Oncoepidemiological situation in the Kaluga oblast of Russian Federation 10 years after the Chernobyl accident

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A study of cancer morbidity and mortality was performed in those rayons of the Kaluga oblast that were contaminated with radionuclides. The main objective of the study was the assessment of the influence of the radiation to the existing levels of cancer morbidity and mortality. Time trends and relative population risks were analysed. Basing on this analysis, it was concluded, that the current levels of morbidity from malignant neoplasms among the population residing in the studied rayons exposed in the result of the Chernobyl accident had been formed mainly in response to a complex of factors arisen before the accident. At present no statistically significant effect of radiation on cancer morbidity (except for thyroid cancer in women of contaminated rayons) has been noted. Levels of cancer morbidity and mortality in contaminated areas basically reflect a general tendency to the changes in cancer incidence in the oblast as a whole. The conclusion is in general agreement with the world data on latent periods for induction of radiogenic cancers and biological effects for levels of irradiation of the population residing in contaminated territories.

Introduction

Four oblasts, namely, Bryansk, Kaluga, Tula and Orel oblasts, were exposed to the highest radioactive contamination in Russia in the result of the Chernobyl catastrophe. About 1,800,000 people reside in these territories contaminated to over 37 kBq/m^2 - by ^{137}Cs [1, 2].

A number of reports of studies of malignancy morbidity and mortality for residents of contaminated territories of Russia have been published in the scientific literature by now. These studies are generally based on data of the state statistical reviews of oblast levels. However, oncological statistics of the oblast level covers all inhabitants of this oblast, i.e. both the ones living in contaminated territories and those residing in " clean" regions. Therefore, oncoepidemiological rates at the oblast level may only partially reflect possible radiation effects to induction of malignant neoplasms in contaminated territories of the oblast.

Let us discuss this situation in detail by the example of the Kaluga oblast. Three rayons of the Kaluga oblast, namely, Ulyanovsky, Khvastovichsky and Zhizdrinsky, suffered most of the contamination due to the Chernobyl accident. The population of these three rayons is 40,000 people, that in its turn makes up 4% of the total population in the oblast.

It is, therefore, very important to single the above three rayons out and to compare rates of morbidity and mortality from malignant neoplasms in these rayons and in the oblast as a whole. There are a number of difficulties associated with undertaking a small volume of selection (40,000 people) and the possibility for fluctuation of spontaneous (background) oncoepidemiological rates. On the other hand, residents of these rayons received small irradiation doses, that makes it difficult to directly calculate radiation effects against the background of in-depth health screening.

The computerised cancer registry was developed and introduced in the Kaluga oblast in 1994 within the framework of the Russian National Medical and Dosimetric Registry established in Russia in 1986 after the Chernobyl accident. The analysis given below is based on individual data on oncological patients collected in the cancer registry for the period since 1981 until 1995.

Materials and methods

Radioecological situation in the Kaluga oblast after the Chernobyl accident and assessment of late stochastic effects

Different rayons of the Kaluga oblast are at a distance of 370 - 500 km from the Chernobyl NPP. In the result of accidental release of radionuclides in aerosol and gaseous forms the oblast was being exposed to radiation contamination approximately since 19^{00} of April 28, 1986. Main contamination continued on April 29, 1986. However, some data suggest, that due to long-term release of radionuclides from the emergency unit into the atmosphere, contamination of the oblast continued in later periods [3].

Totally over 4000 km^2 of the oblast is contaminated in the result of the accident. On the contaminated territory there are 613 settlements (as of 01.01.1996) with over 3.7 kBq/m^2 of ^{137}Cs soil contamination density of the area, where over 105 000 people live. Distribution of settlements by the average ^{137}Cs soil contamination density of the area is presented in Table 1 (average contamination density is 77.7 kBq/m^2 and standard deviation is 79.2 kBq/m^2).

