CHARACTERISTICS OF KIPT STAFF BY GROUPS OF RADIATION RISK

A.N. Dovbnya, A.V. Mazilov, I.A. Stadnik
National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine
E-mail: mazilov@kipt.kharkov.ua

The methodology of individual radiation cancer risk assessment UNSCEAR-94 has been described. Characteristics of KIPT staff at the individual monitoring, in terms of the "Dose-response matrix" have been reviewed. The main results of the calculations of the relative, attributive and absolute radiation risks of KIPT personnel for different sites and different risk groups have been showed. The distributions of the main characteristics of the personnel: age, years on the individual monitoring and the cumulative dose for different radiation risk groups of staff have been investigated.

PACS: 87.53.-j; 87.66.Jj

INTRODUCTION

In the international standards the radiation risk is considering, in the first place, as the increase of the probability of cancer diseases, i.e. carcinogenic risk. For doses of homogeneous whole body exposure above the threshold of 200 mSv established the dose-response relationship. Such a relationship is called "deterministic effect" of radiation impact or "tissue reactions". The severity of deterministic effect is directly proportional to the dose received.

For low doses (less than 200 mSv) unique relationship between exposure and cancer rate was not found. However, there is a probability that the transition of cells of a person after low-dose exposure after some latency period may cause cancer effect if irradiated cells are somatic or genetic mutations result if fetal cells. It is assumed that the probability of the appearance of a stochastic effect is proportional to the dose received, and the threshold value does not exist [1].

Methodology for assessing radiation risk is defined at reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the safety standards of the International Atomic Energy Agency (IAEA) and the recommendations of the International Commission on Radiological Protection (ICRP), and implemented in UNSCEAR-94 model [2-4]. This model estimates individual radiation risks of solid cancers and leukaemia based on individual characteristics of the exposed person: sex, age at exposure, attained age, and the dynamics of exposure.

The main purpose of the assessment of individual radiation risks is to implement the concept of socially acceptable risk. As consistent with international practice and current Radiation Safety Regulations of Ukraine (RSRU-97), an acceptable individual absolute radiation risk of personnel from occupational exposure in the normal mode of operation must not exceed the value of 10^{-3} per year [5].

An important characteristic of the individual occupational risk is the etiologic fraction or attributive risk, i.e. probability of that occupational radiation exposure is a cause of cancer, expressed as a percentage of the total cancer risk. In a number of cases the carcinogenic diseases is relevant to a professional when the etiological fraction is 20…40% [6].

The results of calculations of the relative, absolute and attributive individual radiation risks for 2013 for KIPT personnel. On the basis of the values of absolute individual radiation risks of personnel the groups of the negligible small, acceptable and increased radiation risks have been formed. On the basis of the values of attributive of individual radiation risk the groups of the negligible small, potential and high potential radiation risks have been formed.

1. THE UNSCEAR-94 METHODOLOGY FOR ESTIMATING RADIOGENIC CANCER RISK

UNSCEAR-94 model has been developed by the United Nations Scientific Committee on the Effects of Atomic Radiation for individual radiation risk assessment, according to research conducted among the irradiated population by bombing of Japanese cities (Cohort Life Span Study – LSS).

In this model, the following terms are used:

EAR – the excess absolute risk, the probability of cancer disease due to exposure;

ERR – the excess relative risk, the increase of cancer diseases probability relative to the background causation for given localization, age and sex of person, associated with exposure;

AR – the attributive risk, the exposure factor contribution to the total probability of person‘s cancer diseases (which consists of the baseline cancer rate and *EAR*) among the exposed. In the case of the exposed cohort studies or population attributive risk shows the proportion of all cases of disease in a cohort due to radiation exposure.

According to the UNSCEAR-94 model, if m_0 is the baseline cancer rate for people at some age and sex in the absence of exposure to radiation, and m is the number of cancer cases observed in the group of exposed persons at the same sex and age, the observed number of cancer diseases among the exposed persons may be expressed in the additive form:

$$m = m_0 + EAR, \qquad (1)$$

where *EAR* is the difference between the instantaneous incidence cancer rate, when there has been exposure, m, and what the instantaneous incident rate would have been without exposure, m_0, the "baseline" cancer rate function. For the one person, the *EAR* is the probability of cancer occurrence as a result of exposure to radiation. The relationship between m and m_0 can be expressed through the excess relative risk, *ERR*, or in the multiplicative form:

$$m = m_0 (1 + ERR). \qquad (2)$$

From (1) and (2) it follows that:

$$EAR = m - m_0, \qquad (3)$$

$$ERR = (m - m_0)/m_0. \qquad (4)$$

From (3) and (4) it follows the relationship between the quantities characterizing the excess of the baseline rate of cancer incidence:

$$EAR = m_0 \cdot ERR. \qquad (5)$$

By definition, the attributive risk is the fraction of the probability of radiation-induced cancer risk in the baseline probability of cancer disease for the person at the given age and sex:

$$AR = EAR/m. \qquad (6)$$

From (3), (5) and (6) the attributive risk can be expressed through relative as follows:

$$AR = ERR/(1 + ERR). \qquad (7)$$

According to the UNSCEAR-94 for solid cancers the following generalized *ERR* model are using, in which radiation-induced relative cancer risk for age at exposure *g*, sex *s*, cancer site *l* and dose D_g is given by:

$$ERR_{sol}(s,l,g) = a_{s,l} \times D_g \times \exp(b_l \times (g - 25)), \quad (8)$$

where *a* and *b* are parameters, depending on a sex and cancer site, that are given in Table 1.

