RISK ASSESSMENT IN HYGIENE

UDC 314.42:616-006.04
DOI: 10.21668/health.risk/2023.3.04.eng

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Research article

ANALYSIS OF CARCINOGENIC RISK AND DYNAMICS OF POPULATION MORBIDITY AND MORTALITY IN THE IRKUTSK REGION DUE TO MALIGNANT NEOPLASMS AND CARCINOGENIC RISK FACTORS

I.G. Zhdanova-Zaplesvichko[1,2], N.V. Efimova[3], D.F. Savinykh[1], M.F. Savchenkov[4]

[1] Federal Service for Surveillance over Consumer Rights Protection and Human Well-being, Irkutsk regional office, 8 Karla Marksa St., Irkutsk, 664003, Russian Federation
[2]Irkutsk State Medical Academy of Postgraduate Education – the branch of the Russian Medical Academy for Continuous Occupational Education, 100 Yubileinyi microdistrict, Irkutsk, 664049, Russian Federation
[3]East-Siberian Institute of Medical and Ecological Research, 3 12a microdistrict, Angarsk, 665827, Russian Federation
[4]Irkutsk State Medical University, 1 Krasnogo Vosstaniya St., Irkutsk, 664003, Russian Federation

Morbidity and mortality caused by malignant neoplasms (MNs) is a priority challenge for health care.

We analyzed some rough and standardized levels (oncological morbidity and mortality) over 2009–2018 based on official statistics. We ranked the RF regions as per the standardized morbidity level and established that the Irkutsk region took the 1st rank place among 85 RF regions as per it; it took the 16th rank place as per the 'rough' level. Morbidity and mortality levels that were higher in the Irkutsk region than the national average were established for such localizations as trachea, bronchi and lung cancer; prostate cancer; cervical cancer. The mortality to morbidity ratios were on average equal to 0.45 in the Irkutsk region and 0.49 in the RF as a whole; we identified a certain decrease in them, by 19.3 % and 20.0 % accordingly. We provided evidence of unacceptable individual carcinogenic chemical risk for people in cities with developed chemical industry and non-ferrous metallurgy. High carcinogenic radiation risks were caused by natural radon levels in soils. We calculated some prognostic morbidity and mortality levels: in 2021, the standardized morbidity level would be between 270.9 and 329.8 cases per 100 thousand people; the 'rough' level, between 372.7 and 532.4. The 'rough' mortality level would be between 220 and 230 cases per 100 thousand people.

We determined some priority tasks for future research aimed at identifying adverse effects produced by environmental factors and lifestyle-related factors as well as some tasks related to developing relevant targeted activities aimed at eliminating and mitigating cancer-inducing exposures.

Keywords: *carcinogenic risk, morbidity, mortality, malignant neoplasms, population, chemical factor, radiation factor, prognosis.*

Cancer morbidity and mortality are growing in many regions of the world and this fact highlights medical and social significance of the issue [1–3]. A trend of growing prevalence of chronic non-communicable diseases, cancer included, is associated with various factors such as changes in the age structure of population that involve longer life expectancy and

Inga G. Zhdanova-Zaplesvichko – Candidate of Medical Sciences, Head of the Department for Organizing the Activities; Associate Professor of the Department of Public Health and Health Care (e-mail: zhd_i@mail.ru; tel.: +7 (914) 935-23-27; ORCID: https://orcid.org/0000-0003-0916-0302).

Natalia V. Efimova – Doctor of Medical Sciences, Professor, Leading Researcher at the Laboratory of Environmental and Hygienic Researches (e-mail: medecolab@inbox.ru; tel.: +7 (395) 555-40-85; ORCID: http://orcid.org/0000-0001-7218-2147).

Dmitry F. Savinykh – Head of the Irkutsk Regional Office of the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, Chief State Sanitary Inspector for the Irkutsk Region (e-mail: savinykh_df@38.rospotrebnadzor.ru; ORCID: https://orcid.org/0000-0002-7242-940X).

