MEDICO-DEMOGRAPHIC CRITERIA IN ESTIMATING THE CONSEQUENCES OF THE CHERNOBYL ACCIDENT

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1. INTRODUCTION

Upon the Chernobyl accident, there were many preconceived interpretations of the demographic evolution of the contaminated territories, in particular, those concerning quantitative estimates of the additional mortality caused by the accident. Regardless of the opinion of specialists[1,2] the public associates every manifestation of worsening health of emergency workers and residents of contaminated areas with radiation factor.

Correct comparison of population statistics in affected and unaffected areas prior to and after the accident allows to detect any noticeable deviations in basic medico-demographic parameters in contaminated territories from a common trends, if at all. In view of that when in 1990 in Nuclear Safety Institute a start has been made on construction of an information support system for government and regional executives to overcome the consequences of the Chernobyl disaster [3] a specialised data bank on demography and medical statistics (MDBD) was created. Nowdays it embraces official population statistics for almost all regions of Russia for the period 1982-1994. For example there is a structure of data bank on mortality from different reasons being a constituent of MDBD shown in Fig. 1.

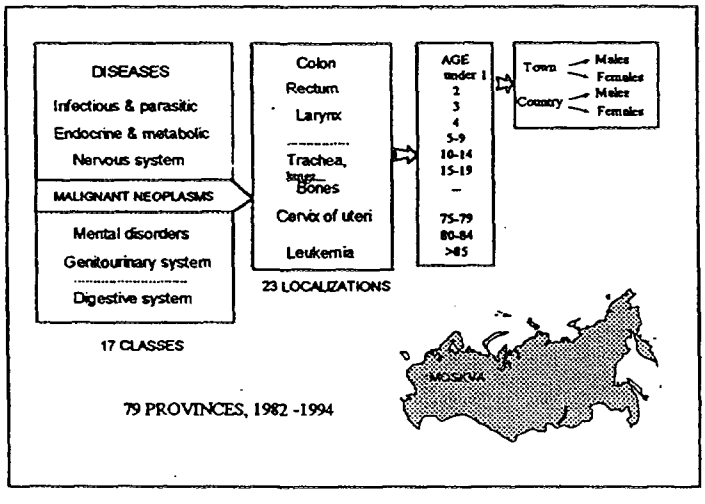

Fig. 1. Structure of data bank on mortality from different reasons

Data of MDBD are also valuable as a broad-based reference in study of emergency workers (EW) health statistics. For the majority of EW registered in Russia participation in decontamination work was a short-term episode (2-3 months)[4] which superimposed on their different base health levels depending on their native regions. So, it is particularly important to take into account territorial features as well as disadvantageous trends in people health all over Russia .

2. MATERIALS AND METHODS.

In the Russian Federation there are about 56.0×103 km2 contaminated areas (137Cs density >37 kBq.m-2) assigned to 17 provinces with 2.7 million people. The population fell into 3 groups according to the zoning of contaminated territories. Some 90,000 live in the zone of boundary resettlement, ZR (> 555 kBq.m-2), another 325,000 live in the zone of voluntary resettlement, ZVR (185 - 555 kBq.m-2) and the others live in favourable social and economic status zone which is of 85% of the affected territories.

In fact there is no specialised statistics on the exposed population systematically collected to cover all contaminated areas. The most primitive data of variations of population size have been collected by the State Committee on Statistics since 1992 in ZR and ZVR only. Actually health statistics available for areas of different contamination density are rather poor and some serious omissions in organisation of statistical data collection were made In spite of that altogether with all the data collected in MDBD it allows us to be sure of not overlooking radiation health effects in demographic development of the affected populations in Russia. To follow long-term trends we can refer to the whole province (oblasts) population statistics. Territories referred as ZR are located in one province (Bryanskaya oblast - BO) and those referred as ZVR are spread over four provinces of central Russia (BO, Kaluzhskaya, Orlovskaya and Tulskaya oblasts). Residents of both zones are a considerable part of the oblast populations (except Kaluzhskaya oblast), countrypeople in particular (Table I). In comparative analysis of oblast statistics we can use standardised indexes since detailed information on population size and age-sex structure is available from MDBD, for the zones only crude indexes are used.

