Review of Epidemiological Finding in Study of Medical Consequences of the Chernobyl Accident in Ukrainian Population

Anatoly Ye. PRYSYAZHNYUK, Volodymir G. GRISHTSHENKO,
Zoya P. FEDORENKO*, Ludmila O. GULAK*, Mykola. M. FUZIK

Scientific Center for Radiation Medicine of Academy of Medical Science of the Ukraine,
53, Melnikov str., Kiev, 04050, Ukraine. E-mail root@ucr.kiev.ua
**Institute of Oncology of Academy of Medical Science of the Ukraine,*
33/43, Lomonosov str., Kiev, 03022, Ukraine. E-mail root@ucr.kiev.ua

Abstract

Evaluation of the health status of different groups of the Ukrainian population affected by the Chernobyl accident is one of the most important problems in elimination of the consequences of the Chernobyl disaster. A lot of scientific researches devoted to study of health effects and based on established registers of victims of the Chernobyl accident had drawn conclusion about worsening of health of main groups of the affected population: Chernobyl accident recovery operation workers, evacuees from Prypyat city and 30km zone, and residents of the most contaminated with radionuclides territories. Most remarkable stochastic effect of radiation due to the Chernobyl accident is increase of thyroid cancer incidence rate in the above-mentioned groups of the Ukrainian population. For female breast cancer and some other solid cancers there are suggestions of increases. Further observation is needed for long term stochastic and non-stochastic effects.

1. Introduction

The accident at the Chernobyl Nuclear Power Plant on April 26th, 1986 is an unprecedented complicated and large-scale disaster in views of its origin, spreading of radionuclides on relatively large territories and the number of affected population. The release of dangerous radioactive substances diffused over the wide areas of Ukraine, Belarus and Russia. Chernobyl accident recovery operation workers (CAROW), who participated in elimination of the consequences of the accident, as well as inhabitants of territories neighbouring Chernobyl received substantial dose of radiation.

According to National Report (2001) [1], during 15 years after the accident the rural population of the Ukraine received 46.21 thousand person-Sv of accumulated collective dose. Average external dose in the rural inhabitants during that period constituted 0.6-41 mSv. Average accumulated external and internal dose per person in the territories with a density of nuclear fall-out more than 555 kBq/m^2 exceeded 70 mSv.

Average external effective dose to the evacuated inhabitants of the 30-km zone formed 20-30 mSv; Prypyat city - 10-12 mSv and Chernobyl city - 20 mSv. Taking into account the internal component, this evaluation should be doubled. The main group of CAROW who participated in elimination of the accident consequences in 1986 have received mean dose of 100-200 mSv, and CAROW in 1987 - 50-100 mSv.

Doses to thyroid for the population of the contaminated territories have shown significant burden on this organ, especially in children. Estimated average of thyroid dose equivalent in the most contaminated areas constituted 187 - 220 mSv in adults and children, while 877-1360 mSv only in children. Collective dose to thyroid in Ukrainian children is estimated to be 400,000 person-Gy, and in the most contaminated districts - 57,000 person-Gy [2].

Evaluation of health status of the population affected by the Chernobyl accident is one of the most important problem in elimination of the consequences of the Chernobyl disaster. According to regulation of

Ukrainian government, there was established State Registry of Ukraine of persons affected by the Chernobyl accident (SRU). In 2000 there were registered 1,258,241 persons, including 249,000 CAROW, 71,510 evacuees and 193,250 children [1]. Health care system in Ukraine and principles of activity of SRU are described in details by [3].

To follow up haematological and thyroid cancer consequences two special registries are in operation; Ukrainian Haematological Registry at Scientific Centre for Radiation Medicine, and Morphological Registry of Thyroid Cancer at Kiev Research Institute of Endocrinology and Metabolism.

The main cancer epidemiological studies related to the Chernobyl consequences are based on a data base of National Cancer Registry (NCR), which was established in 1989 and covers all territory of Ukraine. Personal information about all cancer cases is collected in NCR using a network of regional and city cancer registries [4, 5, 6]. In the last years joint efforts between Research Institute of Oncology and Scientific Centre for Radiation Medicine allowed to establish a frame of special sub-registry of NCR: cancer patients from the sufferers by the Chernobyl accident (CAROW, evacuees, and people still living in the contaminated territories). Before these registries, in Ukraine since 1953 there existed a system of cancer registration based on paper documents which were filled in all cancer hospitals (oncological dispensaries).

Results of studies in the above-mentioned institutes have been published in periodical medical literatures in Russian, Ukrainian languages as well as in proceedings in national and international symposia, conferences, congresses and another scientific forums. The main purpose of the current paper is review of publications performed and devoted to epidemiological researches of health status, especially about leukaemia and solid cancer in the groups of the Ukrainian population affected by the Chernobyl accident.

2. Somatic disorders in the main groups of population affected by the Chernobyl accident

2.1. Health status of residents in the contaminated territories with radionuclides

There were observed significant changes of health status of the population still living in the contaminated territories with radionuclides [7]. During 1988-1999 prevalence and incidence of diseases in these people increased by more than 2 times (from 620.9 to 1275.6 ‰ and from 305.5 to 746.0 ‰, respectively). Increases of morbidity were observed in almost all diseases classes, especially blood and blood circulation classes (10.8-15.4 times), endocrine pathology (4.1-8.1 times), neurological system and sense organs (3.8-5.0 times), skin and underskin cellulose (4.0-4.6 times). There were also observed more than two fold increases in the level of morbidity of digestive organs, urinarygenital and muscular-skeletal systems. It should be pointed out that the level of morbidity in the contaminated areas has exceeded the Ukrainian population level since 1993-1994.

There was observed a tendency that morbidity in inhabitants of the contaminated areas depends on the level of contamination. Since 1988 through 1997 the most remarkable increase was observed in the population of the territories with the highest level of contamination (so-called the 2nd zone of “obligatory resettlement”) - by 4.2 times. In the areas with the intermedium level of contamination (so-called the 3rd zone of “guaranteed voluntary resettlement”) morbidity increased by 2.3 times. And in the areas with the lowest level of contamination (so-called the 4th zone of “enhanced radiation control”) - only by 1.4 times. Only in the 2nd zone, however, there was observed significantly higher level of pathology in comparison with the Ukrainian population level. Such difference in the levels of morbidity of inhabitants in the different zones was demonstrated for almost all diseases classes. Attention should be drawn to the higher excess of mental disorders in all contaminated territories. In the 2nd zone the maximal level of mental disorders incidence reached 69.7 ‰ rather 4.4-5.4 ‰ in the Ukrainian adult population.

There was performed an incidence cohort study of inhabitants in the contaminated territories with different dose of thyroid gland irradiation [7], which registered high relative risks of blood circulation diseases, especially cerebrovascular pathology and muscular-skeletal system.