Mikhail F. Savchenkov – Academician of the Russian Academy of Sciences, Doctor of Medical Sciences, Professor of the Common Hygiene Department (e-mail: mfs36@mail.ru; tel.: +7 (914) 912-57-14; ORCID: http://orcid.org/0000-0002-1246-8327).

ageing, chemical and physical contamination of the environment, and behavioral risk factors [4]. Among basic causes of malignant neoplasms (MNs), we should mention not only genetic factors, exposure to chemical carcinogens in ambient air or food but also working conditions [5–9]. The National Goals of the RF development[1] and targets stipulated by the Cancer Control Federal Project include growing life expectancy at birth of the RF population up to 78 years (by 2030), a decrease in mortality among working age population, a decrease in mortality caused by neoplasms, malignant ones included (down to 185.0 cases per 100,000 people by 2024). To achieve them, it is necessary to know how population levels as regards MNs are formed in different regions in the country, the Irkutsk oblast included. MNs morbidity is known to be mostly concentrated and growing among people of older ages (the highest share of cancer incidence is identified in the age group of 65–69 years) [10]. Therefore, considering the ongoing population ageing in Russia, we can assume a further growth in the number of MNs cases as well as their greater significance as a major reason for disability among the RF population [11].

Several studies have been accomplished with their focus on epidemiological aspects of oncological pathology in Siberian regions where morbidity has been established to grow; this growth was more apparent among urban population [12–14]. MNs morbidity among population in the Irkutsk oblast is one of the highest in the Siberian Federal District [15]. According to statistics, malignant neoplasms occupy the first rank place among reasons for disability in adult population of the Irkutsk oblast; the 2nd rank place, in the total mortality; 4th rank place, in the mortality of working age population[2]. All this highlights specific relevance of the issue for the region. Therefore, it is necessary to prevent and reduce incidence of malignant neoplasms in the Irkutsk oblast and provide scientific substantiation for development of the most effective preventive activities.

The aim of this study was to evaluate carcinogenic risk levels and accomplish profound analysis and prediction of morbidity and mortality caused by malignant neoplasms among the Irkutsk oblast population.

Materials and methods. Individual and population carcinogenic risks associated with chemical pollution in ambient air were calculated according to the methods stipulated in the Guide Human Health Risk Assessment from Environmental Chemicals (R 2.1.10.1920-04)[3]; when calculating risk levels, we relied on average annual data of social and hygienic monitoring (SHM) over 2000–2018. MNs morbidity and mortality among the Irkutsk oblast population was analyzed in 2009–2018 by using official statistical reports (From no. 7 Data on Incidence of Malignant Neoplasms), materials from the annual data collections Malignant Neoplasms in Russia and Socially Significant Diseases among the RF Population, and official data provided in the UIISS (Unified Interdepartmental Information Statistic System)[4].

We analyzed morbidity and mortality in the Irkutsk oblast in comparison with their national rates in the Russian Federation. The analysis covered ‘rough’ and standardized morbidity rates, including men and women separately, in 10-year dynamics; structure of the

[1] O natsional'nykh tselyakh i strategicheskikh zadachakh razvitiya Rossiiskoi Federatsii na period do 2024 goda: Ukaz Prezidenta RF ot 07.05.2018 № 204 [On national goals and strategic tasks of the Russian Federation development for the period up to 2024: the RF President Order dated May 07, 2018 no. 204]. *Prezident Rossii: the official web-site of the RF President*. Available at: http://www.kremlin.ru/acts/bank/43027 (April 12, 2023) (in Russian); O natsional'nykh tselyakh razvitiya Rossiiskoi Federatsii na period do 2030 goda: Ukaz Prezidenta RF ot 21.07.2020 № 474 [On national goals and strategic tasks of the Russian Federation development for the period up to 2030: the RF President Order dated July 21, 2020 no. 474]. *GARANT: information and legal support*. Available at: https://base.garant.ru/74404210/ (April 12, 2023) (in Russian).

[2] Forma S51 [Statistical Report Form C51]. *Irkutskstat*. Available at: https://irkutskstat.gks.ru/storage/mediabank/death_rate2019.html (January 18, 2021) (in Russian).

[3] Guide R 2.1.10.1920-04. Human Health Risk Assessment from Environmental Chemicals. Moscow, The Federal Center for State Sanitary and Epidemiologic Surveillance of the RF Ministry of Health, 2004, 143 p. (in Russian).