Table 1

Distribution of settlements from the zone of radioactive contamination of the Kaluga oblast by average ^{137}Cs soil contamination density around the settlement and mean external doseof irradiation for 10 years after the accident at the Chernobyl NPP

Interval of ^{137}Cs contamination density, kBq/m^2		Mean dose of additional external irradiation for 10 years after accident, mGy [2]	Number of settlements	Part, %
Left edge [1]	Right edge			
3.7	18.5	3	112	18.27
18.5	37.0	7.5	146	23.82
37.0	74.0	15	157	25.61
74.0	111	25	51	8.32
111	148	35	35	5.71
148	185	45	37	6.04
185	222	55	27	4.40
222	259	65	24	3.92
259	296	75	11	1.79
296	333	85	6	0.98
333	370	95	3	0.49
370	444	110	4	0.65

[1] - for 8 settlements soil contamination density is below 3.7 kBq/m^2;

[2] - mean external dose for 10 years of γ-radiation of natural sources is 6-7 mGy.

The contamination density of a small soil section around a settlement is a random value, a distribution density of which may be approximated by logarithmically normal laws. Thus, for instance, ^{137}Cs contamination of administrative centres of the mostly contaminated rayons is as follows:

Zhisdra: average density is 74.7 kBq/m^2 with range of 8.1 - 174 kBq/m^2;

Ulyanovo: average density is 145.8 kBq/m^2 with range 86.6 - 219 kBq/m^2;

Khvastovichi: average density is 57.0 kBq/m^2 with range 5.6 - 151 kBq/m^2.

The major radiation loads were received by the population of the contaminated rayons of the oblast in 1986. Irradiation of the thyroid of children and adolescents (mean dose is 250 mGy) was the most significant unfavourable health effect in the process.

External doses to the whole body were assessed by modelling the atmospheric transport of the main dose-forming radionuclides, as well as data on reconstruction of the radionuclide composition of fallout [3]. An upper limit of the dose was obtained without consideration of a protection coefficient for different groups of population. Thus, for epidemiological assessment a mean dose of additional external irradiation in 1986 after the Chernobyl accident may be estimated by the mean ^{137}Cs soil contamination density around the settlement with the proportionality coefficient of $4.68 \cdot 10^{-2}$ mGy/(kBq/m^2). For 1987 the proportionality coefficient is $3.68 \cdot 10^{-2}$ mGy/(kBq/m^2). For the first 10 years after the accident the proportionality coefficient is approximately equal to 0.27 mGy/(kBq/m^2). Table 1 gives the distribution of settlements by external dose from the moment of the accident until the end of 1995. Doses of internal whole body irradiation from incorporated isotopes of Caesium in the oblast were significantly less during all years after the accident (in 1986 the average internal dose was 0.5 mGy, the value was less in subsequent years).

Thus, one may consider that radiation loads to the whole body from external and internal exposure are not significant in contaminated territories of the Kaluga oblast where the density of surface soil contamination with ^{137}Cs is not higher than 15 Ci/km^2 (555 kBq/m^2).

Based on the above radioecological data, an attributive risk of induction and deaths due to radiogenic cancers among the population of the contaminated rayons of the Kaluga oblast was assessed. To make assessments the reported models of radiation risk were used [4, 5]. According to calculations, during the post-accident period the attributive risk is maximal for thyroid cancer (20-25%) and leukaemia (5-7%). The attributive risk for solid cancers will not exceed 0.4%. Thus, the expected morbidity and mortality (excluding thyroid cancer) from radiogenic cancers are within limits of the statistical errors of a spontaneous level of malignancy morbidity and mortality. Checking the above mentioned theoretical prognosis on the basis of actual data about oncoepidemiological situation in the Kaluga oblast for a decade after the Chernobyl accident is of great interest.

Materials and methods of epidemiological analysis

Data of the formal oncological statistics for the period since 1981 until 1995 were the material for studies presently under discussion. Information on patients with primarily established diagnosis of a malignant neoplasm and death cases was retrospectively recovered mainly from the archive records stored in the Kaluga cancer dispensary (the chart of dispensary registration, death notification, etc.). Data on number of population in the Kaluga oblast and distribution of the population of administrative regions by sex and age obtained from the materials of the State Committee on Statistics were used in the study.

