do not fully reproduce the procedures applied by the ICRP, which includes, in particular, a combination of additive and multiplicative models, while (6) is an additive model.

Because the major difference of survivorship function of the Russian population from "composite" is observed for men, as the upper estimate in a similar way, we estimate the value of the NRC for men only. It was equal to 0,029.

Such a small value of the NRC for the Russian population in comparison with the "composite" ICRP population and, especially, the Japanese population is due to the fact that the major impact on mortality and thus on lower life expectancy is the the mortality from radiogenic cancer, which, according to (6) increases significantly with age. An average lifespan for the Russian population does not allow this to be realized.

Therefore, the rate of the radiation damage as a proportion of deaths from radiogenic cancer adopted by the ICRP is such that it is less important in cases where the major mortality is caused by the other causes. It is higher in Russia, than in Europe and Japan. When this indicator is applied, we achieve a paradox: exposure for the Russian population is less harmful than for the European population. However, this is the problem of choosing the index and in this paper it is not considered.

Features of the intensity of cancer mortality in the Russian population

As for the features of the other component of interpopulation migration – background intensity of cancer mortality, they can be seen in Figure 3-9, where on the basis of WHO data in 2008 the ratio of the background intensity of mortality of the Russian population to the intensity of mortality of the "composite" population is shown, related to its component in [2] (table A.4.12, -13, -16, -17)

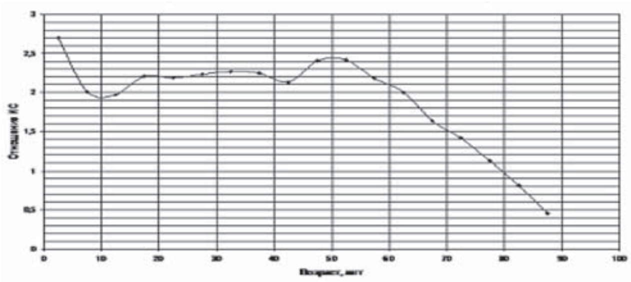

Figure 3. The ratio intensity of cancer mortality from all causes in men Russian population to the intensity mortality in Euro-American population.

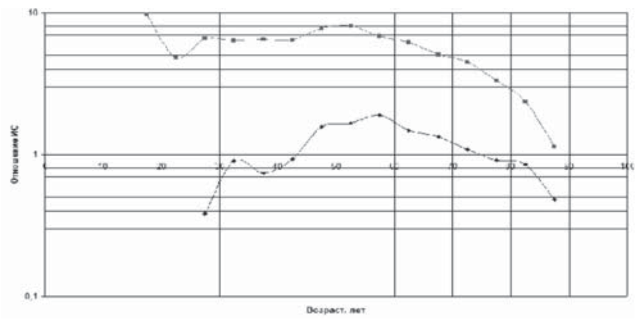

Figure 4. Same for esophageal cancer (diamonds) and stomach (squares).

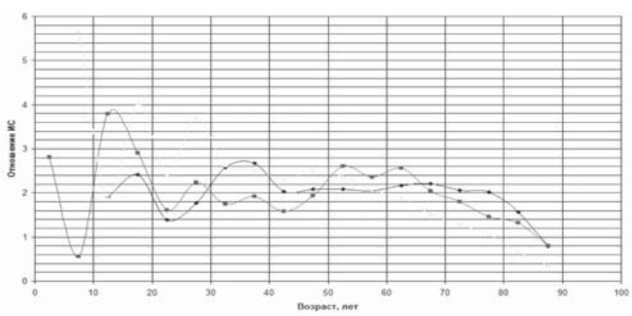

Figure 5. Same for colon cancer (diamonds), liver (squares) and lungs (diamonds).