[4] Ofitsial'nye statisticheskie pokazateli [Official statistical indicators]. *EMISS: state statistics*. Available at: https://www.fedstat.ru (May 04, 2023) (in Russian).

MNs morbidity; 'rough' and standardized (the world standards, WHO, 2001) mortality rates. We identified a rank place that belonged to the Irkutsk oblast among 85 RF regions as per its 'rough' and standardized MNs morbidity rates. The rates were analyzed in dynamics and correlations between morbidity and mortality as well as their correlations with the age structure of the population were evaluated in the Statistica 6.0 software package (Pearson's correlation and regression analysis (r)). Statistical significance was taken at $p < 0.05$.

Specific territories in the Irkutsk oblast were combined into several clusters by k-mean clustering considering average long-term morbidity as per priority cancer sites. We calculated and compared potential carcinogenic risk rates caused by chemical and radiation exposure on territories with the highest morbidity rates (Cluster 1).

Predictive estimates of morbidity and mortality rates are based on statistical models that cover data collected over a 10-year period and this allows considering the latest trends. 2021 indicators were calculated relying on estimated population number in 2021 so that we could derive a calculated number of new MNs cases and deaths caused by them.

We calculated ratios between standardized morbidity and mortality rates to assess effectiveness of healthcare provided for MNs patients. This allows removing influence of differences in age and sex structure of the population living on the analyzed territories. Moreover, this ratio is considered an index that describes validity of registration: when it is qualitative, the number of deceased, even for cancer sites with high fatality rates, should not be higher than the number of diseased [16]. These ratios were compared by using a share of ratio differences (RDS), which determines a difference between two ratios in percent. It was calculated as per the following formula:

$$\text{RDS} = (R_1 - R_2 / R_1) \cdot 100,$$

where R_1, R_2 are compared ratios. In most cases, R_1 should represent a higher ratio; however, R_1 represented national RF ratios in this study and they were higher than R identified for the Irkutsk oblast in most cases.

Results and discussion. More than 10,000 MNs cases are registered annually in the Irkutsk oblast. In 2018, 11,999 MNs cases were registered in the Irkutsk oblast for the first time (including 5559 among men and 6440 among women) (Table 1).

Obviously, average long-term morbidity rate (ALM) equals 432.44 among the Irkutsk oblast population over 2009–2018 and this was 11.7 % higher than the national average (387.12 in the RF). If taken in dynamics, the morbidity rate has an apparent ascending trend. It grew by 68.7 % in the Irkutsk region between 2003 and 2018 (the national average rate grew slower and increased only by 19.6 %). Over the last decade, the growth has been 33.9 % (it is 19.6 % in the RF). By the end of 2018, 60,052 patients with cancer were registered in the region (the 'rough' morbidity rate was 499.1 in the Irkutsk oblast, which was 17.3 % higher than the national average (425.46). MNs prevalence equaled 2497.8 per 100,000 people in the Irkutsk oblast (2562.3 in the RF).

Standardized ALM was 292.36 in the Irkutsk region over 2009–2018 and this was 24.1 % higher than the national average (235.58 in the RF). The standardized morbidity rate has an apparent ascending trend in the analyzed period. Over the last decade, this rate has grown by 18.2 % in the Irkutsk oblast (the national average rate grew slower and increased by 8.5 %). In 2018, the standardized MNs morbidity rate was 320.2 ± 3.07 in the Irkutsk oblast and was 29.8 % higher than the national average (246.77 ± 0.33).

We ranked 85 RF regions as per the standardized morbidity rate and established that the Irkutsk oblast was among the top five regions with the highest cancer morbidity for many years. In 2018, the Irkutsk oblast took the 1st rank place among 85 RF regions (the 1st rank place for men and 2nd rank place for women) and the 16th rank place as per the 'rough' morbidity rate.