We compared morbidity and mortality from general malignant neoplasms (MN) for the population of the contaminated rayons with the rates for the oblast as a whole. The following localisations predominating in the general MN incidence structure were studied: MN of the gastrointestinal tract (GIT) (ICD-9: 150-159.9) and MN of respiratory organs (ICD-9: 160-163.9) [6]. Cases of leukaemia and thyroid cancer were also considered. The latter are the earliest indicators of exposure to ionising radiation according to general world understanding.

Standardised incidence and mortality ratios (SIR and SMR) of cancer were calculated for population (men and women separately) of contaminated areas in 1981-1995, using the rates of the whole oblast in 1981-1995 as standard. These calculations were made for each year between 1981 and 1995 and for the periods before and after accident. To test for different trends in SIR (SMR) before and after accident, linear regressions are performed separately for the periods 1981-1985, 1986-1995, and 1981-1995. Population relative risks (RR) of cancer in the population of the studied rayons compared to the ones of the oblast were estimated. Age standardised cancer morbidity and mortality rates (ASR) were used as the initial data to estimate risk. A possible contribution of radiation exposure was determined by comparing of population risks before and after the accident.

Similar studies for the oblast level were conducted by us previously, i.e. population risks for increase of cancer incidence in the contaminated oblasts rating to Russia as a whole (the population of Russia were presented as a control group) was analysed. Figure 1 indicates results of these studies. As one may see, processes of the change in levels of oncological morbidity in the Kaluga oblast and Russia are basically the same. The change in risk after the accident noted for some localisations was within assessment errors.

As noted above, this comparison of the whole oblast with Russia (even though the population of the mostly contaminated territories makes up not more than 4% of the population of the oblast) may hardly reflect an actual situation of possible effects of the accident. That is why we present results immediately on MN morbidity and mortality trends in the rayons.

Results and discussion

For all years of observation since 1981 until 1995 the general numbers of the population in the three mostly contaminated rayons of the Kaluga oblast changed only slightly. The Chernobyl accident caused no migration of the population from these rayons. According to their age composition the contaminated rayons are the “oldest” ones by comparison to the oblast as a whole. People older than the working age are almost one third of the population of these rayons, mainly because of the number of women.

All malignant neoplasms

Since 1981 until 1995 standardised incidence ratios for all forms of malignant neoplasms among the male population of the three contaminated rayons of the oblast exceeds 100% mainly in the post-accident years. However, difference in time trends before and after the accident is statistically insignificant. No statistically significant differences between coefficients of regression calculated for the periods before (1981-1985) and after (1986-1995) the accident are observed (Figure 2). Standardised incidence ratios for all forms of MN calculated for the periods of observation before and after the accident are given in Table 2. A significant increase of SIR in the post-accident period was noted in the male population of the studied rayons in relation to the oblast rates. However, the observed increase of SIR is not statistically significant in comparison to the pre-accident period and it is almost unchanged with reference to first 5 years after the accident. As for the female population of these rayons, it should be noted, that although after the accident MN incidence ratios increased significantly, they just approached the oblast rates in the post-accident period.