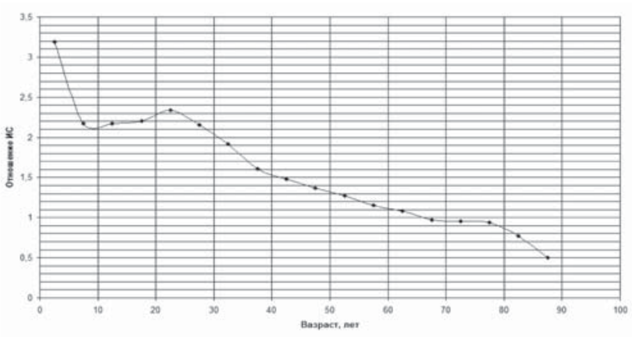

Fig.6. The same for all causes, women.

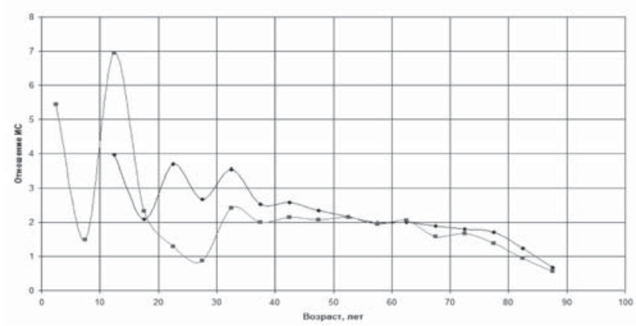

Figure 8. The same for colon cancer (diamonds) and liver (squares), women

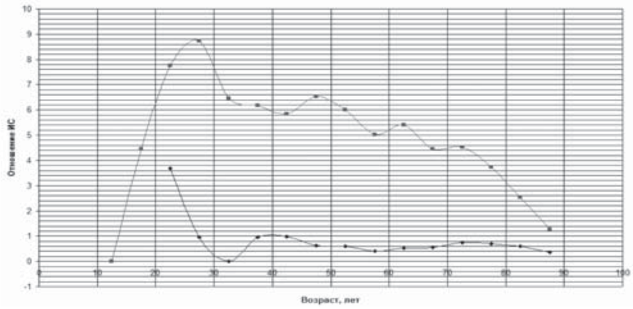

Fig.7. The same for cancer of the esophagus (diamonds) and stomach (squares), women.

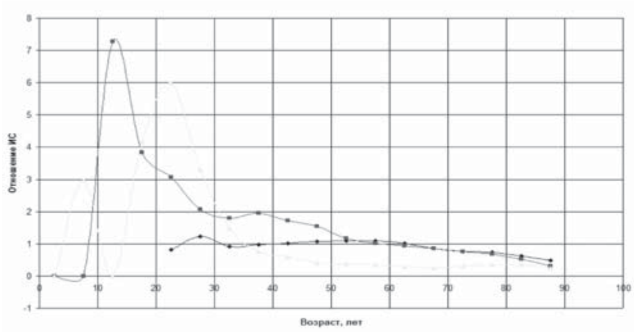

Figure 9. The same for breast cancer (diamonds), ovary (squares) and lung (diamonds), women.

As can be seen from the figures, the overall intensity of cancer mortality of the Russian population for the age groups that are relevant to the assessment of the NRC is higher than that of the European 2 times in men and 1-2 times in women. Therefore it is not clear how this excess balances the effect of increasing the NRC due to reduced life expectancy. Assessing the impact of the background intensity of cancer of different localization, mortality was obtained only for men, because women have less differencesso we can expect the same result as in men.

Evaluation of NRC for the Russian population, taking into account differences in intensity of cancer of various localization mortality.

To account for differences in background intensity of cancer mortality ICRP allows to apply the following formula (so-called interpopulation transport) [1]:

$$\Delta\mu_{rcl}^{(2)}(t_0,t,D) = \Delta\mu_{rcl}^{(1)}(t_0,t,D)\left[p_l + (1-p_l)\frac{\mu_{cl}^{(2)}(t)}{\mu_{cl}^{(1)}(t)}\right] \quad 3$$

Where:

p_1 – the weighting factor for the transfer to the so-called additive model;

$(1 - p_1)$ – A multiplier for the transfer to a multiplicative model;

l – The number of cancer localization;

(1) – the index of the results of observation of the irradiated population;

(2) – index estimates for the population protected from exposure.