Table 1

Parameters of UNSCEAR-94's ERR model for the solid cancers

Cancer site	ICD-10	Parameter *a*, Gr^{-1}		Parameter *b*, year^{-1}
		male	female	
Respiratory	C33, C34	0.37	1.06	0.021
Stomach	C16	0.16	0.62	–0.035
Bladder	C67	1.00	1.19	0.012
Liver	C22	0.97	0.32	–0.027
Oesophagus	C15	0.23	1.59	0.015
Colon	C18	0.54	1.00	–0.033
Breast	C50	–	1.95	–0.079
Other solid cancers	–	0.59	0.39	–0.059
All solid cancers	C00–C80	0.45	0.77	–0.026

The statistical analysis of observation data of LSS cohort shows that the increasing of solid cancer diseases occurs only after approximately 5-15 years after exposure. It is the latent period of late effect of radiation for solid cancers.

According to [7], for the prolonged exposure the excess relative radiation risk for solid cancer diseases at age *u* will be:

$$ERR_{SOL}(u) = a_{s,l} \times \sum_{g=g_0}^{g=u-10} D_g \times \exp(b_l \times (g - 25)), \quad (9)$$

where *u*-10 means average latent period for solid tumors.

Knowing $ERR_{\mathrm{SOL}}(u)$ and baseline cancer incidence rate of localization *l* at age *u* for sex *s* – $m_0(s,l,u)$, it is possible to calculate $AR_{SOL}(u)$, $EAR_{SOL}(u)$ and probability of solid cancer disease taking into account the factor of radiation exposure – $m_{SOL}(s,l,u)$:

$$AR_{SOL}(u) = \frac{ERR_{SOL}(u)}{1 + ERR_{SOL}(u)} \times 100\%, \qquad (10)$$

$$EAR_{SOL}(u) = m_{0SOL}(s,l,u) \cdot ERR_{SOL}(u), \qquad (11)$$

$$m_{SOL}(s,l,u) = m_{0SOL}(s,l,u) + EAR_{SOL}(u). \qquad (12)$$

For the calculation of excess absolute risk of the radiation-induced leukaemia EAR_{LEU} at age *u* after exposure to radiation at age *g* the UNSCEAR-94 model offers the following expression:

$$EAR_{LEU}(s,g,u) = a_{s,g} \times D_g \times (1 + 0.79 \cdot D_g) \times \exp(-b_{s,g} \times (u - g - 25)), \quad (13)$$

where *a* and *b* are parameters, depending on a sex and age at exposure, which are given in Table 2.

Table 2

Parameters of UNSCEAR-94's EAR model for the leukaemia (on 10^5 people in the year)

Age at exposure	Parameter *a*, Gr^{-1}		Parameter *b*, year^{-1}	
	male	female	male	female
0…19	3.3	6.6	0.17	0.07
20…39	4.8	9.7	0.13	0.03
40…	13.1	26.4	0.07	0.03

According to [7], for the prolonged exposure the excess absolute radiation risk for leukaemia diseases at age *u* will be:

$$EAR_{LEU}(u) = \sum_{g=g_0}^{g=u-2} a_{s,g} \times D_g \times \left(1 + 1.58 \cdot \sum_{g=g_0}^{g} D_g\right) \times \exp(-b_{s,g} \times (u - g - 25)), \quad (14)$$

where $\sum_{g=g_0}^{g} D_g$ is the cumulative dose at age *g*; *u* – 2 means average latent period for leukaemia. Knowing the value of absolute risk of leukaemia EAR_{LEU} and baseline leukaemia incidence rate at age *u* for sex *s* – $m_{0\mathrm{LEU}}(s,u)$,), it is possible to calculate attributive AR_{LEU} and relative ERR_{LEU} excess risks of leukaemia, and also probability of disease leukaemia at age *u*, taking into account the fact of exposure – $m_{\mathrm{LEU}}(s,u)$:

$$AR_{LEU}(u) = \frac{EAR_{LEU}(u)}{m_{0LEU}(s,u) + EAR_{LEU}(u)} \times 100\%, \quad (15)$$

$$ERR_{LEU}(u) = \frac{EAR_{LEU}(u)}{m_{0LEU}(s,u)}, \qquad (16)$$

$$m_{LEU}(s,u) = m_{0LEU}(s,u) + EAR_{LEU}(u). \qquad (17)$$

2. RADIATION RISK GROUPS

According to data of International organization of labour, on 1 million workers there are about 100…1000 cases of injuries with a fatal termination annually. Therefore by the International commission on radiological protection it was set a level of socially acceptable risk, equal $10^{-4}…10^{-3}$ in a year. An occupational risk, exceeding a threshold value of 10^{-3} is considered as a high risk, and a risk, not excelling a threshold value of 10^{-4} is considered as a negligibly small risk.

Under National radiation safety standards of Ukraine (NRBU-97) the amount of the total absolute radiation risk EAR_{ALL} for the regular mode of operations of personnel must not exceed the value of 10^{-3} in a year [5]. Via the amount of absolute radiation risk EAR_{ALL}, a personnel, working with the sources of ionizing radiation, can be associated with the one of next absolute radiation risk groups:

– negligibly small risk: $EAR_{\mathrm{ALL}} < 10^{-4}$;

– socially acceptable risk: $10^{-4} \le EAR_{\mathrm{ALL}} \le 10^{-3}$;

– high risk: $EAR_{\mathrm{ALL}} > 10^{-3}$.

An attributive radiation risk is an important index for establishing a connection between workers's cancer disease and occupational radiation exposure. In some European countries there are some schemes to compensate those workers (or their relatives) in whom cancer may have arisen from the exposure to radiation at work, based on the attributive risk value [6, 8].