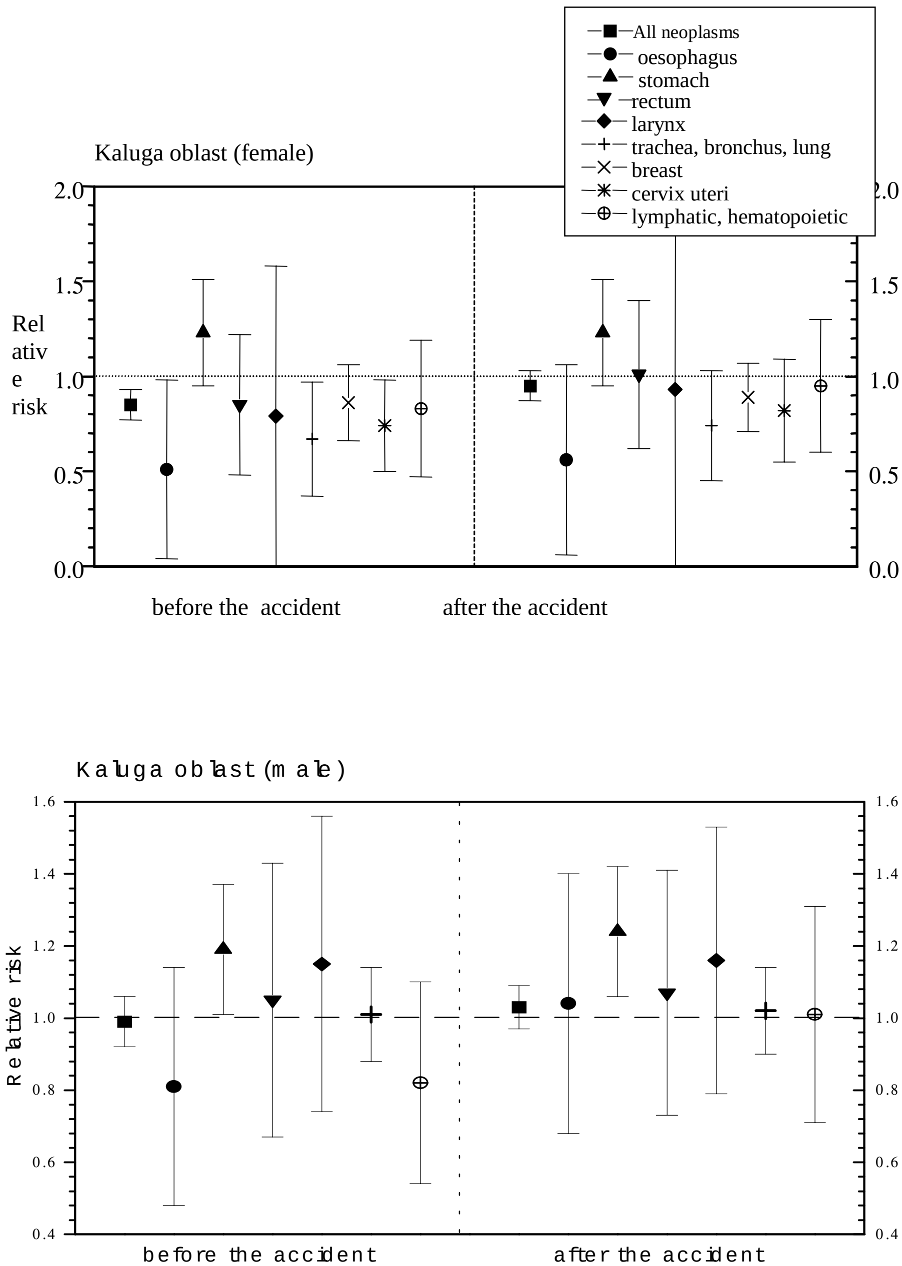

Fig. 1. Relative population risk of cancer morbidity for the population of the Kaluga oblast before (1981-85) and after the accident (1986-93).

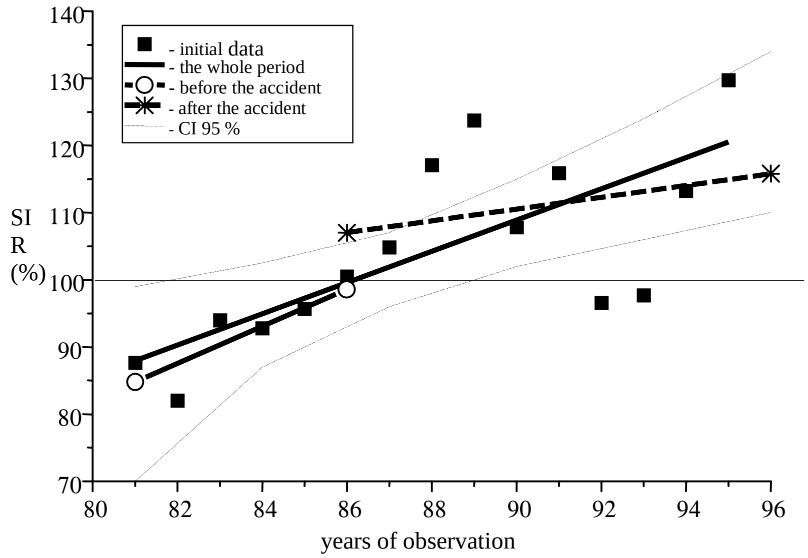

Fig. 2. Morbidity trends for all cancers among the male population of the contaminated areas of the Kaluga oblast.