As pointed out [8, 9] since 1990-1991 a sign of demographical crisis has been observed, peculiarities of which are a significant decrease of birth-rate and a steep increase of mortality, including a high level of infant mortality. That happened in the negative radiation-ecological situation due to the Chernobyl disaster and its consequences. Forecasting calculation suggests worsening of the main demographical indexes in the contaminated territories. It is difficult, however, to estimate the size of load due to ionising radiation in the worsening demographical situation.

2.2. Health status of Chernobyl accident recovery operation workers (CAROW)

During the last period of time there were registered significant changes toward worse health status of CAROW [10, 11]. The proportion of healthy persons among this relatively young and healthy population at the moment of participation in elimination of the Chernobyl consequences decreased from 78.7% to 10.3%. In the people who have received external dose of radiation more than 250 mSv the percentage of healthy persons decreased to 7.2% due to increase of non-cancer chronic pathology which is the leading cause in their invalidity and mortality. There were observed increases of morbidity due to neurological diseases, diseases of sense organs, endocrine system, blood circulation, digestive organs, urinogenital system, and blood and haemopoetic system. The levels of these pathologies exceeded the incidence figures in the adult population of Ukraine.

There was observed a high level of psychiatric disorders incidence, especially in 1990-1993 [12]. In the structure of all diseases priority belongs to digestive organs pathology, system of blood circulation, neurological system and sense organs [13]. These three diseases classes compose 85-87% from all causes of invalidisation.

According to epidemiological cohort studies [14] the most significant increase of prevalence and incidence of chronic non-cancer diseases was observed in CAROW of 1986-1987 in comparison with persons who participated in the later period of time. Fourteen years follow-up of CAROW who had acute radiation disease demonstrated high risks of leukaemia and combined forms of immunodeficit. In a third of these patients there were observed relapse of skin lesions. In clinical symptomatology there was observed domination of radiation cataracts, hypothyreoidism, organic pathology of nervous system. About 90% of recovered patients from acute radiation diseases are severe invalids. The main cause of death of them is sudden heart death. Obtained data [13] suggest a relationship between dose of irradiation and chronic non-cancer morbidity among CAROW.

In CAROW there were observed annual increase of mortality. The level of CAROW mortality approximated to figures of the mortality in the Ukrainian population of labourable ages [12]. In the last six years there was observed two fold annual increase of death rate of blood circulation system diseases, respiratory, digestive systems and endocrine pathology. In the structure of causes of death the first place belongs to pathology of blood circulation system.

2.3. Health status of the adult population of evacuees

According to State Registry of the Ukraine (SRU) [15, 16], in the adult population of evacuees from Prypyat city and the 30-km zone around Chernobyl NPP there were observed negative tendency of health status. Since 1988 through 1999 the percentage of healthy persons decreased from 67.7 % to 29.0 %. In the same time the relative frequency of pathology increase from 31.5 % to 71.0 %. During the above-mentioned period of time the prevalence of diseases increased by more than 3 times, and the incidence - by 2 times.

The morbidity level was higher rather than the population level for the next classes of diseases: pathology of endocrine system, blood and haemopoetic system, mental disorders, neurological system and sense organs, system of blood circulation, digestive, and muscular-skeletal systems.

In evacuees there was observed 1.5 fold increased incidence of thyroid gland pathology due to the

acquired hypothyreoidism, thyreoidite and non-toxical nodular goiter. Annual level of thyroid pathology in female was higher rather than in male. There is an increase of this pathology with age, and more significant increase was observed in the people older 30.

There are some peculiarities in the structure of evacuees' morbidity. In the early post-accidental period the leading role was mental disorders which relative frequency reached 14%. In the following years the leading places belonged to blood circulation diseases, respiratory, neurology systems and sense organs, and digestive organs.

There was performed a special cohort study of evacuees' morbidity [16] with different terms of evacuation from Prypyat city and the 30-km zone around Chernobyl NPP: the first twenty four hours, 8-12 days and 19-50 days. The highest level of morbidity was observed in Prypyat inhabitants of the earliest evacuation, the prevalence figure of which in 1988-1998 composed 7780 ± 212.4 ‰. The lowest level of morbidity was observed in the sub-cohort of evacuees during 19-50 days after the accident. The level of prevalence was 3124 ± 108.8 ‰, two times lower than the earliest sub-cohort. The intermedium level was observed for 8-12 days evacuees; 5436.6 ± 62.2 ‰ of prevalence.

A study of evacuees' mortality pointed out that at the present time its level does not exceed the population level. Nevertheless, in separate years (1993, 1994) the mortality level in teenagers (15-17 years old) was higher than in 18-29 years and corresponded with the mortality in older population groups. In the structure of death causes the highest relative frequency was observed due to blood circulation diseases (47.6-83.1 %), neoplasms (7.4-16.5 %), and traumas and poisoning (2.7-19%).

2.4. Health status of children affected by the Chernobyl accident

The percentage of healthy children who were evacuated or born from CAROW decreased from 30% in the first post-accidental years to 2.8 - 5.0% [17]. The percentage of invalid children affected by the Chernobyl accident by four times exceeds the Ukrainian population level

There was revealed an increase of somatic diseases prevalence during the follow-up period. In 1999 the level of all diseases prevalence (49,967 per 10,000 children) was twice the figure in 1987-1988 (25,948 per 10,000 children). The most remarkable changes were registered in index of prevalence of digestive organs diseases (4,659 in 1988 and 10,122 in 1999 per 10,000 children), nervous system diseases (2,369 and 4,350 per 10,000 children, correspondingly).

Comparison of morbidity figures with those in the identical age groups of non-affected children suggests a significant difference between two groups (in 1999 by 3 times higher in the affected children). A tendency of increase was determined distinctly in digestive organs pathology, nervous system and the diseases in pathogenesis of which the main the role belongs to changes of immune system [17, 18, 19].

There was denoted that the main risk of health damage in children living in the contaminated territories were connected with blood diseases, haemopoetic system, endocrine system pathology, digestive organs disorders and mental disorders [19].

The increased level of morbidity may be related with both radiological and non-radiological factors (contamination of soil with radionuclides, heavy metals, pesticides, chemical composition drinking water and so on). Portion of ionising radiation contributing to the increased morbidity is considered from 2 to 20 %.

The most unfavourable changes were observed in the children with high dose of irradiation of thyroid gland (over 200 cGy) and *in utero* irradiated children. Among them the percentage of practically healthy does not exceed 2.6-5.0 % [13].Since 1986 there were observed determined effects of irradiation on thyroid gland: primary functional reaction observed in 1986-1987, beginning of formation chronical autoimmunal thyreoiditis in 1990-1992, and clinical realisation of diseases - in 1992-1993.