Depending of the attributive risk values for solid cancers AR_{SOL}, attributive risk of leukaemia AR_{LEU} and attributive risk of respiratory system AR_{RESP}, the personnel, exposed to radiation, can be associated with the one of next attributive radiation risk groups:

– negligibly small risk: AR_{SOL}<10%, AR_{LEU}<50%, AR_{RESP}<20%;

– potential risk: AR_{SOL}≥10%, or AR_{LEU}≥50%, or AR_{RESP}≥20%;

– high potential risk: AR_{SOL}≥20%, or AR_{LEU}≥75%, or AR_{RESP}≥30%.

3. DESCRIPTION OF KIPT PERSONNEL

Presently there are 331 employees of NSC KIPT on individual dosimetric control: 282 men aged 20 to 87 years, with experience of work with the sources of ionizing radiation from 0 to 55 years, and 49 women aged 25 to 80 years, with experience of work with radiation sources from 0 to 50 years. The average cumulative dose for men is 61.44 mSv for men and 49.40 mSv for women (see Table 1).

The distribution by age, experience with exposure to radiation and cumulative dose of KIPT personnel is presented on Figs. 1-3. As obvious from these figures, almost the half of personnel at individual monitoring are more then 60 years old and have experience of work with the sources of ionizing radiation more than 20 years. Nevertheless, only 41% of personnel has the cumulative dose more than 50 mSv, and from them only 16% – the cumulative dose more than 150 mSv.

On Fig. 4 the dynamics of change of average annual dose is represented from the years of work with ionizing radiation sources for the employees, being at individual monitoring in 2013. From this picture evidently, that the average annual dose of these employees for the last 19 years did not exceed the value of 2 mSv, that comparably with the mean value of natural radiation background of Earth – 2.42 mSv/year.

Table 3

The main characteristics of the personnel at individual monitoring

Personnel	Quantity		Age, years			Duration of occupational exposure, years			Cumulative dose, mSv		
	abs. unit	%	min	avg	max	min	avg	max	min	avg	max
Male	282	85.2	20	56	87	0	21	55	0.07	61.44	580.04
Female	49	14.8	25	56	80	0	22	50	0.04	49.40	181.33
All	331	100.0	20	56	87	0	21	55	0.04	59.66	580.04

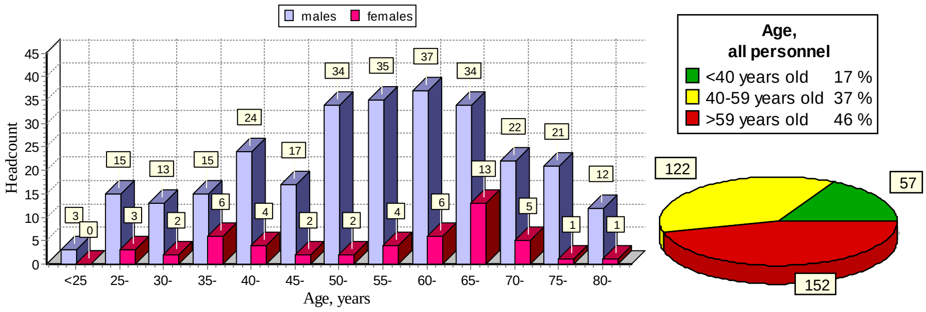

Fig. 1. Distributing of NSC KIPT personnel among age-dependent groups

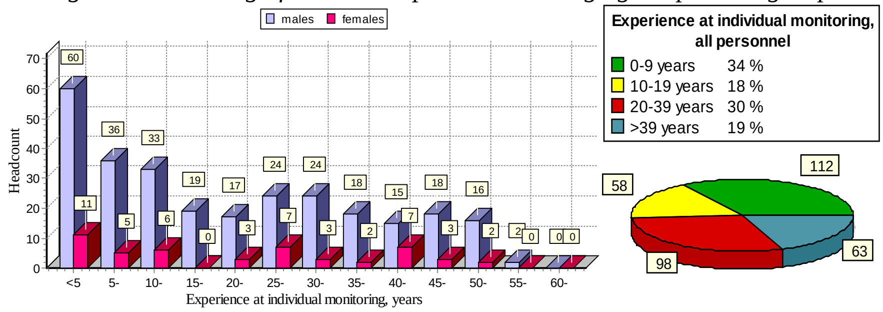

Fig. 2. Distributing of NSC KIPT personnel from experience with sources of ionizing radiation