Table 2

SIR of cancer among the population of the contaminated rayons of the Kaluga oblast before (1981-1985) and after (1986-1990, 1991-1995) the accident

Forms of MN	**Males**			**Females**		
	1981 - 85	1986 - 90	1991 - 95	1981 - 85	1986 - 90	1991 - 95
	SIR (%)			SIR (%)		
All MN	90.82	110.61*	110.77*	35.22	64.22	83.77
MN of GIT	125.75*	138.02*	121.27*	84.58	72.70	93.55
MN of respiratory organs	79.91	101.60	110.16	116.48	116.73	150.80*
Leukaemia	154.94	94.05	105.46	88.91	14.76	59.57

* - here and in other tables the sign indicates a higher significant difference (95%) from the oblast rates.

Figure 3 shows calculations of the relative population risks of malignant diseases for the population of the studied rayons. Referring to the figure, the relative risk of morbidity for all forms of MN in all three rayons of the oblast in the post-accident years increased by 1.13 times. However, in the pre-accident period the risk of MN for the males of these rayons has a statistically significant difference from this figure for the Kaluga oblast. The post-accident risk is 1.22 (confidence interval (CI) = 1.16-1.27) for the male population (Figure 3); for women this value does not exceed 1. Besides, it should be noted, that the observed change in the risk in the post-accident period by comparison to that in the pre-accident period is within assessment errors.

Standardised mortality ratios from all forms of MN also have the tendency to growth in mortality trends in every following year. Time trends for the period after the accident in all studied rayons does not differ significantly from the tendency of mortality growth for the whole period of observation (Figure 4). Standardised mortality ratios (SMR) from all MN for the population of the contaminated rayons before and after the accident are given in Table 3. The observed SMR increase (males) in the studied rayons in reference to the oblast rates occurred within limits of assessment errors as compared with the pre-accident period.

Figure 5 presents rates of the relative population risks (RR) of deaths from MN among the male population of the observed rayons. One may see, that RR of mortality from all forms of MN is already higher 1.0 before the accident; the change in the risk after the accident is within assessment errors in relation to the pre-accident period. Besides, after the accident RR of mortality for males of the contaminated rayons is reliably higher the oblast rates.

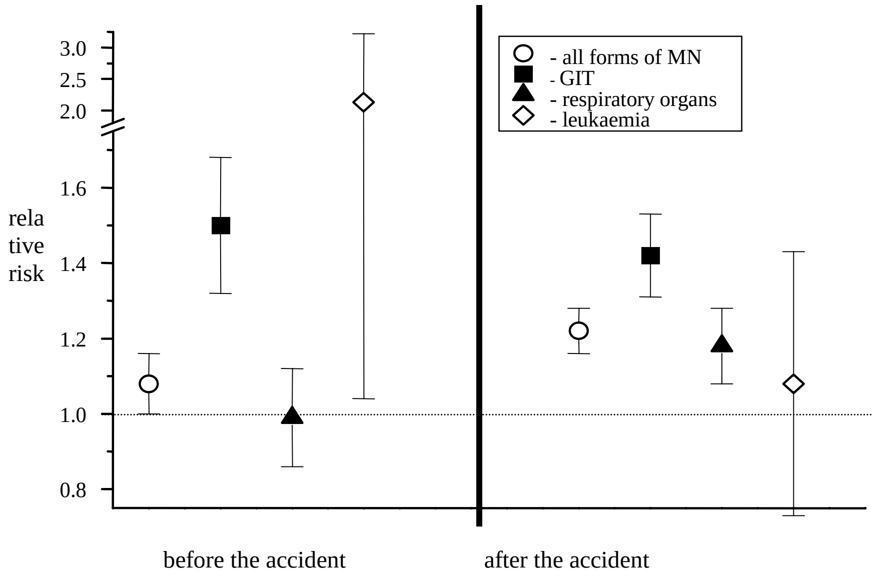

Fig. 3. Relative population risk of cancer morbidity in the male population of the contaminated areas before (1981-85) and after (1986-95) the accident.