In the latest period after the Chernobyl accident the forecasting of health status of the children affected

by radiation is unfavourable [20]. The higher proportion of these children has developed pathology in most organs and systems: thyroid gland - 32.6 % (15.4 % in the control group, P<0.05), respiratory system - 26.0 % (13.7 % in the control group, P<0.05), heart-vessel system (including vegeto-vessel distonia) - 57.8 % (31.8 % in the control group, P<0.05), gastro-intestinal tract - 18.9 % (8.9 % in the control group, P<0.05), immunological deficiency - 43.5 % (28.0 % in the control group, P<0.05), and endocrine infertility in girls - 32.0 % (10.5 % in the control group, P<0.05).

3. Cancer incidence rates in main groups of population affected by Chernobyl accident.

Cancer incidence rates after the Chernobyl accident were studied in the population of the territories of Kiev and Zhytomir regions neighbouring with the nuclear power plant. The most contaminated districts included in the study were Narodichy and Ovruch districts of Zhytomir region, Ivankov, Polesskoye and now unpopulated former Chernobyl districts. At the moment of the Chernobyl accident these five districts accounted 274 thousand of population including 59,200 children. In 2000 the four most contaminated districts (without unpopulated Chernobyl district) had 125,000 residents (including 21,600 children). During the period of observation for 1980-2000 there were registered 11,400 cases of cancer and leukaemia, including 126 cases in children [21].

Cancer incidence rates for the period of 1990-1997 were studied in Chernobyl accident recovery operation workers (CAROW) of 1986 and 1987 years who were chosen from 6 regions of Ukraine: Dnepropetrovsk, Donetsk, Kharkov, Kiev, Lugansk regions and Kiev city [22]. The sample population containing the records on 95,000 CAROW as of 1990 was constructed based on the data acquired from the State Registry of Ukraine of persons affected due to the Chernobyl accident (SRU). Cancer incidence in the Ukrainian evacuees was studied based on the data base contained in SRU. In 1990 there were accounted 51,500 evacuees [22, 23].

3.1. Cancer incidence rates in residents of the most contaminated territories

Cancer incidence rates in the population living in various regions are illustrated in Figure I for the period 1980-2000 [21]. Cancer rates in the populations still living in the most contaminated districts were consistently lower than for the overall Ukraine or for Kiev and Zhytomir regions. Cancer incidence rates in all four groups show a similar pattern of temporal increase. Regression coefficients, which characterise the increment per year, do not differ significantly [21, 22, 23, 24].

Comparison of standardised incidence ratios (SIR) for all cancers in the most contaminated districts is shown in Table 1 for various periods of observation. Irrespective of the sub-periods for 1990-1993, 1994-1997 and 1998-2000, there is no significantly increased cancer incidence for all cancers in the residents of

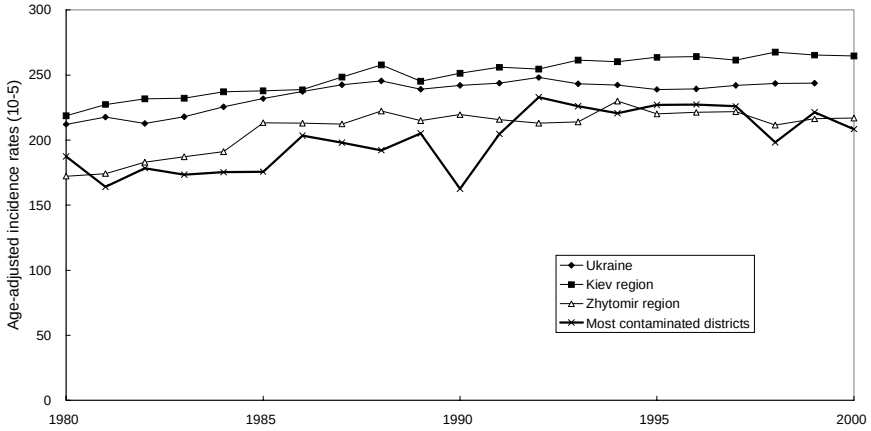

Fig. I. Incidence rates for all cancers in various regions of the Ukraine. Males and females.

Table 1. Standardised incidence ratios for various cancers in residents of the most contaminated districts in Zhytomyr and Kiev regions.

Years of observation	Number of person-years of observation	Observed numbers of cases	Expected numbers of cases	SIR (%)	95% CI
All cancers (ICD-IX 140-208), males and females					
1990-2000	**1660971**	**5378**	**6781**	**79.3**	**77.2 - 81.4**
1990-1993	654501	2143	2607	82.2	78.8 - 85.7
1994-1997	556631	1820	2283	79.7	76.1 - 83.4
1998-2000	449839	1415	1891	74.8	70.9 - 78.7
Leukaemia and lymphoma (ICD-IX 200-208), males and females					
1990-2000	**1660971**	**310**	**295.7**	**104.8**	**93.2 - 116.5**
1990-1993	654501	127	114.1	111.3	92.8 - 131.5
1994-1997	556631	100	98.8	101.2	82.3 - 122.0
1998-2000	449839	83	82.8	100.3	78.7 - 121.8
Thyroid cancer (ICD-IX 193), males and females					
1990-2000	**1660971**	**107**	**57.3**	**186.7**	**151.4 - 222.1**
1990-1993	654501	24	22.4	107.2	68.6 - 154.4
1994-1997	556631	48	19.3	249.1	183.6 - 324.6
1998-2000	449839	35	15.60	224.4	150.1 - 290.8
Breast cancer (ICD-IX 174) females					
1993-1997*	389645	162	107.8	150.3	127.1 - 173.4
1998-2000*	240917	97	64.1	151.3	121.2 - 181.4

*Because of significant territorial variation of breast cancer incidence in the Ukraine SIR was calculated on a base of local standard 1980-1992.

the most contaminated districts.

For leukaemia and lymphomas (Figure II) in the population from the contaminated districts there were pronounced annual incidence fluctuations. Such annual figures showed an increase for the period 1987-1991 and 1999-2000. Analysis of aggregated time periods for leukaemia and lymphoma incidence rates showed higher levels in 1986-1991, 1992-1997 and 1998-2000 in comparison with the pre-accident period (1980-1985) (Table 2). When individual subtypes of these diseases were evaluated, a comparable increase was seen for lymphoid leukaemia in 1986-1991 and (non-significantly) for 1992-1997, 1998-2000. For myeloid leukaemia there was an increase in 1986-1991 and 1998-2000 [21, 24].

A screening (ascertainment) effect could be supposed for the first after-accident period. The overall regression coefficients for this entire period do not suggest any significant difference among the different

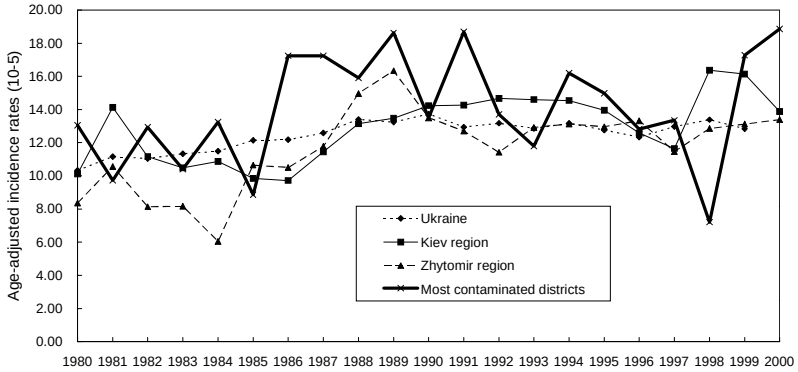

Fig. II. Incidence rates for leukaemia and lymphoma in various regions of the Ukraine. Males and females.