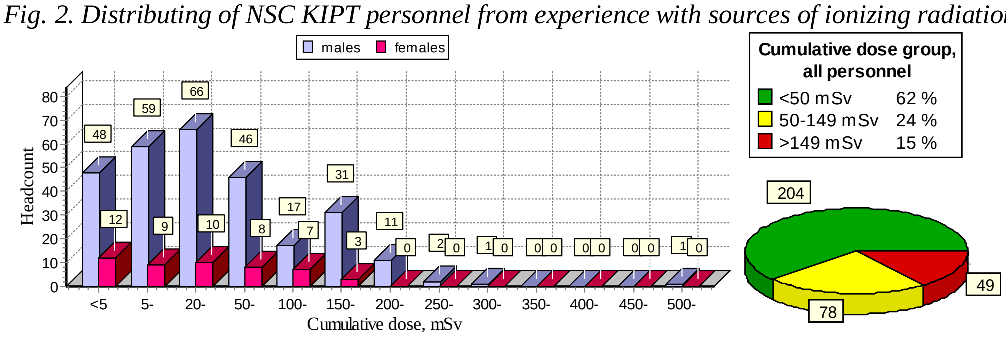

Fig. 3. Distributing of NSC KIPT personnel from cumulative dose

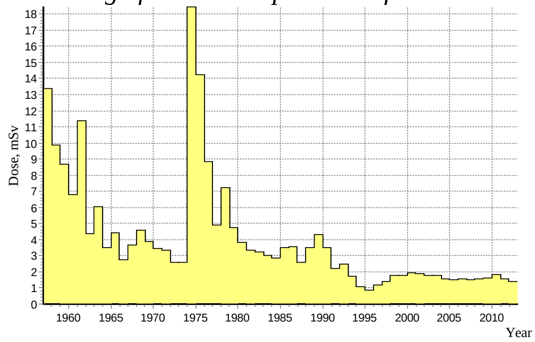

Fig. 4. Dynamics of average annual dose from the years of workfor employees, being at individual monitoring in 2013

4. CHARACTERISTICS OF KIPT PERSONNEL BY THE GROUPS OF RADIATION RISK

The results of radiation risks calculations on 2013 for NNC KIPT personnel are showed in Table 4. The risks were estimated for 305 persons who have experience at individual monitoring at least two years.

The baseline cancer rate data for solid tumors and leukaemia were taken from Bulletin of National cancer registry of Ukraine № 14 for 2011-2012 [9].

Table 4

Excess radiation risks of personnel for different cancer sites

Cancer site	ERR, %			AR, %			$EAR \cdot 10^{-3}$			SIR		
	min	avg	max	min	avg	max	min	avg	max	min	avg	max
All tumours	0.00	1.97	18.41	0.00	1.89	15.55	0.000	0.260	3.240	1.00	1.02	1.18
All solid tumours	0.00	1.81	18.45	0.00	1.72	15.58	0.000	0.250	3.200	1.00	1.02	1.18
Leukaemia	0.00	5.80	26.97	0.00	5.23	21.24	0.000	0.009	0.046	1.00	1.06	1.27
Bladder	0.00	6.38	67.18	0.00	5.48	40.19	0.000	0.070	1.000	1.00	1.06	1.67
Oesophagus	0.00	2.62	34.15	0.00	2.37	25.45	0.000	0.000	0.040	1.00	1.03	1.34
Respiratory system	0.00	3.30	28.46	0.00	3.02	22.15	0.000	0.080	0.740	1.00	1.03	1.28
Liver	0.00	3.25	39.33	0.00	2.97	28.23	0.000	0.010	0.090	1.00	1.03	1.39
Female breast	0.00	1.40	17.58	0.00	1.27	14.95	0.000	0.030	0.370	1.00	1.01	1.18
Colon	0.00	2.04	20.48	0.00	1.93	17.00	0.000	0.020	0.310	1.00	1.02	1.20
Stomach	0.00	0.72	6.95	0.00	0.71	6.50	0.000	0.010	0.090	1.00	1.01	1.07
Other solid cancers	0.00	1.48	17.28	0.00	1.42	14.74	0.000	0.110	1.680	1.00	1.01	1.17

In the Table 4 the values of the standardized incident ratio (*SIR*) are also presented, its shown the ratio of the cancer rate in exposure to radiation group of people *m* to the expected baseline cancer rate m_0.

According to the values of total absolute radiation risk EAR_{ALL} were formed groups of negligibly small, socially acceptable and high radiation risk.

19 persons (6.2% of personnel which risks were assessing for) entered in the group of high radiation risk. In the group of socially acceptable radiation risk entered 116 human – 38.0% of personnel. In a group negligibly small risk 170 human entered – 55.8% of personnel.

The values of basic characteristics and risks of personnel by the groups of absolute radiation risk are presented in the Table 5. In the Accumulated dose column the values of the accumulated doses of personnel, that are using in risks on 2013 calculation, i.e. got by personnel up to 2011, are given.

Tables 6-8 shows the distributions of the relative number of employees by the groups of absolute radiation risk in the age groups, experience at individual monitoring groups and cumulative dose groups. As we see from the tables, the absolute radiation risk has the most marked linear dependence from cumulative dose. All personnel having cumulative dose of 300 mSv or more, belongs to the high absolute radiation risk group. All personnel having cumulative dose less then 100 mSv, belongs to the negligible small and socially acceptable radiation risk groups. Data from Tables 6 - 8 are shown in Fig. 5.

Table 5

The values of the basic characteristics and risks of the personnel in the absolute radiation risk groups

Value	Age, years	Experience on individual monitoring, years	Cumulative dose, mSv	AR_{SOL}, %	AR_{LEU}, %	EAR_{ALL}, $*10^{-3}$
High absolute radiation risk group, 19 people (6.2 % of personnel)						
Min	71	45	174.35	4.82	3.42	1.0077
Avg	75	50	226.23	6.35	6.60	1.2380
Max	86	55	578.28	15.58	13.77	3.2442
Socially acceptable absolute radiation risk group, 116 people (38.0 % of personnel)						
Min	50	11	34.42	0.54	0.26	0.1038
Avg	67	36	104.31	3.14	4.89	0.4608
Max	87	54	262.67	7.83	20.01	0.9998
Negligibly small absolute radiation risk group, 170 people (55.8 % of personnel)						
Min	25	2	0.19	0.00	0.00	0.0000

Avg	47	10	15.89	0.24	5.31	0.0168
Max	78	30	64.34	1.99	21.24	0.0984

Fig. 5 shows that all staff at the age under 50 years with experience at individual monitoring under 10 years (men) and 20 years (women) belongs to the group of negligible small absolute radiation risk, this suggest that personnel working with sources of ionizing radiation in KIPT have enough high level of radiation protection.