Cluster analysis results indicate that the highest primary MNs morbidity as per the

Table 1

MNs morbidity rates in dynamics identified among the Irkutsk oblast population and in the RF over 2009–2018

Year	Absolute number		Primary morbidity (actual incidence) (per 100,000)					
			'Rough'		Rank place*	Standardized		Rank place *
	Registered MN patients	First diagnosed cases	Irkutsk oblast	RF		Irkutsk oblast	RF	
2009	41,396	9332	372.7	355.8	34	270.9	227.4	3
2010	43,438	9595	383.4	364.2	33	275.5	231.1	6
2011	44,874	9955	410.0	365.4	23	286.7	228.1	4
2012	46,280	10,021	413.3	367.3	23	283.2	227.6	5
2013	48,020	10,275	424.2	373.4	25	288.0	229.2	3
2014	50,174	10,389	430.2	388.0	31	287.9	235.2	3
2015	52,148	10,804	447.4	402.6	28	296.4	241.4	3
2016	54,635	11,122	461.0	408.6	26	302.9	242.6	3
2017	57,536	11,626	483.1	420.3	19	311.9	246.6	2
2018	60,052	11,999	499.1	425.5	16	320.2	246.8	1
ALM**	**49,855**	**10,512**	**432.4**	**387.1**		**292.4**	**235.6**	

Note: * means the rank place of the morbidity rate in Irkutsk oblast among all RF regions (ranking is performed as per descending in the rate), **ALM is average long-term morbidity.

leading cancer sites is identified in Cluster 1 that includes Irkutsk, Bratsk, Sayansk, Usolie-Sibirskoe, Ust-Ilimsk, Cheremkhovskoe municipal settlement, Svirskoe municipal settlement, Angarskoe municipal settlement as well as Slyudyanskii and Shelekhovksii districts (1.4 million people overall). In addition to that, high primary morbidity rates are established on territories included in Clusters 2 and 3. Cluster 2 (482 thousand people) includes seven administrative districts. Cluster 3 (165 thousand people) includes nine administrative districts. The lowest primary morbidity rates as per the leading cancer sites are identified in 10 administrative districts included in Cluster 4 (162 thousand people overall): Balaganskii, Zhigalovskii, Olkhonskii, Ust-Udinskii, Alarskii, Bayandaevskii, Bokhanskii, Nukutskii, Osinskii, and Ekhirit-Bulagatskii districts.

High cancer incidence rates can be explained not only by qualitative diagnostics and treatment but also effects produced by technogenic factors. In this study, we considered some environmental factors that could have certain significance for occurrence and progression of blastoma-causing processes including adverse chemical exposures as well as radiation exposure such as radon occurrence in housing and public buildings. Natural ionizing radiation sources are the leading factor causing radiation exposure of the Irkutsk oblast population. According to data derived by long-term observation (over 2001–2017), the Irkutsk oblast population tend to be exposed to elevated (more than 5.0 mSv/year) doses created by natural ionizing radiation sources (5.1 mSv/year). Several zones with elevated radon emissions are registered in the Irkutsk oblast including those located in towns included in Cluster 1: Ust-Ilimsk (the average dose is 7.34, the critical one is 17.32 mSv/year) and Irkutsk (the average dose is 2,93, the critical one reaches 18,61 mSv/year). Elevated radon levels, including those identified in housing and public buildings as well as water supply sources, are caused by geological peculiarities of the earth crust in the Irkutsk oblast. We have not established any critical zones in other towns and settlements in Cluster 1. Table 2 provides data on average annual individual and population carcinogenic risk rates caused by chemical and radiation exposure identified on the most risky territories.

Levels of ambient air pollution tend to be very high in the Irkutsk oblast due to emissions from industrial enterprises and motor transport. This includes pollution with carcinogenic chemicals. Along with thermal

Table 2

Individual and population carcinogenic risks caused by chemical and radiation exposure

Territories in Cluster 1	Individual risk		Population carcinogenic risk (the number of additional MNs cases)	
	chemical (ICR)	average annual radon levels, mSv/year	chemical	radiation
Angarsk	6.50E-04	1.72	154.9	22.5
Shelekhovkii district	1.00E-03	2.13	64.9	7.6
Irkutsk	7.31E-04	2.93	449.8	99.2
Bratsk	1.06E-03	2.56	249.6	33.1
Sayansk	8.01E-05	1.93	3.1	4.1
Usolie-Sibirskoe	1.25E-04	2.29	9.9	9.9
Ust-Ilimsk	1.03E-06	7.34	0.1	33.5
Cheremkhovo	2.50E-05	2.15	1.3	6.1

Table 3

'Rough' and standardized mortality rates due to MNs among the Irkutsk oblast population and in the RF in 2009–2018