Table 2. Leukaemia and lymphoma incidence rates in the population (children and adults) of 5 most contaminated districts in Zhytomyr and Kiev regions, Ukraine.

Disease	ICD9 code	Mean annual age-adjusted incidence rate (10^{-5})			
		1980–1985	1986–1991	1992–1997	1998–2000
Leukaemia and lymphoma	200–208	10.12 ± 0.75	15.63 ± 1.06	13.41 ± 1.10	13.82 ± 1.52
Lympho- and reticulosarcoma	200, 202	1.84 ± 0.33	2.70 ± 0.41	3.70 ± 0.58	3.36 ± 0.90
Hodgkin's disease	201	1.82 ± 0.34	2.47 ± 0.48	2.10 ± 0.48	1.23 ± 0.50
Multiple myeloma	203	0.54 ± 0.16	1.03 ± 0.25	0.78 ± 0.22	1.38 ± 0.40
Lymphoid leukaemia	204	3.08 ± 0.40	4.93 ± 0.59	2.97 ± 0.49	4.11 ± 0.75
Myeloid leukaemia	205	0.49 ± 0.17	1.99 ± 0.41	1.06 ± 0.30	2.32 ± 0.62
Other leukaemias	206–208	2.35 ± 0.36	2.51 ± 0.41	2.81 ± 0.53	1.41 ± 0.53

territories [21]. Because of large-scale out-migration of the people from the contaminated areas, there is a concern that some members of the group of highest potential risk may have been lost to follow-up.

On the western part of Ukraine there was performed a study of morbidity and mortality rate of leukaemia and lymphoma in relation to the Chernobyl accident during the period 1981-1994 [25, 26, 27, 28]. There were studied the population in two regions: Rivne and Ivano-Frankivsk, which correspond to the contaminated and the non-contaminated regions as a result of Chernobyl accident, respectively. The study has revealed that leukaemia and lymphoma morbidity and mortality rate increased mainly during the period 1987-1994 in both regions, irrespectively of their being or not being contaminated by radionuclides. The most pronounced increase was observed in older age groups of the population of two regions. Besides, among different forms of these diseases there were registered increases of non-Hodgkin's lymphoma, chronic lymphocytic leukaemia and multiple myeloma.

The radiation-related origin of the dramatic increase of thyroid cancer incidence is not in doubt [29, 30]. In Ukraine, the overall incidence of thyroid cancer was approximately doubled during the post-Chernobyl (Figure III). In the Kiev region and city of Kiev, where some 70% of the population of Pripyat and the 30-km zone settled, the increases were significant (Figure IV). A dramatic increase occurred in 1996 and 1999 for the most contaminated areas [21].

In the 5 most contaminated districts, female breast cancer rate remained relatively stable during 1980-1992 (Figure V), though lower than in Ukraine as a whole or in regions that include contaminated districts. In 1993-2000, however, an increase in the rate of female breast cancer (Table 1) occurred in the 5 most contaminated districts; which now corresponds more closely to the rate typical of Ukraine as a whole [21, 22, 23].

A molecular-genetic study at Institute of Urology and Nephrology of AMS of Ukraine in collaboration

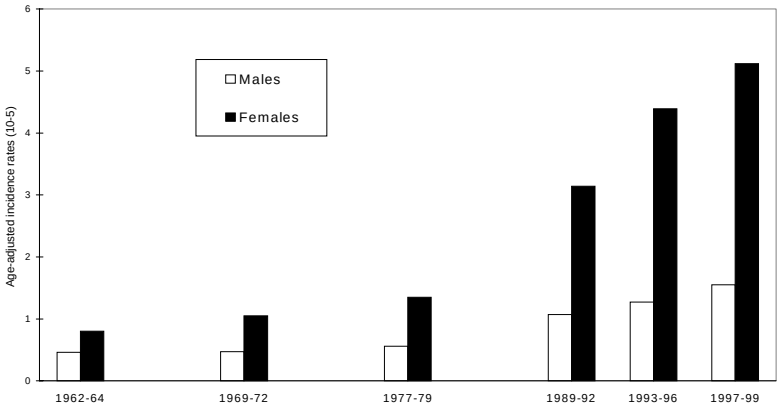

Fig. III. Mean annual age-adjusted thyroid cancer incidence rates in the Ukraine.

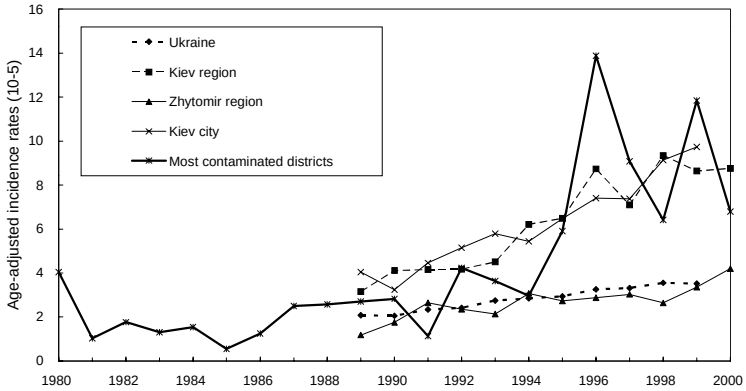

Fig. IV. Thyroid cancer incidence rates in various regions of the Ukraine.

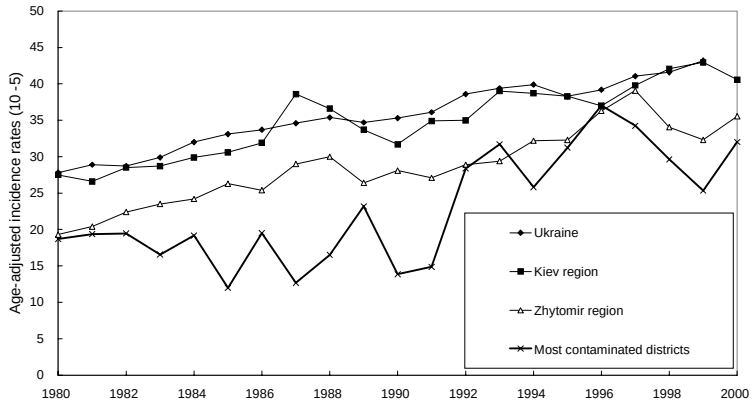

Fig. V. Breast cancer incidence rates in various regions of the Ukraine.

with medical experts of University of Osaka (Japan) gave the evidence that, among prostate adenoma patients who are inhabitants of the contaminated territories, in 53% there happened mutagenic inactivation of tumour-supressional gene, p53 and in 96% - development of pre-cancer changes in urotelii of urinary bladder [31]. The authors has connected these changes with chronic influence of low level ionising radiation which leads to genetic instability with possible development to chiefly invasive cancer of urinary bladder.