Strictly scientific basis for the formula (3) does not exist. It's like values adopted by ICRP expert. Their values in accordance with paragraph. A.140 in [2] are given in Table 1.

The same table shows the approximate average values of $\mu_{cl}^{(2)}(t)/\mu_{cl}^{(1)}(t)$, taken by us on the basis of the figures given above, the relative damage according to Table A.4.18 in [2], as well as the intermediate results of calculations.

As a result of the approximate estimates $\Delta\mu_{rcl}(t_0,t,D)$ for the Russian population turned out to be an average of 1,856 times higher than for the ICRP population. A corresponding increase in the value of NRC, obtained earlier and equal 0.029, gives the value of 0.0538. This is more than the value of NRC for men of the ICRP population in 1.47 times.

Table 2

Recalculation of radiogenic intensity of mortality from «composite» population to the Russian

№ (l)	Localization	p_1 [2]	$(1 - p_1)$ [2]	$\frac{\mu_{cl}^{(2)}(t)}{\mu_{cl}^{(1)}(t)}$	$(1-p_l)\times \frac{\mu_{cl}^{(2)}(t)}{\mu_{cl}^{(1)}(t)}$	$p_l+(1-p_l)\times \frac{\mu_{cl}^{(2)}(t)}{\mu_{cl}^{(1)}(t)}$	Относительный вклад рака *l*-й локализации, [2]	Относительный вред от рака *l*-й локализации
1	Esophagus	0,5	0,5	1,25	0,625	1,125	0,026	0,30
2	Stomach	0,5	0,5	5,0	2,5	3,0	0,12	0,36
3	Colon	0,5	0,5	2,0	1,0	1,5	0,138	0,21
4	Liver	0,5	0,5	2,0	1,0	1,5	0,075	0,113
5	Lung	0,7	0,3	2,0	0,6	1,3	0,124	0,16
6	Bone	0,5	0,5	2,0	1,0	1,5	0,011	0,0163
7	Skin	0,0	1,0	2,0	2,0	2,0	0,008	0,016
8	Breast	1,0	0,0					
9	Ovary	0,5	0,5					
10	Bladder	0,5	0,5	2,0	1,5	1,5	0,036	0,054
11	Thyroidgland	0,0	1,0	2,0	2,0	2,0	0,010	0,02
12	Bonemarrow	1,0	0,0	2,0	0,0	1,0	0,144	0,144
13	Other solid cancers	0,5	0,5	2,0	1,0	1,5	0,256	0,384
14	Gonads	0,5	0,5	2,0	1,0	1,5	0,053	0,0795
	Total							**1,856**

Conclusions

An approximate evaluation of the impact of differences in the intensity of mortality of the Russian population for all causes and from cancers at various sites, from those populations for which ICRP calculated the ratio of nominal risk showed that due to the higher mortality rate of the Russian population for all causes this ratio should be less than 1.26 times, and due to the higher intensity of cancers mortality – more than 1.86 times. Thus, the difference of the cumulative effect makes it advisable to increase the NRC for the Russian population of approximately 1.5 times.

Obviously, for real recommendations similar calculations should be made more detailed, taking into account age-based differences in background intensity of cancer mortality.

List of references

1. Gubin A.T., Sakovich V. A., Methodological problems of practical assessments of radiogenic risk. Radiation hygiene, T. 7, No. 1, 2014
2. Publication 103 of the International Commission on radiological protection (ICRP). Trans. from English./ Under the general editorship of M.F. Kiselev and N. T. Shandala. M. Pub. OOO PKF "Alan", 2009. – 312 p.