Table I. Characteristics of population in the most contaminated oblasts in Russia.

Oblast	Population size, 1994 $\times 10^3$	Percentage of zone residents in population, %		
		Oblast	Villages	Towns
Bryanskaya	1470.9	33	26	8
Kaluzhskaya	1092.0	10	7	19
Orlovskaya	914.3	31	14	61
Tulskaya	1820.1	51	46	74

As a reference we take national average values and data averaged over Central Economic Region (CER) being an administrative union of 12 oblasts and Moscow city with some 30 million people of which 7% are under exposure.

To form reference group for EW cohort we took selected age group of 20-45 (as of 1986) of urban males in various regions of Russia as it is known that approximately 90% of EW are males mostly from towns [4].

3. RESULTS

3. 1. Dynamics of population size and age structure.

Present demographic situation in Russia accumulated the problems of the past, including consequences of the World War II, and recent social, and economic difficulties, including decrease in life standard and crisis of national medical surveillance. Since early 90s changes of population size in Russia were determined by two opposite processes - natural decrease and positive migration balance. For the whole Russia population it resulted in depopulation. In CER this process evolved even more rapidly. In contrast to that in the most contaminated areas number of inhabitants was about the same owing to newcomers (Table II). In ZR immigration in the past few years has became a considerable phenomenon in demographic situation. For the period 1992-1994 total number of new residents in ZR was 15,000 people, that is about 16% of the population. The only possible reason attracting newcomers might be compensations and economic privileges granted by the federal government to residents of contaminated areas. It should be noted that emigrants have not been exposed and they bring their own reproduction traditions and different health problems. If uncontrolled migration goes on it will certainly misrepresent health statistics in the zone.

Table II. Change of population size and its components

Territory	Population size*, $\times 10^3$			Natural decrease, 1994 per 1000	Migration coefficient, 1994 per 1000
	1992	1993	1994		
ZR	89.9	90.6	89.9	- 8.7	14.1
ZVR (BO)**	152.0	151.7	151.7	- 5.7	9.0
BO	1463.8	1465.4	1470.9	- 7.1	12.5
ZVR***	314.6	325.5****	325.2	- 10.0	10.8
CER	30383	30277	29872	- 10.4	7.2
Russia	148295	148146	147968	- 6.1	5.5

* permanent residents

** ZVR assigned to Bryanskaya oblast

*** ZVR located in 4 oblasts

**** In 1993 several new settlements came into ZVR .

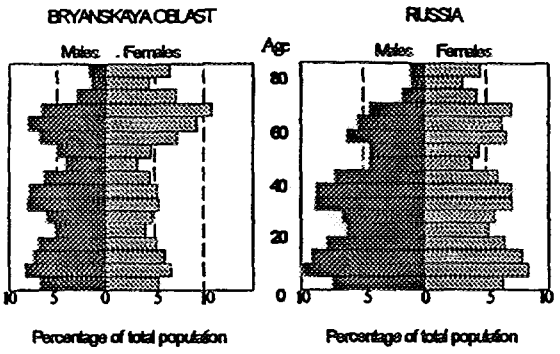

Fig. 2. Age-sex piramid for rural population in BO and Russia, 1994 ·

Age structure of CER population is demographically 'old' one[5,6] . In 1994 proportion between the young, working-age people and pensioners was as follows : 24% , 59% of and 17%. In towns part of working-age people(62%) is higher than that in country (54%). In the oblasts of interest part of pensioners is even higher, it is about one third of rural population [7].

Deficiency in young and working age people in rural population is clearly demonstrated in Fig. 2. It is a reason for high mortality crud indexes. The very small part of fertilise age females is quite important for understanding of low birth-rate.

3. 2. Birth-rate

Economic difficulties and deficiency of women of fertile age caused by birth-rate reduction in the 60s resulted in long-term tendency for the birth-rate to decrease in all regions of Russia since 1986. In 1993 some increase in number of women in fertile stabilised the situation (Fig. 3).