3.2. Cancer incidence in Chernobyl accident recovery operation workers (CAROW).

Standardised cancer incidence ratios (SIR) of different organs in CAROW of 1986, 1987 are illustrated in Table 3 for periods 1990-1993 and 1994-1997. Significant excess is observed in CAROW for all cancers in the first years following the accident, especially for the period 1990-1993 [22, 23].

Leukaemia and lymphoma are diseases that have drawn special attention after the Chernobyl accident. A study of leukaemia and lymphoma in a cohort of Russian recovery operation workers has shown excess of leukaemia and elevated radiation risks [32, 33, 34], but the data weren't confirmed in a case-control study [30].

In Ukraine an international haematological review was performed in relation to diagnosis validation evaluation of diagnostic material quality. The international experts panel has proved the adequacy of diagnostic criteria applied in different regions of Ukraine as satisfying the international standards and high quality level of diagnosis of acute and chronic leukaemia [35, 36]. The percentage of confirmed cases of Hodgkin disease and non-Hodgkin lymphomas for which histological slides were available was high, but the availability of data from the different sources (oncological or haematological dispensaries) has to be improved.

Table 3 Standardised incidence ratios for various cancers in Chernobyl accident recovery operation workers of 1986 and 1987.

Years of observation	Number of person-years of observation	Observed numbers of cases	Expected numbers of cases	SIR (%)	95% CI
All cancers (ICD-IX 140-208), males					
1990-1997	**577536**	**1496**	**1354**	**110.5**	**104.9 - 116.1**
1990-1993	263084	538	443	121.5	111.2 - 131.8
1994-1997	314452	958	911	105.1	98.5 - 111.8
Leukaemia and lymphoma (ICD-IX 200-208), males					
1990-1997	**577536**	**183**	**81.6**	**224.2**	**191.7 - 256.7**
1990-1993	263084	81	31.8	255.0	199.5 - 310.5
1994-1997	314452	102	49.9	204.6	164.9 - 244.3
Thyroid cancer (ICD-IX 193), males					
1990-1997	**577536**	**37**	**8.4**	**442.7**	**300.0 - 585.3**
1990-1993	263084	13	3.3	393.0	179.4 - 606.6
1994-1997	314452	24	5.1	475.2	285.1 - 665.4
Breast cancer (ICD-IX 174), females					
1990-1997	**39188**	**44**	**29.1**	**151.2**	**106.5 - 195.8**
1990-1993	15913	12	10.9	110.2	47.9 - 172.6
1994-1997	23275	32	18.2	175.6	114.8 - 236.5

A study based on the data base from the SRU for CAROW who were exposed in the period 1986-1987, the leukaemia and lymphoma incidence rate was significantly elevated in the years 1990-1993 and 1994-1997 [22, 23].

Other group of investigators has followed the incidence of leukaemia in CAROW of 1986 and 1987 up to the end of 1996 [37, 38]. In a cohort of 74.7 thousand CAROW (aged 20-69) there were registered 48 leukaemia cases during 1987-1996. The results were tabulated for the entire period of follow-up. The SIR ratio values were relative to the comparable age and period-specific rate for Ukraine as a whole. SIR for all leukaemia (107,8%, 95% CI 77.3 - 138.3%) were not elevated for the whole period of time. SIR for chronic lymphoid leukaemia did not indicate changes. However, SIR for chronic myeloid leukaemia suggested a increase of this malignancy (SIR - 258.7; 95% CI 127.8 - 389.5%). In 1989-1991 there was observed high risk of leukaemia in CAROW of 1986 in comparison with CAROW of 1987 [39].

Russian CAROW from the same period displayed their increase in all types of leukaemia, chronic lymphoid leukaemia and chronic myeloid leukaemia [32, 33, 34]. In Belorussian CAROW (again from 1986-1987) excess of acute leukaemia was seen for 1990-1991 [40].

Besides, Table 3 demonstrates the most significant increases in thyroid cancer occurred in CAROW of 1986, 1987 in the periods 1990-1993 and 1994-1997 [22]. A statistically significant increase in breast cancer incidence rate was also observed in female CAROW of 1986, 1987 in the period 1994-1997, but not during 1990-1993 (Table 3).

3.3. Cancer incidence rate in evacuees from 30-km zone.

Standardised cancer incidence rates of different organs in evacuees are illustrated in Table 4 for the periods; 1990-1993, 1994-1997. There is some evidence of increase of this pathology in the above-mentioned group of sufferers by the Chernobyl accident. Leukaemia and lymphoma cases are significantly elevated only for the 1990-1993 sub-period [23]. The most significant increases occurred in thyroid cancer in both 1990-1993 and 1994-1997 sub-periods. About female breast cancer a small increase is suggested [22, 23].

Table 4 Standardised incidence ratios for various cancers in evacuees from 30 km zone.

Years of observation	Number of person-years of observation	Observed numbers of cases	Expected numbers of cases	SIR (%)	95% CI
All cancers (ICD-IX 140-208), males and females					
1990-1997	**408882**	**870**	**1234**	**70.5**	**65.8 - 75.2**
1990-1993	208805	432	618	69.9	63.3 - 77.8
1994-1997	200077	438	616	71.1	64.5 - 77.8
Leukaemia and lymphoma (ICD-IX 200-208), males and females					
1990-1997	**408882**	**74**	**59.6**	**124.2**	**95.9 - 152.5**
1990-1993	208805	43	30.0	143.4	100.5 - 186.3
1994-1997	200077	31	29.6	104.7	67.9 - 141.6
Thyroid cancer (ICD-IX 193), males and females					
1990-1997	**408882**	**66**	**12.9**	**513.4**	**389.6 - 637.3**
1990-1993	208805	23	6.4	362.0	214.1 - 510.0
1994-1997	200077	43	6.5	661.4	463.7 - 859.1
Breast cancer* (ICD-IX 174) females					
1990-1997	**235072**	**72**	**52.3**	**137.7**	**105.9 - 169.5**
1990-1993	119915	37	25.7	143.9	97.5 - 190.2
1994-1997	115157	35	26.6	131.7	88.1 - 175.3

*Because of significant territorial variation of breast cancer incidence in the Ukraine SIR was calculated on a base of local standard 1980-1992.

3.4. Cancer incidence rates in children sufferers by the Chernobyl accident

Children constitute a group vulnerable to radiation. Cancer incidence rates in the children population of the most contaminated districts in Zhytomyr and Kiev regions are provided in Table 5, including the data for the period before the accident (1980-1985). When compared to the pre-accident values (1980-1985), the only significant excess observed in children is for thyroid cancer diagnosed during 1992-1997 and for leukaemia during 1986-1991, though the latter result may have other explanations than radiation.