Years	Absolute number	Mortality rate per 100,000 people					
		'Rough'		Rank place*	Standardized		Rank place*
		Irkutsk oblast	RF		Irkutsk oblast	RF	
2009	4751	194.4	204.9	43	135.4	125.2	17
2010	4682	185.3	204.4	55	131.7	124.0	25
2011	4759	194.9	202.5	49	133.5	120.2	16
2012	4604	190.0	201.0	54	126.1	117.7	31
2013	4916	203.1	201.1	43	134.0	116.8	11
2014	4885	201.8	199.5	44	130.3	114.6	13
2015	4953	205.2	202.5	42	131.4	114.8	16
2016	5015	208.0	201.6	37	131.9	112.8	9
2017	5166	214.7	197.0	32	132.9	109.0	5
2018	5080	211.6	200.0	39	129.0	108.6	11
AMR	**4881**	**200.9**	**201.5**		**131.6**	**116.3**	

Note: * means the rank place of the mortality rate in Irkutsk oblast among all RF regions (ranking is performed as per descending in the rate).

power stations, various industrial enterprises emit carcinogenic chemicals in ambient air such as aluminum production in Bratsk and Shelekhov, petrochemical and electrolysis-chemical plants in Angarsk, and vinyl chloride production in Sayansk. Productions with carcinogenic hazards have long been functioning on territories where health risks were accumulated due to previous economic activities (including Svirsk, Usolie-Sibirskoe, and Baikalsk).

Obviously, the highest individual carcinogenic risks under potential chemical exposure are established for people living in large industrial centers such as Bratsk (1.06E-03) and Shelekhovskii district (1.00E-03); these risk rates are considered unacceptable. They are followed by Irkutsk (7.31E-04), Angarsk (6.50E-04), and Usolie-Sibirskoe (1.25E-04). The risk is considered acceptable in Sayansk (8.01E-05), Cheremkhovo (2.50E-05), and Ust-Ilimsk (1.03E-06). The highest average annual radon level (7.34 mSv/year) was identified in Ust-Ilimsk; these levels did not exceed 2.93 mSv/year on all the other territories in Cluster 1. Population risk rates are associated not only with ambient air being polluted with carcinogens but also with the number of exposed population; therefore, the most risky territories primarily include cities with population higher than 200 thousand people (Angarsk and Bratsk) as well as the oblast center Irkutsk (more than 600,000 people).

Average annual mortality rate equaled 200.9 in the Irkutsk region over 2009–2018 (201.5 in the RF) (Table 3).

In 2018, the 'rough' mortality rate equaled 211.6 in the Irkutsk oblast, which was 5.8 % higher than the national average (200.03).

The mortality rate tended to grow over the analyzed period. It grew by 8.8 % in the Irkutsk oblast between 2009 and 2018 (the growth was negative in the country as the national average mortality rate dropped by 2.4 %).

In 2018, the standardized mortality rate equaled 129.0 ± 1.89 and was 18.8 % higher than the national average (108.56 ± 0.21). Over 2009–2018, the long-term average standardized mortality rate equaled 131.6 in the Irkutsk oblast, which was 13.1 % higher than the national average (116.3). Over 2009–2018, a descending trend occurred in the standardized mortality rate as it went down by 4.7 % in the Irkutsk oblast (the national average declined faster and went down by 13.3 %).

We ranked RF regions as per the standardized mortality rate due to MNs and established that the Irkutsk oblast was among those with the highest standardized MNs mortality rate in 2018 as it held the 11th rank place out of 85 regions (13th rank place for men and 15th rank place for women) and the 39th rank place as per the rough mortality rate (39th rank place for men and 31st rank place for women).

Next, we calculated mortality / morbidity ratios as per their standardized rates; this made it possible to assess healthcare quality in the Irkutsk oblast and the RF in general by eliminating influence of different age structure. On average, the ratio was 0.45 in the Irkutsk oblast and 0.49 in the RF over 2009–2018; we also established a decline in the ratios, by 19.3 % and 20.0 % accordingly. This dynamics is easily described by linear regression equations: R (Mr/Mb) = -0.0085x + 0.4983 (R^2 = 0.880) for the Irkutsk oblast; R (Mr/Mb) = -0.0128x + 0.5655 (R^2 = 0.987) for the RF. Therefore, we assume that a growth in the morbidity rate with a simultaneous decline in the mortality rate indicates that cancer is identified more effectively and more qualitative healthcare is provided for cancer patients.