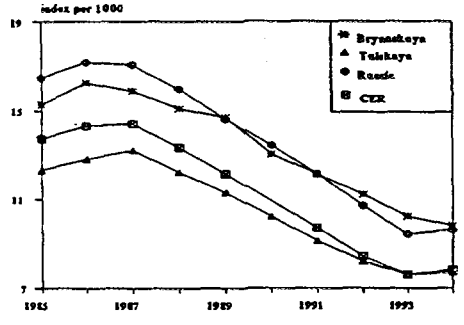

Fig. 3. Birth-rate dynamics in Bryanskaya and Tulskaya oblasts, CER and Russia (crude index).

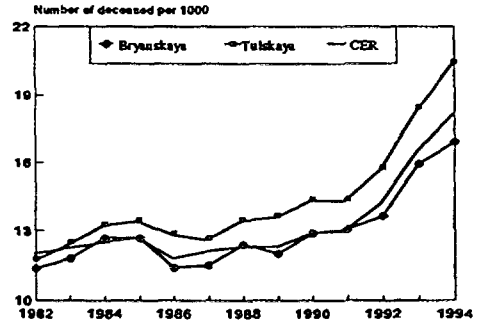

Fig. 4. Dynamics of total mortality in Bryanskaya, Tulskaya oblasts and CER (crude indexes).

Table III. Crude indexes of birth-rate and mortality in tested and reference territories.

Territory	Percentage of countryfolk in population, 1994 (%)	Birth-rate, index, per 1000			Total mortality, index, per 1000		
		1992	1993	1994	1992	1993	1994
ZR	53	13.1	12.3	11.2	15.1	18.4	19.8
ZVR	51	10.2	9.4	9.5	15.1	17.9	19.5
Bryanskaya	32	11.2	10.2	9.8	13.7	15.9	16.9
Kaluzhskaya	26	9.2	8.0	8.2	13.2	15.8	17.4
Orlovskaya	37	9.7	9.2	9.5	14.0	16.0	16.8
Tulskaya	19	8.2	7.7	7.6	15.8	18.4	20.5
CER	17	8.4	7.6	7.8	14.3	16.6	18.2
RUSSIA	27	10.7	9.4	9.6	12.2	14.5	15.7

In general in Russia birth-rate in country areas is higher than that in towns. Hence urbanisation degree (Table III) should be taken into account as well as difference in population age structure when one compares birth-rate baselines in the oblasts of interest. Against the baselines the birth-rate situation in contamination

zones is appreciably better. Every year in the period 1992-1994 ZR birth-rate ranked first, birth-rate in ZVR was a little lower but still well above CER average values (Table III).

Both in ZR and ZVR in rural areas birth-rate declined even slower then the broad base values, in contaminated towns it was about the same as in unaffected ones (Table IV). So, disadvantageous processes occurring in contaminated zones, are not as intense as in unaffected territories in the country in particular.

3. 3. Total Mortality

In Russia in recent years very low birth-rate combined with a rapid growth in mortality. In fact total mortality started to increase in the oblasts of interest well in advance of the accident. The tendency was broken off in 1985 only and resumed after 1987 (Fig. 4). This phenomenon was seen everywhere in Russia and it is believed to be a short-term effect of the anti-alcohol campaign conducted in those years[5,6]. The early 90s were marked by accelerating growth of mortality rates.

Table IV. Birth-rate in rural and urban areas in tested and reference territories (index per 1000)

Territory	Rural			Urban		
	1992	1993	1994	1992	1993	1994
ZR	12.7	12.0	11.7	13.5	12.9	10.7
ZVR (BO)*	11.6	11.0	10.7	12.4	11.5	10.5
BO		10.9	10.3		9.9	9.6
ZVR **	10.0	9.3	9.4	10.3	9.5	9.5
CER		8.4	8.3		7.4	7.8

* Territories in BO assigned to ZVR

** All territories with ZVR status

Table V. Mortality of rural and urban subpopulations in BO (index per 1000)

Territory	Rural population			Urban population		
	1992	1993	1994	1992	1993	1994
ZR	18.3	22.4	24.7	11.6	13.9	14.3
ZVR (BO)	15.8	18.1	18.8	12.0	13.2	13.9
BO	18.5	21.5	22.7	11.4	13.3	14.2

* - territories in BO assigned to ZVR

In the past decade in Russia growth of rural mortality (in standardised indexes) overtakes the urban one [7,8]. Higher percentage of countryfolk in ZR and ZVR populations is one of the reasons for crude mortality indexes in ZR and ZVR being higher than the broad-based values (Table III). But if we take rural and urban people separately the excess over entire oblast values both for ZR and ZVR is less (Table V) is much less.