According to [41] there was observed a steep increase of thyroid cancer incidence rate in children and adolescents of Ukraine. Before the Chernobyl accident (1981-1985) the level of morbidity constituted 0.05 per 100,000 children. In the post-accidental period the dynamics of this pathology was: 0.11 in 1986-1990, 0.41 in 1991-1995, and 0.40 per 100,000 children in 1996-2000.

Status of haemopoetic system due to acute and chronic irradiation has been studied in 42,888 children inhabiting the four contaminated regions of Ukraine during 15 years after the Chernobyl accident [42, 43]. Data analysis suggested absence of excess leukaemia and lymphoma incidence rate during 1980-1999 in comparison with spontaneous background. But, in a group of 3,840 exposed children with high risks of oncohematological pathology [42], 11 cases of acute leukaemia were registered during the period of observation of this cohort.

There was also performed a study of the incidence of acute childhood leukaemia during 1980-1996 in 12 large territories of Ukraine including 4 regions which were contaminated by the Chernobyl accident [44, 45, 46]. This study has revealed an increase of acute childhood leukaemia incidence rate in most of the regions excluding Kiev city. Certain specificity of different types of leukaemia in children age groups of 0-4, 5-9, 10-14 was revealed. It should be pointed out that the incidence rate of acute leukaemia in 10-14 years increased mainly in the contaminated regions. Acute myeloid leukaemia had a tendency to increase in 10-14 years. In the post-accidental period (1986-1996) there was also observed an increase of inherited leukaemia in most of territories.

With relation to this finding there is a very interesting study of acute leukaemia occurrence among the children exposed *in utero* due to the Chernobyl accident [47]. To ascertain the effect of *in utero* radiation exposure and the development of leukaemia a review was undertaken of leukaemia subtypes occurring

Table 5 Standardised incidence ratio (SIR) for cancer in children population (0-14) of the most contaminated districts in Zhytomyr and Kiev regions.

Site of tumours (code ICD-IX) and years of observation	Number of person-years of observation	Observed numbers of cases	Expected numbers of cases	SIR (%)	95% CI
All cancers (140-208)					
1980-1985	337076	44	36.48	120.62	84.98 - 156.26
1986-1991	209337	44	22.69	193.95	136.64 - 251.26
1992-1997	150170	31	16.26	190.62	123.51 - 257.72
1998-2000	80656	7	8.70	80.46	20.86 - 140.07
1998-2000 (age 10-29)	107629	37	22.61	163.62	110.90 - 216.34
Leukaemia and lymphoma (200-208)					
1980-1985	337076	21	17.28	121.51	69.54 - 173.49
1986-1991	209337	27	10.75	251.11	156.39 - 345.84
1992-1997	150170	11	7.72	142.49	58.28 - 226.69
1998-2000	80656	2	4.13	48.47	(-18.71) - 115.66
1998-2000 (age 10-29)	107629	10	7.58	131.88	50.14 - 213.61
Leukaemia (204-208)					
1980-1985	337076	19	10.88	174.68	96.13 - 253.22
1986-1991	209337	22	6.78	324.35	188.82 - 459.89
1992-1997	150170	7	4.87	143.70	37.25 - 250.15
1998-2000	80656	0	2.59	0.00	0.00 - 0.00
1998-2000 (age 10-29)	107629	5	2.58	193.63	23.91 - 363.35
Thyroid cancer (193)					
1980-1985	337076	0	1.13	0.00	0.00 - 0.00
1986-1991	209337	2	0.69	289.84	(-111.86) - 691.53
1992-1997	150170	9	0.49	1824.77	632.59 - 3016.95
1998-2000	80656	1	0.28	362.91	(-348.40) - 1074.22
1998-2000 (age 10-29)	107629	6	1.14	527.32	105.38 - 949.27
All cancers except leukaemia and lymphoma, and thyroid cancer (140-208 less 200-208, 193)					
1980-1985	337076	23	18.07	127.29	75.27 - 179.31
1986-1991	209337	15	11.24	133.40	65.89 - 200.91
1992-1997	150170	11	8.05	136.65	55.89 - 217.40
1998-2000	80656	4	4.30	93.06	1.86 - 184.26
1998-2000 (age 10-29)	107629	21	13.89	151.16	86.51 - 215.81

among the children born in the year of Chernobyl accident (1986) and followed 10 years of post-exposure in the most affected region of the Ukraine (Zhytomir region). A comparison of leukaemia cumulative incidence rates was made between the children from the exposed and the non-exposed (Poltava region) territories. For all cell types of leukaemia there was observed a significantly increase of incidence in the exposed region. The rate of acute lymphoblastic leukaemia was more than three times greater in the exposed region than in the unexposed region. The results of this study suggest that the increased risk of acute leukaemia among those children born in 1986 and reside in the radioactively contaminated territories may be associated with exposure to radiation resulting from the Chernobyl accident.

4. Discussion and conclusion

The established system of follow-up, dispanserisation of sufferers by the Chernobyl accident allow to collect annually data about health status of different groups of these people. In this context it should be reminded that the health condition of sufferers by the Chernobyl accident as well as Ukrainian population as a whole are related not only with the consequences of Chernobyl, but with aggravation in the last years of economic, social and environmental conditions in Ukraine. The Chernobyl accident has caused a heavy impact on the environment of vast territories of Ukraine, significant worsening of the economic situation in state, disruption of social life in the contaminated areas, growing anxiety and fears among sufferers, as well

as certain biomedical effects on the people.

From the other side the exposed population undergo much more intensive and active follow-up of their status of health rather than do the general population. Implementation of modern screening procedures (for example ultrasound devices) have improved the quality of diagnostic procedures. These could in some degree influence on the registered figures of diseases. Meanwhile, these figures are basis for analysis and conclusions about long-term tendencies in health status of the population affected by the Chernobyl accident.

Similar trends in incidence rates for cancer were apparent in the different Ukrainian population groups directly affected by the Chernobyl accident (residents of the most contaminated districts, recovery operation workers and evacuees). There is excess of thyroid cancer [21, 22, 23, 24, 29, 30, 41]. For female breast cancer and some other solid cancers there are suggestions of increases. Further studies are required to confirm these tendencies along with evaluation of the effects of screening and improved registration quality. The small number of cases for certain types of cancer and the confounding effect due to out-migration mean that cancer monitoring and surveillance should include not only the contaminated districts but outside regions where such residents are relocated. The apparent increases at least in part may reflect differences in case ascertainment between the affected groups and the general population of Ukraine, not relating with a radiation-related effect [30, 48]. The existing data on cancer and leukaemia-lymphoma incidence after Chernobyl are based on the two registries: Chernobyl registry (SRU) and national cancer registry (NCR). This approach requires more comprehensive linkage between two registries.