Detailed characteristic of the personnel of the high radiation risk group (HRRG) on 2013 year: the distribution by age, experience at individual monitoring and cumulative dose is shown in the Tables 9-11.

Table 6

Distribution of personnel by absolute radiation risk groups according to sex and age

Age, years	Relative number of personnel of the given age group in the absolute radiation risk group:								
	negligibly small			socially acceptable			high		
	men	women	all	men	women	all	men	women	all
<25	0.0	-	0.0	0.0	-	0.0	0.0	-	0.0
25-29	66.7	33.3	61.1	0.0	0.0	0.0	0.0	0.0	0.0
30-34	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
35-39	86.7	83.3	85.7	0.0	0.0	0.0	0.0	0.0	0.0
40-44	91.7	100.0	92.9	0.0	0.0	0.0	0.0	0.0	0.0
45-49	88.2	100.0	89.5	0.0	0.0	0.0	0.0	0.0	0.0
50-54	94.1	0.0	88.9	5.9	50.0	8.3	0.0	0.0	0.0
55-59	71.4	50.0	69.2	25.7	0.0	23.1	0.0	0.0	0.0
60-64	45.9	16.7	41.9	51.4	83.3	55.8	0.0	0.0	0.0
65-69	0.0	7.7	2.1	88.2	92.3	89.4	0.0	0.0	0.0
70-74	13.6	0.0	11.1	59.1	80.0	63.0	27.3	20.0	25.9
75-79	9.5	0.0	9.1	52.4	0.0	50.0	38.1	100.0	40.9
80-	0.0	0.0	0.0	75.0	100.0	76.9	25.0	0.0	23.1

Table 7

Distribution of personnel by absolute radiation risk groups according to sex and experience at individual monitoring

Experience on individual monitoring, years	Relative number of personnel of the given experience at individual monitoring group in the absolute radiation risk group:								
	negligibly small			socially acceptable			high		
	men	women	all	men	women	all	men	women	all
<5	66.7	45.5	63.4	0.0	0.0	0.0	0.0	0.0	0.0
5-9	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
10-14	97.0	100.0	97.4	3.0	0.0	2.6	0.0	0.0	0.0
15-19	100.0	-	100.0	0.0	-	0.0	0.0	-	0.0
20-24	82.4	66.7	80.0	17.6	33.3	20.0	0.0	0.0	0.0
25-29	41.7	0.0	32.3	58.3	100.0	67.7	0.0	0.0	0.0
30-34	4.2	0.0	3.7	95.8	100.0	96.3	0.0	0.0	0.0
35-39	0.0	0.0	0.0	100.0	100.0	100.0	0.0	0.0	0.0
40-44	0.0	0.0	0.0	100.0	100.0	100.0	0.0	0.0	0.0
45-49	0.0	0.0	0.0	61.1	100.0	66.7	38.9	0.0	33.3
50-54	0.0	0.0	0.0	50.0	0.0	44.4	50.0	100.0	55.6
55-59	0.0	-	0.0	0.0	-	0.0	100.0	-	100.0
60-	-	-	-	-	-	-	-	-	-

Table 8

Distribution of personnel by absolute radiation risk groups according to sex and cumulative dose

Cumulative dose, mSv	Relative number of personnel of the given cumulative dose group in the absolute radiation risk group:								
	negligibly small			socially acceptable			high		
	men	women	all	men	women	all	men	women	all
<5	79.2	66.7	76.7	0.0	0.0	0.0	0.0	0.0	0.0
5-	100.0	88.9	100.0	0.0	0.0	0.0	0.0	0.0	0.0
20-	74.2	20.0	67.1	12.1	70.0	19.7	0.0	0.0	0.0
50-	10.9	0.0	9.3	84.8	100.0	87.0	0.0	0.0	0.0
100-	0.0	0.0	0.0	105.9	100.0	104.2	0.0	0.0	0.0
150-	0.0	0.0	0.0	83.9	33.3	79.4	12.9	66.7	17.6
200-	0.0	-	0.0	9.1	-	9.1	100.0	-	100.0
250-	0.0	-	0.0	50.0	-	50.0	0.0	-	0.0
300-	0.0	-	0.0	0.0	-	0.0	100.0	-	100.0
350-	-	-	-	-	-	-	-	-	-
500-	0.0	-	0.0	0.0	-	0.0	100.0	-	100.0