In BO difference in rate of true growth of mortality (standardised index) in post-accident period and prior to the accident was not significant: average annual increase of standardised index was 0.33 (± 0.09) deceased persons per 1000 a year in 1982-1985 and 0.41 (± 0.13) in 1987-1993 [8]. A dramatic increase of mortality seen after 1992 was a common effect for all territories in CER. As to long-term trends (1982-1994) the analysis of test to reference ratio of standardised mortality indexes showed that in BO mortality rate grows slower than in neighbouring oblasts : for rural subpopulation in BO annual increase of mortality rate is 2.1% less than in control (at significance level 99.99%) that is 28 deceased persons per 100,000 in a year.

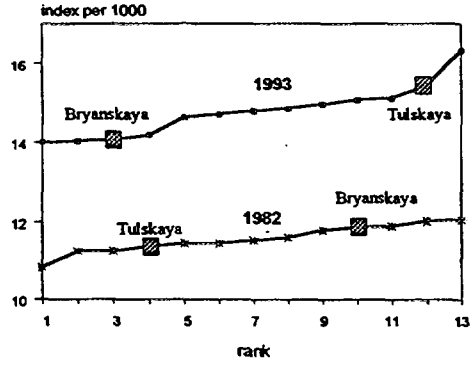

Fig. 5. Standardised mortality indexes (see explanation in text).

To provide another support to the conclusion that the most contaminated oblast is in better condition now let us compare the mortality situation in BO with that in other oblasts in CER. Fig. 5 presents standardised total mortality indexes in 13 administrative units of CER according to their ranks in 1982 and 1993. In other words, the oblast that holds the first place has the lowest mortality level, the highest mortality level corresponds to the thirteenth place. One can see that mortality levels have risen everywhere since 1982 and BO changed from tenth position to third while in many others the situation became worth, for instance in Tulskaya oblast.

For the past decade reduction of lifetime expectancy of rural males in BO was more substantial than that for the population at large but not for females (Table VI). As a result the difference between sexes reached extremely high value of 13.4 years. It should be noticed that for rural males in Tulskaya oblast life expectancy is even less than in BO (55.9 against 58.6). It means that

there are more important factors responsible for the shortening of lifetime than radiation. In towns the situation in BO is better than in Russia (Table VI).

3. 4. Mortality from different reasons.

In connection with radiological consequences of the accident the public is very anxious about cancer mortality. In fact it does grow in the oblasts of interest; also in all other regions in CER. For the period 1982-1994 in rural areas in BO standardised indexes (all site neoplasms) increased from 131 to 171 deceased person per 100,000 against 150 and 185 in control population in 4 unaffected neighbouring oblasts.

Statistics show that standardised cancer mortality rate in BO population has been one of the lowest one in CER in the period 1982-1994. For example, in 1993 BO held the second place (rank = 2) among 13 others in 1993. Besides, there is no any correlation between growth of mortality and average individual or collective doses: Orlovskaya, Tulskaya and Kaluzhskaya oblasts held 3, 7 and 10 places correspondingly. And in oblasts of interest rates of cancer mortality growth prior to and after the accident were the same statistically.

Analysis of test to reference population index ratio displayed that at 95.5% significance level cancer mortality standardised indexed grew in rural subpopulation in BO more rapidly than in control (0.8% a year). Having the better situation with the other indexes it is reasonable to attribute this fact to special attention to cancer problems and better cancer certification in the affected areas [9].

Certainly, epidemiological researches and statistics of cancer incidence will dive more convincing data on stochastic effects of radiation exposure. But as to people health statistics recent increase of accidental mortality (accidents, injuries, poisoning etc.) causes more alarm than does cancer mortality. Since 1987 standardised accidental mortality indexes have increased 5 - 6 times everywhere as cancer mortality increase was well beyond that (less than 30% for the same time). As a result approximately equal number (in some oblasts even more) of people die in accidents and from cancer nowadays although ten years ago the proportion was 2:3.