References

1. Fifteen years of Chernobyl catastrophe. Experience of mitigation. National Report of the Ukraine, K.:Chornobylinterinform, 2001, 144 p. (in Ukrainian).
2. Ministry of the Chernobyl Affairs of Ukraine. Ten years after the accident at the Chernobyl nuclear power plant. Ukrainian National Report, Kiev (1996). (In Ukrainian).
3. Oleg Nasvit. Research and Managing Institution in Ukraine concerning the Radiological Consequences of the Chernobyl Accident. In: T. Imanaka (Ed) - Research Activities about Radiological Consequences of the Chernobyl NPS Accident and Social Activities to Assist the Sufferers by the Accident. Research Reactor Institute, Kyoto University, March 1998, pp.58-64.
4. Gulak L.O. Cancer register of the Ukraine: Experience of formation and usage in scientific researches and branch administration. Environment and Health, Kiev, ¹ 2, 1997, pp. 12-13. (In Russian).
5. Winkelmann R., Gulak L., Okeanov A., Remennik I. Cancer registration techniques in the New Independent States of Former Soviet Union /IACR, Lyon, 1998, 200 p.
6. 6 Gulak L.O. Methodological aspects of large scale cancer register formation. Oncology, Kiev, Vol. 3, ¹ 2-3, 2001, pp.198-202. (In Russian).
7. Buzunov V.A., Pirogova Ye.A., Tereshtchenko V.M. at al. Dinamic of adult population health living on contaminated with radionuclieds territories in: Medical Consequences of the Chernobyl Accident, Monograph in 3 books."MEDECOL" interdisciplinary Scientific and Research Centre BIO-ECOS, Kiev, 1999, Book 1, -pp. 108-119. (In Russian).
8. Omelyanets N.I., Kartashova S.S. Medico-demographycal consequences . //Chernobyl catastrophe. - K., 1995. - P.414-417. (in Russian).
9. Omelyanets N.I., Kartashova S.S. , Dubova N.F., Savtchenko A.B. Integral estimation of Social - economic and demographyc condition in contaminated with radionucleads regions of the Ukraine, in: Remote medical consequences of the Chernobyl Catastrophe: Proceeding 2 international conference, 1-6 June, - K., 1998. - pp.102-103. (In Ukrainian).
10. Buzunov V.A., Strapko N.P., Krasnikova L.I. Time trend of health of Chernobyl NPP accident consequences liquidates. In.: Medical Consequences of the Chernobyl Accident, Monograph in 3 books. "MEDECOL" Interdisciplinary Scientific and Research Centre BIO-ECOS, Kiev, 1999, Book 1, pp.65-85.
11. Buzunov V.A., Strapko N.P., Pirogova Ye.A. et al. Epidemiology of non-cancer diseases among Chernobyl

accident recovery operation workers. / International Journal of Radiation Medicine , 2001, 3(3-4): 9-25.

12. Nyagu A.I., Loganovsky K.N., Chuprovsky N.U. et all. Neuropsychiatric effects in: V.G.Bebeshko, A.N.Kovalenko (Eds). - Book 2. Clinical aspects of the Chernobyl catastrophe. - K.: "MEDECOL" interdisciplinary Scientific and Research Centre BIO-ECOS, Kiev 1999, pp.154-186. (In Russian).
13. Medical Consequences of Chernobyl nuclear power station accident. Book 2. Clinical aspects of the Chernobyl catastrophe. V.G.Bebeshko, A.N.Kovalenko (Eds).- K.: "MEDECOL" interdisciplinary Scientific and Research Centre BIO-ECOS, pp. 399. (In Russian).
14. Medical Consequences of the Chernobyl Nuclear Power Plant Accident. Book 1. Epidemiology of Medical consequences of the Chernobyl NPP Accident. V.A .Buzunov, L.A.Likhtarev (Eds). "MEDECOL" interdisciplinary Scientific and Research Centre BIO-ECOS, Kiev 1999, pp.315. (In Russian).
15. Buzunov V.A., Pirogova Ye.A., Prikashtchikova Ye.Ye., Strapko N.P. Dinamic health status adult population evacuated from 30 km zone and Pripyat city in Medical consequences of the Chernobyl Accident Monograph in 3 books."MEDECOL" interdisciplinary Scientific and Research Centre BIO-ECOS, Kiev, 1999, V. 1, -pp. 86-107. (In Russian).
16. Buzunov V.A., Pirogova Ye.A., Repin V.S. at all. Epidemiologic studies of non-cancer incidence of adult population evacuated from Pripyat and 30-km zone surround the Chernobyl NPP. / International Journal of Radiation Medicine , 2001, Vol. 3(3-4).- pp.26-45.
17. Korol N.A., Treskunova T.V., Duchota T.A. Children health status affected by accident on CNPP in: Medical consequences of the Chernobyl Accident, Monograph in 3 books."MEDECOL" interdisciplinary Scientific and Research Centre BIO-ECOS, Kiev, 1999, Book 1, -p. 120-134. (In Russian).
18. Romanenko A.E., Bomko E.I., Bomko A.A. Estimation of health effects of long-term chronic exposure of the low lively radiation among children exposed in consequence of the disaster at the Chernobyl nuclear power plant //Low doses of ionizing radiation: biological effects and regulatory control: Proceeding of 1st int. conf., Seville, Spain, 17-21 November, 1997. - Vienna, 1997. - P. 326-329.
19. Romanenko A.E., Bomko E.I., Kostenko A.I.,Bomko A.A. Incidence of children resident on radioactively contaminated territories of Ukraine and chronically exposed to low doses of ionising radiation. / International Journal of Radiation Medicine , 2001, Vol. 3(3-4).- pp.61-70.
20. Stepanova Ye. I. Medico-biological consequences of Chernobyl catastrophe in affected children population. "MEDECOL" interdisciplinary Scientific and Research Centre BIO-ECOS, Kiev, 1999, Book 2, -p. 5-32. (In Russian).
21. Prysyazhnyuk A. et al. Results of long-term monitoring of solid cancers and leukaemia in population still living in the most contaminated with radionuclides territories of the Ukraine after the Chernobyl accident (preliminary report). In: International Conference "Fifteen Years after the Chornobyl Accident. Lessons Learned". Kiev, 2001. Chornobylinterinform. P. 3-118.
22. Prisyazhniuk, A. et al. Epidemiological study of cancer in the Ukraine with reference to the Chernobyl accident. p. 199-228 in: Seventh Symposium on Chernobyl-Related Health Effects, Tokyo, 25-16 November 1998.
23. Prysyazhnyuk A. Ye. et al. Malignant neoplasms in different groups of population affected by the Chernobyl accident. In: International Journal of Radiation Medicine, 2001, Vol. 1, No 1-2, P. 110.
24. Prisyazhniuk, A., V. Gristchenko, V. Zakordonets et al. The time trends of cancer incidence in the most contaminated regions of the Ukraine before and after the Chernobyl accident. Radiat. Environ. Biophys. 34: 3-6 (1995).
25. Wyhowska J., Lukawecki L., Mazurok A., Ciapka O., Fabryka A. The multiple myeloma morbidity before and after nuclear catastrophe in Chernobyl. A study of two administrative districts of the Ukraine: Rivnensk and Ivano-Frankovsk //Applied Biology Communications. - 1997. - 7, Suppl. 1. - P. 175.
26. Lukawecki L., Vygovska Y., Prysyaznyuk A., Mazurok A., Tsiapka O., Masliak Z., Fabryka A. The chronic lymphocytic leukaemia morbidity before and after nuclear catastrophe in Chernobyl //Acta Haematologica Polonica. - 1998. -29, Suppl. - P. 119. (In Polish).
27. Y.I.Vygovska, L.M.Lukavetsky, A.A.Mazurok, O.M.Tsiapka, A.V.Fabryka. Mortality rate caused by leukemia and lymphoma in Ukraine before and after Chernobyl catastrofe //Brit.J. of Haematology. - 1998.-102.-P.36.
28. Y.I.Vygovska, L.M.Lukavetsky, A.Ye.Prysyaznyuk, A.A.Mazurok, O.M.Tsiapka, Z.V.Masliak, A.V.Fabryka, L.O.Karlyuk, A.S.Kalis. Haemablastosis incidence rate in representative terrytories of the Ukraine before and after