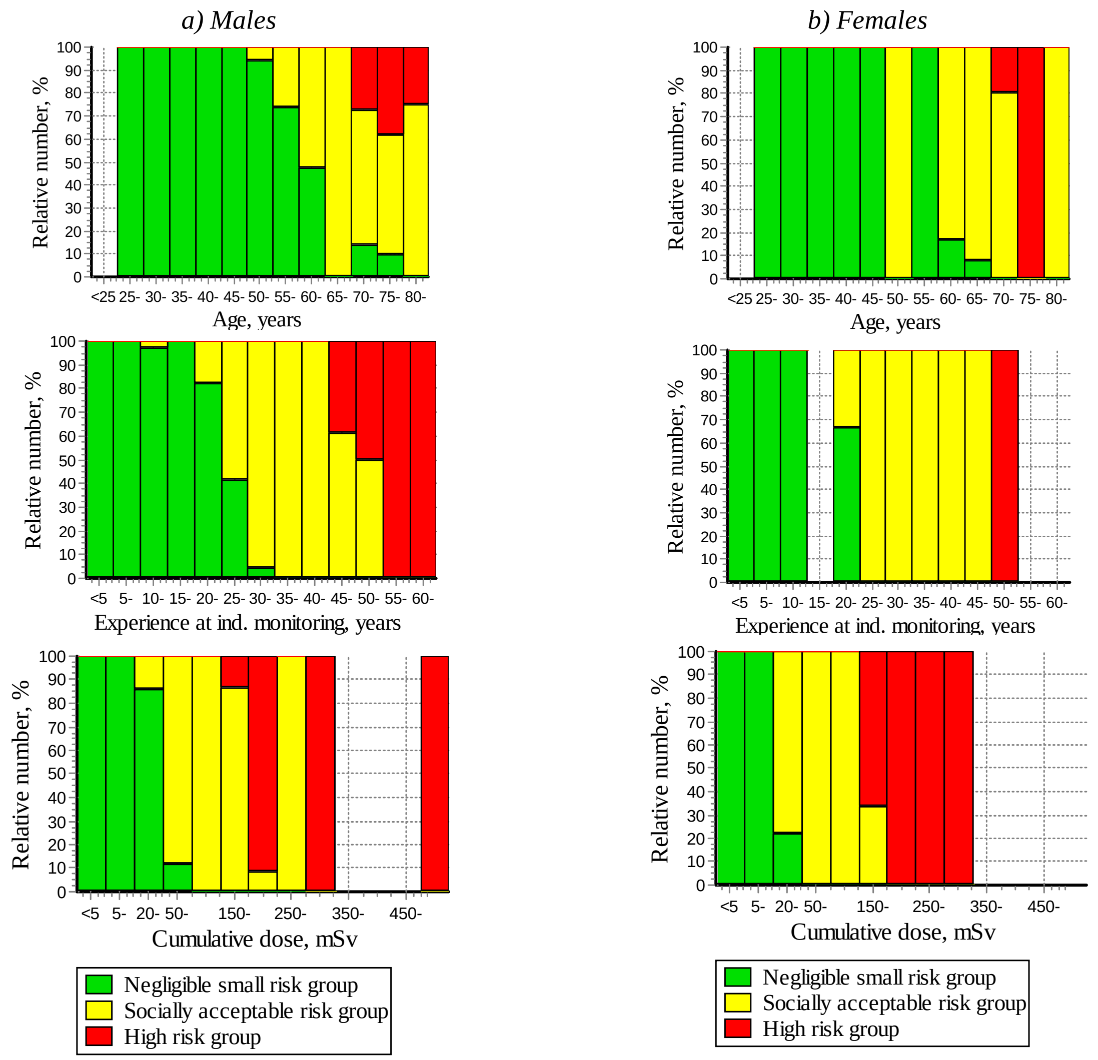

Fig. 5. Distribution of personnel by absolute radiation risk groups according to age. experience at individual monitoring and cumulative dose for males (a) and females (b)

As we can see from Table 9, 84.2% of HRRG personnel belong to the age groups of 70 to 79 years, one-third of all personnel at this age belons to the HRRG. Table 10 shows that personnel with experience at individual monitoring from 50 to 54 years is about half of the high radiation risk group, 55.6% of all personnel with such experience belons to the HRRG. Table 11 shows that almost a third of HRRG personnel have cumulative dose of 150 to 200 mSv, but only 17.6% of the personnel within this range of the cumulative dose belons to the HRRG.

Table 9

Distribution of personnel from HRRG according to sex and age

Age, years	Men			Women			All personnel		
	abs. unit	% in HRRG*	% in all group**	abs. unit	% in HRRG*	% in all group**	abs. unit	% in HRRG*	% in all group**
<70	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
70-74	6	35.3	27.3	1	50.0	20.0	7	36.8	25.9
75-79	8	47.1	38.1	1	50.0	100.0	9	47.4	40.9
80	3	17.6	25.0	0	0.0	0.0	3	15.8	23.1
Total	17	100.0	6.0	2	100.0	4.1	19	100.0	5.7

* % in HRRG – reletive number of personnel of given age and sex in the high radiation risk group.

** % in all group – reletive number of HRRG personnel among all personnel of given age and sex at individual monitoring.

Table 10

Distribution of personnel from HRRG according to sex and experience at individual monitoring

Experience at individual monitoring, years	Men			Women			All personnel		
	abs. unit	% in HRRG	% in all group	abs. unit	% in HRRG	% in all group	abs. unit	% in HRRG	% in all group
<45	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
45-49	7	41.2	38.9	0	0.0	0.0	7	36.8	33.3
50-54	8	47.1	50.0	2	100.0	100.0	10	52.6	55.6
55-59	2	11.8	100.0	0	0.0	0.0	2	10.5	100.0
60	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Total	17	100.0	6.0	2	100.0	4.1	19	100.0	5.7

Table 11

Distribution of personnel from HRRG according to sex and cumulative dose

Cumulative dose, mSv	Men			Women			All personnel		
	abs. unit	% in HRRG	% in all group	abs. unit	% in HRRG	% in all group	abs. unit	% in HRRG	% in all group
<150	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
150-	4	23.5	12.9	2	100.0	66.7	6	31.6	17.6
200-	11	64.7	100.0	0	0.0	0.0	11	57.9	100.0
250-	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
300-	1	5.9	100.0	0	0.0	0.0	1	5.3	100.0
350-	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
400-	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
450-	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
500-	1	5.9	100.0	0	0.0	0.0	1	5.3	100.0
Total	17	100.0	6.0	2	100.0	4.1	19	100.0	5.7

Distributions of KIPT personnel at th individual monitoring by attributive risk of solid cancers, leukaemia and respiratory system are shown in Fig. 6. The attributive risk indicates the probability of occupational radiation exposure causation of these cancer diseases. As can be seen from these figures the probability of radiogenic solid cancer disease doesn't exceed 5% for 90% of the personnel. The probability of leukaemia caused by occupational exposure doesn't exceed 15 for 94% of the personnel. The probability of oncological diseases of respiratory system caused by radiation, does not exceed 10 for 94% of the personnel. The maximum values of the attributable risk does not exceed the threshold for the group of high potential attributive risk, so the cancer diseases of the KIPT personnel at individual monitoring can not be considered as professional for now.