Table VI. Average expected lifetime in rural and urban areas in tested and reference territories (years)

Territory	1982/83		1992/93	
	Rural	Urban	Rural	Urban
	Bryanskaya oblast			
Males	61.7	64.8	58.6	62.3
Females	72.4	72.8	72.0	71.8
	Russia			
Males	59.8	63.1	59.4	61.0
Females	73.0	73.7	70.6	71.4

The most frequent cause of accidental death is acute alcoholism (24% in BO, 16% in CER, 15% in Russia, 1994), suicides rank next in frequency (10-15%). Although data are not available it is reasonable to think that the situation is even worse as people there have extra money as a compensation from government for being irradiated.

Another reason for the rapid increase in mortality rates in the past few years was the disorganisation of the state health surveillance resulting from economic difficulties. In villages it has never been good and is now about to disappear. Although there were no marked changes in provision of doctors and beds in hospitals (Table VII) it did not reflect the real situation.

Table VII. Provision of doctors and beds (per 10, 000)

Territory	doctors			beds		
	1985	1989	1993	1985	1989	1993
ZR			20			136
BO	33.1	35.6	36.7	128	140	127
CER	58.2	59.7	50.7	136	141	130

Number of doctors in contaminated areas is about half as many as in BO as a whole so there is no much benefits for the affected people in excess of beds in hospital. According to some indirect indexes the health care in rural areas was adversely affected everywhere in CER [8]. For instance, in rural areas in Ryazanskaya oblast index reflecting the accessibility and quality of medical surveillance dropped by almost 1000 times in the past decade. In villages in BO it was 3 times only, possibly owing to more attention being paid by federal and local administrations to health care in connection with the accident.

3. 5. Prognosis up to 2010

Calculations of perspective population size and age-sex structure were made to follow the future demographic development in BO and in whole Russia. To do that we used method of movement of age distribution with one year interval. Under unstable social situation and economic difficulties the demographic situation will very much depend on dynamics of such economic factors as national income and national product. If optimistic scenario realises [10] recession in industry will be overcome in 1996 and pre-crisis level of economics will be restored by 2000 followed by national product steady increase by 3.5% a year. In this case by 2010 living standard of the population will be about the present one of EC population. Pessimistic scenario imitates prolonged economic stagnation till 2000 and about 20-year time delay in restoration of living standard.

Experts in demography predict further drop in birth-rate till the beginning of XX century, by that time percentage of one-child families in the population at large will run to 40-50% and of childless families - to 30-35% , by 2010 the situation won't be a great deal better (50 and 15-20% correspondingly) in case of pessimistic scenario [11]. If economic reforms are in progress birth-rate may show compensative growth. Infant mortality being at the present-day level or even higher for next 10 years will decrease by 2010 in optimistic scenario only. Specialists do not see chance for drop in mortality rate till 2000. At best, some reduction is possible near 2010.

Based on these estimates we calculated some characteristic parameters for BO population and national averages under optimistic and pessimistic scenarios. Migration was omitted because of highly unpredictable character of the process. Briefly results are as follows. Depopulation will be overcome, at best, by 2010 both in BO and in Russia. Under stagnation conditions drop in size of population will be more significant in BO (up to 15-20% and 5-10% in Russia). Number of women of fertile age will increase till 2003 (by 2-3% in BO and 1-2% in Russia) and then decline all over Russia in any case. And in pessimistic scenario low birth-rate will contribute to depopulation along with high mortality rates.

We concluded that further changes in demographic situation being not very sizeable will be more adverse in BO since its population is 'older' and therefore, more sensitive to negative factor influence. For example, percentage of old people (older 60) in population in 1994 was 20.7 in BO and 16.7 in Russia. By 2000 in pessimistic scenario it will increase by 1-2% and then decline up to 16-18% in BO and 14-16% in Russia in 2010. Population will rejuvenate at the sacrifice of old people dying out. And it will be more intensive in BO than in Russia. In optimistic scenario BO will be again in worse situation as by 2010 every fourth will be older 60, that will cause looses in labour reserves and require additional financial support of medical and social surveillance of old people.