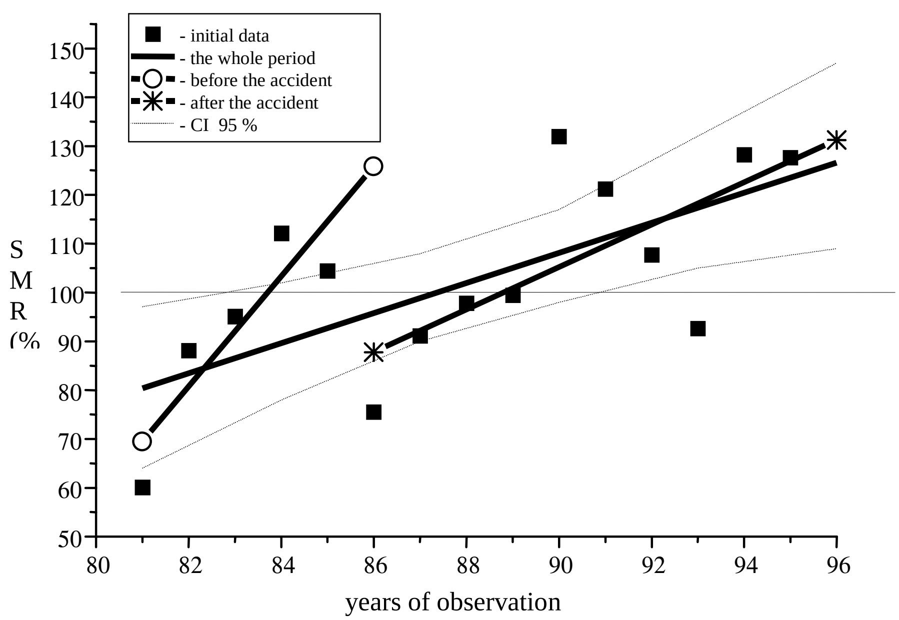

Fig. 4. Mortality trends for all cancers among the male population of the contaminated areas of the Kaluga oblast.

Table 3
SMR of cancer among the population of the contaminated rayons of the Kaluga oblast before (1981-1985) and after (1986-1990, 1991-1995) the accident

Forms of MN	Males			Females		
	1981 - 85	1986 - 90	1991 - 95	1981 - 85	1986 - 90	1991 - 95
	SMR (%)			SMR (%)		
All MN	92.23	98.94	116.27*	67.53	76.64	89.45
MN of GIT	97.47	115.59	131.93*	69.51	74.25	91.37
MN of respiratory organs	79.79	95.05	91.02	45.93	67.08	171.87*
Leukaemia	85.02	94.66	106.35	64.96	37.42	19.96

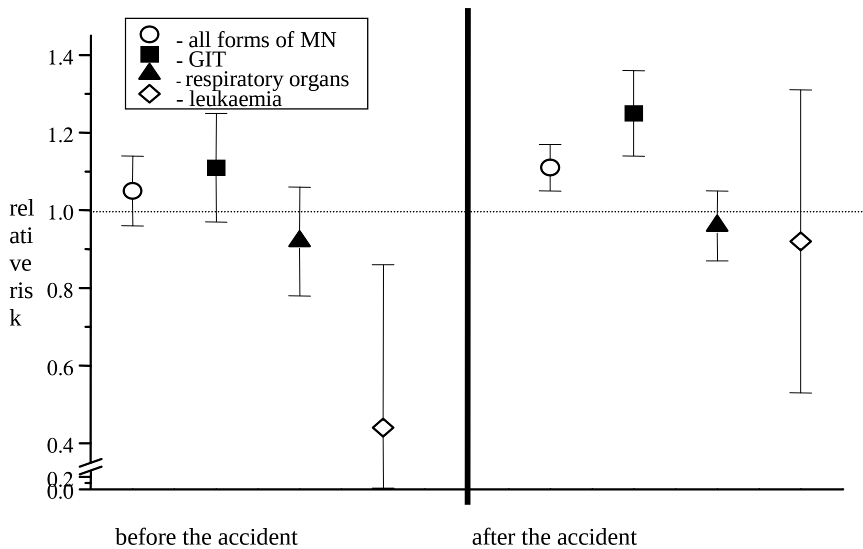

Fig. 5. Relative population risk of cancer mortality for the male population of the contaminated areas before (1981-85) and after (1986-95) accident.