Table 12

The values of the basic characteristics and risks of the personnel in the attributive radiation risk groups

Value	Age, years	Experience with sources of ionizing radiation, years	Cumulative dose, mSv	AR_{SOL}, %	AR_{LEU}, %	AR_{RESP}, %	EAR_{ALL}, $*10^{-3}$
Group of non-neoplastic diseases (heart attacks, strokes), 1 people(0,3 % of personnel)							
-	80	55	578.28	15.58	13.77	22.15	3.2442
High potential risk group, 0 people (0.0% of personnel)							
-	-	-	-	-	-	-	-
Potential risk group, 3 people (0.9 % of personnel)							
Min	74	49	158.64	6.16	11.15	20.19	0.6743
Avg	78	51	305.61	9.96	14.97	20.96	1.6420
Max	80	55	578.28	15.58	20.01	22.15	3.2442
Negligibly mall risk group, 302 people (99.1 % of personnel)							
Min	25	2	0.19	0.00	0.00	0	0.0000
Avg	56	22	60.21	1.64	5.13	2.83	0.2481
Max	87	55	302.55	8.59	21.24	19.02	1.4233

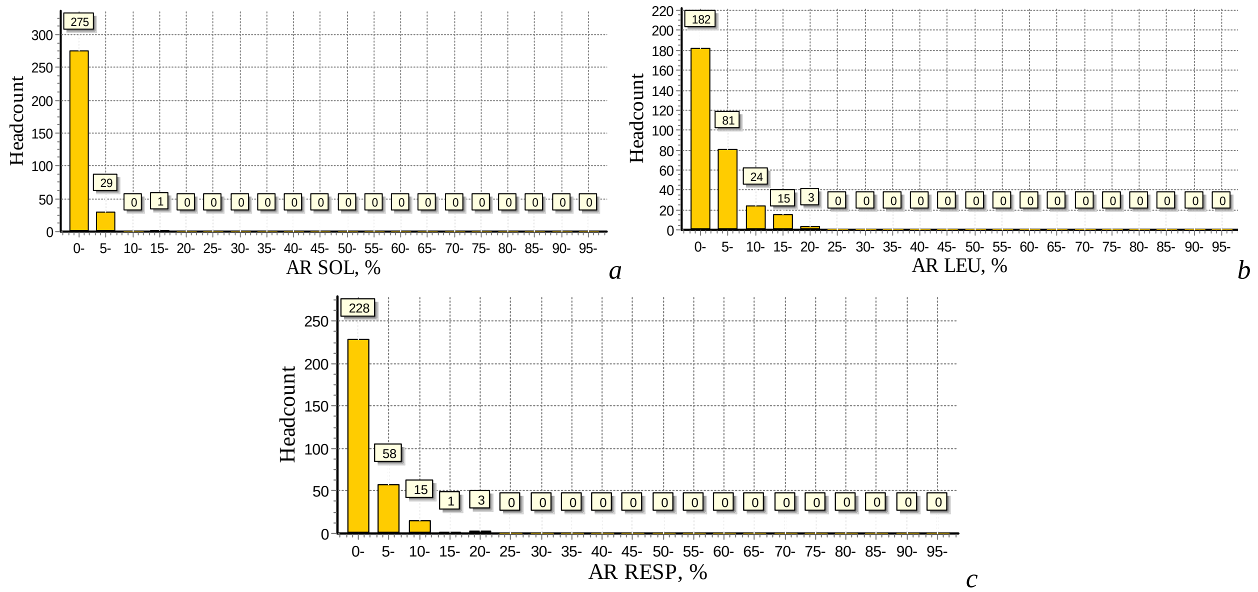

Fig. 6. Distributions of personnel by attributive risk of solid cancers (a), leukaemia (b) and respiratory system (c)

From the values of attributive radiation risks of solid cancers (AR_{SOL}), leukaemia (AR_{LEU}) and respiratory system (AR_{RESP}) of personnel the groups of high potential (AR_{SOL}≥20%, or AR_{LEU}≥75%, or AR_{RESP}≥30%), potential (AR_{SOL}≥10%, or AR_{LEU}≥50%, or AR_{RESP}≥20%) and negligible small (AR_{SOL}<10%, AR_{LEU}<50%, AR_{RESP}<20%) attributive risk groups were formed.

The values of the basic characteristics and risks of personnel by the groups of attributive radiation risk are shown in the Table 12.

The group of high potential attributive risk has not any person. The group of potential attributive risk has three human (0.9% of personnel). The group of negligible small attributive risk has 302 people (99.1% of personnel) The group of non-neoplastic diseases (heart attack, strokes) was also formed by the values of the cumulative doses of personnel (D≥500 mSv), only one employee was included in this group, at the age of 80, with experience at individual monitoring of 55 years.