3. 6. Emergency workers.

Analysis of published data on liquidator health statistics[4] against the background of population statistics discovered particular important points.

Temporal changes. The disadvantageous tendencies typical for population act for EW too, in particular alcohol-dependent hypermortality of working-age males mentioned above. That explains to some extent increase of mortality indexes in the cohort.

While the negative trends are in progress EW get older with time. Changes that occurred in liquidator health conditions for the past 10 years just due to that reason were appreciable. It is well known that total

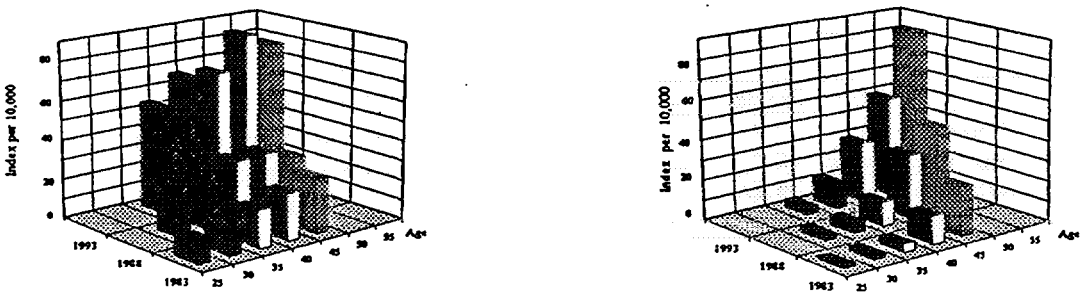

Fig. 6. Accidential (left) and cancer (right) mortality rate, rural males in Tulskaya oblast

mortality intensity increases exponentially with age and even more rapid for cancer mortality. For instance, cancer mortality index doubles in going from age group 40-44 to the next group 45-49. Fig. 6 demonstrates with rural male subpopulation of Tulskaya oblast (where approx. 10% of EW live) that in case of accidental mortality (accidents, injuries, poisoning etc.) social and economical difficulties make greater impact than the 'ageing effect' while in case of cancer mortality the latter is the crucial factor.

Spatial distribution. EW live in all regions of Russia but in different proportions: about 18% in CER, 21% in Northern Caucasus Region, 16% in Ural Region etc. [4]. Russia features strongly pronounced distinctions in character of demographic development of different regions, that is determined by social and economic variations, ecological factors, national traditions and habits, and different levels and quality of medical aid. As a result even standardised mortality indexes deviate widely (up to 2 times) through this country. It is seen in Fig. 7 where the territorial variety of total mortality rates (standardised indexes) with urban males in all provinces in 1992 and 1993 is shown. Territories are ranked according to index in 1992 and for every one there is a corresponding value in 1993. A spread of values ranged up to 100% in 1992 and became even more in 1993. Lowest mortality rates were fixed in Northern Caucasus provinces and the highest in Far-East Region. Note that in 1993 mortality increased all over Russia.

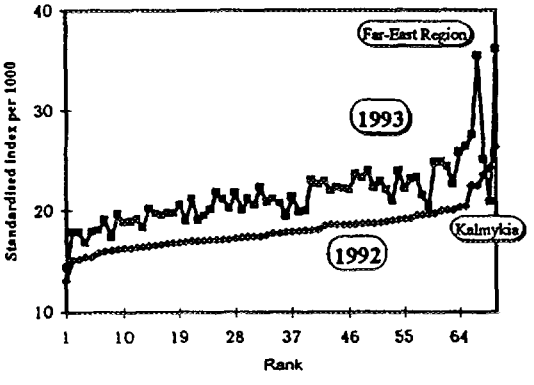

Fig. 7. Urban male total mortality rate distribution through all provinces of Russia.

Table VIII. Total mortality rates for EW cohort and reference groups in different regions, per 1000.

	Min	EW[5]	Russia	Max
1991	5.3	5.1	7.6	11.1
1993	7.7	9.5 (12.2*)	11.8	17.7

* EW exposed in 1986.

Table IX. Disease incidence for EW cohort and population in different regions, 1992, per 10,000.