Chernobyl accident /Ukrainian medical newes. - 1998. -2, ¹1-2. pp.252-253. (in Ukrainian).
29. Prisyazhniuk, A., O.A. Pjatak, V.A. Buzanov et al. Cancer in the Ukraine, post-Chernobyl. Lancet: 338(8778): 1334-1335 (1991)
30. .United Nations. Sources and Effects of Ionizing Radiation. Volume I: Sources; Volume II: Effects. United Nations Scientific Committee on the Effects of Atomic Radiation, 2000 Report to the General Assembly, with scientific annexes. United Nations sales publication E.00.IX.3 and E.00.IX.4. United Nations, New York, 2000.
31. Romanenko A., C.Lee, S.Yamamoto et al., Urinary bladder lesions after the Chernobyl accident: immunhistochemical assessment of p. 53, proliferation cell nuclear antigen, cycling D 1 and p 21 WAF1/Cip 1. Jpn. J. Cancer Res. -1999. - ¹ 90. -p.144-153.
32. Ivanov, V.K., E.V. Nilova, A.I. Gorsky et al. Leukaemia incidence in the population of the contaminated districts of the Bryansk region after the Chernobyl accident (1991-1996 data). in: Fifteen Years after the Chernobyl Accident. Lessons Learned. International Conference, Kiev, 18-20 April 2001, PP. 3-66.
33. Ivanov, V.K., A.F. Tsyb, A.I. Gorsky et al. Leukaemia and thyroid cancer in emergency workers of the Chernobyl accident: estimation of radiation risks (1986-1995). Radiat. Environ. Biophys. 36(1): 9-16 (1997).
34. Ivanov, V.K., A.I. Gorski, A.F. Tsyb et al. Radiation risks of leukemia among Russian emergency workers, 1986-1997. in: International Symposium on Radiation and Homeostasis, Kyoto, Japan, 13-16 July 2001. (In press).
35. Romanenko A.Ye. et al. Main results of pilot study of leukaemia and related diseases in participants of mitigation consequences of Chernobyl catastrophe in Ukraine. In: International Conference “Fifteen Years after the Chornobyl Accident. Lessons Learned”. Kiev, 2001. Chornobylinterinform. P. 3-69. (In Russian).
36. Dyagil I.S. et al. Experience of international haematological review in Ukraine. In: Ukrainian journal of haematology and transfusiology, 2001, N1, PP. 15-18 (in Russian).
37. Ledoshchuk B.A. et al. Results of the 10-years study of leukemia in Chernobyl accident clean-up workers in Ukraine. In: Risk Analysis: Facing the New Millenium. Proceedings of SRA-Europe 9th Annual Conference/ Rotterdam, the Netherlands. October 10-13, 1999. P.833-836.
38. Ledoshchuk B.A., Gudzenko N.A. Leukemia, lymphoma and related disorders in clean-up workers of the Chernobyl catastrophe consequences: developing of our understanding. In: Foresight and Precaution. Proceedings of ESREL 2000, SARS and SRA-Europe Annual Conference. Edinburgh, Scotland, UK. May 14-17, 2000. P. 765-767.
39. Ledoshchuk B.A., Gudzenko N.A. Haemoblastosis in liquidators: 15 years after Chernobyl catastrophe. Main results and perspective. In: International Conference “Fifteen Years after the Chornobyl Accident. Lessons Learned”. Kiev, 2001. Chornobylinterinform. P. 3-10.
40. Ivanov, E.P. et al. Chernobyl registry and hematological surveillance of Belarus liquidators. p. 171-192 in: Sixth Symposium on Chernobyl-Related Health Effects, Tokyo, 10-11 December 1997.
41. Tronko N.D., Bogdanova T.I. Thyroid cancer in children of the Ukraine (consequences of Chernobyl catastrophe). Kiev: Chornobylinterinform, 1997. 198 p. (in Russian).
42. Bebeshko V.G. et al. Evaluation of blood performing system in Children, evacuated from Prypyat city and inhabited on contaminated with radionuclides territories after Chernobyl accident. In: International Journal of Radiation Medicine, special issue, 2001, Vol. 3, N2, P. 159.
43. Bebeshko V.G. et al. Influence of negative factors of environment on development of leukaemia and lymphoma in children inhabited in Kiev region before and after Chernobyl accident. In: Ukrainian Journal of haematology and transfusiology, 2001, N2, PP. 17-25 (in Russian).
44. G.Moroz. Childhood leukaemia in Kyiv city and Kyiv region after Chernobyl -17 year follow up // British Journal of Haematology. - 1998. -Vol.102, ¹1. - P.19.
45. Moroz G., Drozdova V., Kireyeva S. Analysis of prognostic factors of acute leukemia after Chernobyl in children of Kyiv //Annals of Hematology. - 1999.- Suppl. II to Vol. 78. - P.40.
46. Moroz G., Drozdova V. Risk of acute childhood leukaemia in Ukraine after the Chernobyl reactor accident // The Hematology Journal. - 2000.- Vol. 1, Suppl. 1. - P. 3.
47. Andrey G Noshchenko, Kirsten B Moysich, Alexandra Bondar, Pavlo V Zamostyan, Vera D Drosdova and Arthur M Michalek. Patterns of acute leukaemia occurrence among children in the Chernobyl region. / International Journal of Epidemiology 2001; 30: 125-129.
48. Boice, J.D. Jr. and L.E. Holm. Radiation risk estimates for leukaemia and thyroid cancer among Russian

emergency workers at Chernobyl. Letter to the editor. Radiat. Environ. Biophys. 36: 213-214 (1997).