CONCLUSIONS

Average age of personnel at individual monitoring in 2013 is 56 years for men and women. Average experience with exposure to radiation is 21 years for men and 22 years women. Average cumulative dose is 61.44 mSv for men and 49.40 mSv for women. Average annual dose of personnel in 2012 amounted to 1.38 mSv, which is comparable with background radiation – 1.14 mSv/year. Maximum of annual dose of personnel in 2012 was 3.64 mSv, which is about 5.5 times less than the annual dose limit – 20 mSv/year.

High absolute radiation risk group (where individual absolute radiation risk is more then socially acceptable level of risk – $1\cdot10^{-3}$/year) on 2013 includes 19 employees (6.2% of the staff at individual monitoring). The average age of the group is 75 years, average experience with sources of ionizing radiation – 50 years, average cumulative dose in 2011 (that were taken into risks account on 2013) – 226.23 mSv. Minimum age in the group is 71 years, minimum experience with sources of ionizing radiation – 45 years, minimum cumulative dose – 174.35 mSv. Main contribution to the total individual absolute risk of radiation of workers was made by the risk of solid cancers. Maximum of solid cancers attributive risk (the probability of cancer diseases caused by occupational exposure) is 15.58%, maximum attributive risk of leukaemia – 13.77%, maximum attributive risk of respiratory system – 22.15%.

International standards currently uses the following attributable risk thresholds for the cancer diseases classification as radiogenic: for solid cancers – 20%, for leukaemia – 75% for respiratory system – 30%. Personnel with the values of the attributive risk, equal or exceed those thresholds, refered to the group of high potential attributive risk, and in the case of oncological diseases such personnel may be eligible for the financial compensation depending on amount of attributable risk.

The group of high potential risk of cancer diseases induction on 2013 has not included any employee on individual monitoring in KIPT.

The group of potential attributive risk (there is an excess of attributable risk threshold values: for solid cancers – 10%, for leukaemia – 50% for respiratory system – 20%) on 2013 includes one man at age 80 years, with experience at individual monitoring 55 years and cumulative dose of 578.28 mSv (his AR of solid cancer is 15.58%, the AR of respiratory system is 22.15%) and 2 women at age 74 and 80 years, with experience at individual monitoring 49 years and cumulative doses of 179.93 mSv and 158.64 mSv, respectively (their AR of respiratory system are 20.19% and 20.56%).

Data obtained will help to manage of radiation risks by planning future occupational radiation exposure, and can be the basis for making decisions about copensation for workers (or their relatives) in whom cancer may have arisen from the exposure to radiation at work.

REFERENCES

1. Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards // *Intermediate edition. A series of IAEA safety standards, № GSR Part 3 (Interim).* Vienna: IAEA, 2011.
2. United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and Effects of Ionizing Radiation: UNSCEAR 1994 Report to the General Assembly, with Scientific Annexes. 272 pages. No index. ISBN 92-1-142211-6. U.N. Sales No. E.94.IX.11. 1994.
3. Methods for estimating the probability of cancer from occupational radiation exposure // *International Atomic Energy Agency (IAEA), IAEA-TECDOC-870.* Vienna: IAEA, 1996, p. 55.
4. ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection // *ICRP Publication 103.* Ann. ICRP 37 (2-4).
5. Radiation Safety Standards of Ukraine (NRBU-97) // *Public hygiene regulations.* Kiev, 1998.
6. Guidance for the assessment of occupational risk to workers health // *Organizational and methodological foundations, principles and evaluation criteria.* Leadership. P 2.2.1766-03. Russian Ministry of Health. Moscow, 2004.
7. V.K. Ivanov, A.F. Tsyb, A.P. Panfilov, A.M. Agapov. *Optimization of radiation protection: "The dose matrix."* M.: "Medicine", 2006, 304 p.
8. R. Wakeford, B.A. Antell, W.J. Leigh. A review of probability of causation and its use in a compensation scheme for nuclear workers in the United Kingdom // *Health Phys.* 1998, v. 74, p. 1-9.
9. Annual bulletin №14 «Cancer in Ukraine, 2011-2012».

Article received 18.02.2014

ХАРАКТЕРИСТИКА ПЕРСОНАЛА ННЦ ХФТИ ПО ГРУППАМ РАДИАЦИОННОГО РИСКА

А.Н. Довбня, А.В. Мазилов, И.А. Стадник

Описана методология проведения оценки индивидуальных радиационных рисков для пролонгированного облучения UNSCEAR-94. Дана характеристика персонала ННЦ ХФТИ, состоящего на ИДК, в терминах «дозовой матрицы». Приведены основные результаты расчетов относительного, атрибутивного и абсолютного радиационных рисков персонала ННЦ ХФТИ для различных локализаций и различных групп риска. Показаны распределения основных характеристик персонала: возраста, стажа на ИДК и накопленной дозы для различных групп радиационного риска персонала.

ХАРАКТЕРИСТИКА ПЕРСОНАЛУ ННЦ ХФТІ ЗА ГРУПАМИ РАДІАЦІЙНОГО РИЗИКУ

А.М. Довбня, О.В. Мазілов, І.О. Стадник

Описано методологію проведення оцінки індивідуальних радіаційних ризиків для пролонгованого опромінення UNSCEAR-94. Надана характеристика персоналу ННЦ ХФТІ, що перебуває на ІДК, в термінах «дозової матриці». Наведено основні результати розрахунків відносного, атрибутивного й абсолютного радіаційних ризиків персоналу ННЦ

ХФТІ для різних локалізацій і різних груп ризику. Показано розподіл основних характеристик персоналу: віку, стажу на ІДК і накопиченої дози для різних груп радіаційного ризику персоналу.