Malignant neoplasms of GIT and respiratory organs

During all years of observation, MNs of the gastrointestinal tract and respiratory organs predominate in the structure of malignant diseases of the population in the oblast and studied rayons. No qualitative fluctuations in the structure due to the accident are observed.

Morbidity trends for MN of GIT during observation before and after the accident is ambiguous. A clear tendency to growth is noted in the pre-accident period. For the whole period the standardised incidence ratios therewith exceed rates for the oblast as a whole. The situation has changed in the post-accident period; the time trend is characterised by the coefficient of regression equal to 1.49 ± 2.67. This reflects both calculation of the standardised ratios according to the periods before and after the accident (Table 2) and calculation of the relative population risks (Figure 3). Already before the accident the relative population risk for MN morbidity of GIT for the male population of all rayons differs statistically significant from the one of the oblast as a whole. After the accident the risk is statistically significant, though slightly decreased in the absolute value. It should be stressed, that when splitting the post-accident period by 5 years, the relative population risk turned to be higher in first 5 years after the accident, than within following years (1.66 versus 1.22). Since such an immediate increase is not expected for radiation-induced neoplasms, it is necessary to search for other plausible causes. The observed excess could probably be caused by regular screening for malignant neoplasms and involving the most experienced physicians in the examination undertaken in the contaminated areas in the first years after the accident. As for the female population of the contaminated rayons it may be noted that the relative risk of MN morbidity for GIT does not differ significantly from 1.0, and after the accident its rate even decreased (Table 4).

Table 4

Relative population risk of cancers among the female population of the contaminated rayons of the Kaluga oblast before (1981-1985) and after (1986-1995) the accident

Forms of MN	Morbidity		Mortality	
	1981 - 1985	1986 - 1995	1981 - 1985	1986 - 1995
	RR		RR	
All MN	0.79	0.80	0.76	0.85
MN of GIT	1.05	0.93	0.75	0.86
MN of respiratory organs	1.46	1.40*	0.50	1.16
Leukaemia	1.05	0.38	0.82	0.31

Comparing time trends of the standardised mortality ratios for MN of GIT among the male population in the pre- and post-accident periods in all contaminated rayons together one may see, that they have the general directionality, differences in coefficients of linear regression are statistically insignificant. The pace of mortality growth for men is high and exceeds the oblast rates for almost the whole period of observation. Increase of coefficient of linear regression in the post-accident period is noted for the female population, while the level of mortality is just reaching the oblast level (Table 3). The relative population risks for the male mortality from MN of the given localisation before and after the accident are given in Figure 5. It follows from these results that RR in the three rayons was over 1.0 already in the pre-accident period. After the accident the value of risk made up 1.25 (CI = 1.14 - 1.35), increase against the pre-accident risk was within limits of errors.

In spite of the growth of MN morbidity of respiratory organs for the whole period under study, no statistically significant increase of standardised morbidity ratios in the male population after the accident is revealed in the contaminated rayons of the oblast (Table 2). The pace of growth of an incidence rate for all three rayons together in the post-accident period is lower than that in the pre-accident period, though differences in coefficients of linear regression are statistically insignificant (1981-1985: 2.9±2.31; 1986-1995: 1.53±2.35). The change of the relative risks of morbidity for men (Figure 3) and women (Table 4) of all contaminated rayons together was small in the post-accident period and stayed within limits of errors. Some decrease of the risk for the post-accident compared with the pre-accident period is typical for women of the studied rayons. Besides, it should be stressed that MN morbidity risk of the discussed localisation for the female population is the same high for both the pre- and post-accident periods in relation to the oblast as a whole.