Disease	Min	Russia	EW	Max
All site neoplasms	2.4	5.9	7.3	10.4
Malignant neoplasms	1.3	2.7	2	3.4
Endocrine system	1.6	4.2	4.7	9.6
Hemogenetic system	0.7	1.9	3.8	7.9

Territorial variations through one economic region may be considerable as well. For instance, in CER for crude index maximum to minimum ratio showed variations in the range 1.33 for cancer mortality, 1.77 for accidental mortality, 2.7 for respiratory system diseases mortality and 12.3 (!) for mental diseases mortality in 1993. Obviously in such a case one should not take average over economic region but use a proper weighting factors when compare liquidator statistics with population reference group statistics.

Social factors. Many other factors like living in town or country, belonging to certain social group etc. should be taken into account in comparison study of that kind. For example, in some oblasts average expected lifetime for urban males was more than 5 years above than that for rural males (5.5 in Kaluzhskaya oblast, 1993). Pauperisation of pensioners was many times the working people. According to results of selective questioning of among EW conducted in 1994 pensioners were 50% of them but only 20% were of pensionable age[12]. Amongst able-bodied people those who work in State institutions become poorer while business men improve their welfare.

Comprehensive study of EW health is in the future, in this report we show the effect of 'spatial distribution' only. In Table VIII total mortality crude index of EW is compared with that of reference groups (see Materials and Methods) in different regions in 1991 and 1993. EW values were well below the Russia reference group values. The scatter in the indexes through regions was considerable and even very high value of EW of 1986 was substantially below the maximum value (Tyva Republic).

Table IX presents disease incidence for EW cohort and for total population in Russia and peak values. This is the diseases that caused most agitation as to EW health statistics. In all cases EW values are about in the middle of the range limited above and below by peak values.

Relatively good situation with EW health statistics might be a result of special medical surveillance and better clinical examination. However, high proportion of registered invalids among EW and rapid increase that number reported recently, in particular among those who took part in decontamination work in 1986, pointed to certain social and psychological problems being in progress. That may reflect on EW health conditions in near future.

4. CONCLUSIONS.

To summarise, we can say that in the past decade the demographic situation in contaminated areas has been developing in a bad way just as in unaffected territories. Some departures from common tendencies arose from changes in numbers of country people living in the most contaminated areas (ZR). Due to the compensations and economic privileges, which are particularly inviting in severe economic crisis conditions, positive migration increases were higher than in other oblasts in CER. Relocation measures have changed age structure of the affected population so that being a constituent of 'old' population living in CER it is even 'older' than the population at large.

In some respects the most contaminated areas were in a better situation than unaffected ones. Disadvantageous trends in birth-rates and total mortality rates seen in the years following to the accident developed a little more slowly in the zones of interest. According to cancer mortality indexes in CER the situation in BO is not at all bad. Rapid growth of accidental mortality causes more alarm than the dynamics of cancer mortality. There are some reasons to believe that in BO and in the most contaminated areas the prompt attention paid to detect medical consequences of the radiation exposure have mitigated the effect of overall disintegration of medical surveillance, typical all over the country. It can be concluded that the deviations in demographic development of the affected population from a common trends might be attributed to the influence of nonradiation factors arising from countermeasures and at the level of population statistics an influence of radiation has not been revealed yet.

By virtue of excessively 'old' age structure affected population is more sensitive to social and economic changes than the population at large. If economic stagnation continues in near future BO is threatened with more intensive old people dying out followed by certain rejuvenation of the population. If more optimistic scenario realises noticeable increase of old people portion in total population will demand special social and medical care of pensioners.

Against the background of negative common trends EW health statistics is not as bad as the public believes if correct reference group from population is taken. To form control group for EW cohort one should take proper age-sex group from population with the same social status and take into account drift of indexes in time, ageing of the cohort, wide territorial dispersion of indexes etc. Only if the control group meets all these criteria one can discuss role of radiation induced health effects in EW statistics. It should be noted that the build-up of social and psychological problems of liquidators in recent years may affect their health conditions eventually. So, we can establish that the most acute problems of both EW and affected population are in social, economic and psychological spheres but not of radiological nature.

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