Level of mortality from MNs of respiratory organs among the male population has almost not changed in the post-accident period if compared with that of the oblast (Table 3). Besides, for the female population the mortality risk in the post-accident period has increased statistically significant by 2.5 times. This growth is typical for the recent 5 years (1991-1995) in relation to insignificant increase of the risk within first 5 years after the accident (RR for 1990-1995 is equal to 1.66 (CI = 1.08 - 2.24)). According to the results of our prognostic assessments this increase of relative risk of mortality from MN of this localisation may not be explained by radiation effect. It is more likely associated with stochastic fluctuations of death rates and relatively small volume of the selection.

Leukaemia and thyroid cancer

Such forms of MN as leukaemia and thyroid cancer were considered as population “ markers” of radiation exposure, though the number of these cases occurred at the rayon level are small. For the whole period of observation in the three rayons of the oblast 35 cases of leukaemia and 17 deaths from this disease have been registered, 23 cases of thyroid cancer have been revealed.

Morbidity and mortality trends for leukaemia in the studied rayons tend to be negative for the whole period of observation (coefficient of linear regression is 4.09±4.93). Values of the standardised incidence and mortality ratios both before and after the accident are not statistically significant, and for the period since 1986 until 1995 they became lower if compared with that for 1981-1985. The same may be said about relative population risks. However, it should be noted that for the male population of the contaminated rayons the risk of leukaemia morbidity after the accident is slightly higher (Figure 3), than that in the oblast as a whole (RR=1.08 (CI = 0.73 - 1.42)). The relative risk of mortality from leukaemia for the male population has also increased in the post-accident period and approached the oblast rates (Figure 5).

A growth of thyroid cancer morbidity in the contaminated rayons was not noted. However, the level of incidence rates of thyroid cancer for the population of the contaminated rayons significantly exceeds the oblast level for the whole period of observation. There is clearly a negative tendency of morbidity trends for the whole period of observation and for the post-accident period. The coefficient of a linear regression is 21.54±16.08. Women are especially liable to thyroid cancers. For the studied rayons the relationship between female and male incidence has changed insignificantly with the course of time: before the accident - 2.5:1, after the accident - 3:1. Besides, it should be noted that RR for men does not differ significantly from the oblast rates, though the risk exceeds 1.0. Calculations of the relative population risk for women show that the risk is higher 1.0, and it is statistically significant after the accident (RR=2.22 (CI = 1.14 - 3.31). To confirm the causal relationship between the accident and increase in the thyroid cancer morbidity further advanced investigations should be performed. With regard to mortality due to thyroid cancer, we think that discussion of the problem in the paper is premature because of small number of cases.

Conclusions

The above results show that time trends of standardised incidence and mortality ratios from almost all MN localisations for the population of contaminated areas of the oblast are similar before and after the accident. The observed changes in the risk in the post-accident period for some localisations are within the assessment errors. A significant difference in the risk of morbidity and mortality from MNs of female respiratory organs in the contaminated rayons in the post-accident periods compared to the appropriate risk for the oblast is the exception. Besides, after the accident the risk for this localisation in all contaminated rayons of the oblast increased insignificantly within the limits of calculation errors. The difference is most likely caused by a fluctuation of the spontaneous onco-epidemiological rates and is not associated with effects of ionising radiation. The fact of the significant risk of thyroid cancer among women of the contaminated rayons after the accident is to be pointed out.

Thus, at present no statistically significant effect of radiation on malignancy morbidity (except for thyroid cancer in women of the contaminated rayons) has been observed. Levels of the morbidity and mortality in the contaminated rayons mainly reflect the general tendency to the change of MN morbidity for the oblast as a whole, and the observed change in level of the morbidity for some localisations in 1986-1995 happened, obviously, under the influence of some factors formed before the accident. Following the world's research experience and in accordance with our prognostic assessments for the decade, all possible consequences of the Chernobyl accident could not manifest themselves, that requires further maintenance of the cancer registry in these regions of the oblast and study of radiation risks.

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