Predicted MNs morbidity and mortality rates in the Irkutsk oblast were calculated by using the following equations that reflect the identified trends: the standardized rate y = 4.964x + 265.06 (R^2 = 0.931) and the 'rough' rate y = 13.326x + 359.15 (R^2 = 0.979). The prediction periods were substantiated considering the following: polynomial trends had somewhat better approximation properties than linear equations; for the standardized rate, $y = 0.114x^3 - 1.540x^2 + 9.901x + 262.7$ (R^2 = 0.977); for the 'rough' rate, $y = 0.194x^3 - 2.849x^2 + 24.213x + 350.3$ (R^2 = 0.991). Since the 'rough' rate describes an actual situation considering age- and sex-related characteristics of a population, it is advisable to make predictions relying on it. In addition, analysis of polynomial dynamics allows identifying a correct prediction 'range'. Basing on our analysis of a 16-year trend, we established that a 'step' of change equaled 7 years. Consequently, we can make 7-year predictions taking a time moment when a rise in a rate begins as our starting point. In our case, this is a medium-term prediction for the period up to 2021 (3 years).

Given all the aforementioned, we established that in 2021 the predicted standardized morbidity rate would be within 270.9–329.8 cases per 100,000 people with 95 % certainty; the 'rough' morbidity rate would very within 372.7–532.4 cases. We applied the following equations to predict dynamics of MN mortality in the Irkutsk region: y = 133.12 – 0.273x (R^2 = 0.095), which described a trend in the standardized mortality rate; and y = 185.22 + 2.851x (R^2 = 0.904), which described a trend in the 'rough' mortality rate. According to prediction calculations, in 2021 the standardized mortality rate would equal 127.1–132.2 cases per 100,000 people; the 'rough' mortality rate, 220.0–230.0 cases per 100,000 people.

We analyzed prevalence of cancer sites relying on 2018 data and established three groups of malignant neoplasms that were the most significant in the overall (both men and women) structure of cancer morbidity: malignant neoplasms of digestive organs (C15–C26), 24.2 %; melanoma and other malignant neo-

plasms of skin, 13.1 %; malignant neoplasms of respiratory organs (trachea, bronchi, lungs, and larynx), 12.8 %. Priority cancer sites included trachea, bronchi, and lungs (11.8 %) (9.9 % in the RF), skin (11.5 %; 13.1 % including melanoma) (12.6 % in the RF; 14.4 % including melanoma); breast, 10.9 % (11.4 % in the RF); prostate (7.3 %) (6.8 % in the RF); stomach (6.5 %) (5.9 % in the RF); colon (5.9 %) (6.9 % in the RF); kidney (4.8 %) (3.9 % in the RF); lymphoid and hematopoietic tissue (4.6 %) (4.8 % in the RF); rectum, rectosigmoid junction, and anus (4.4 %) (5.0 % in the RF); cervix uteri (3.7 % (2.8 % in the RF); corpus uteri (3.4 %) (4.3 % in the RF); pancreas (3.3 %) (3.1 % in the RF); urinary bladder (2.5 %) (2.8 % in the RF); ovary (2.3 %) (2.3 % in the RF); and esophagus (1.5 %).

The morbidity rates were established to be higher in the Irkutsk oblast than the national average for almost all the analyzed cancer sites (Table 4).

In 2018, the morbidity rates identified in the Irkutsk oblast were higher than the national average for 10 cancer sites: cervix uteri (the Irkutsk oblast rate is 59.4 % higher than the national average); trachea, bronchi, and lungs (55.8 % higher); kidney (54.0 % higher); prostate (49.7 % higher); esophagus (45.9 % higher); stomach (43.5 % higher); pancreas (41.7 % higher); liver and intrahepatic bile ducts (35.6 % higher); thyroid (31.1 % higher); and lymphoid and hematopoietic tissue (30.2 % higher than the national average). The morbidity rates identified for the next five cancer sites were 15–30 % higher than the national average: ovary; female breast; other malignant neoplasms of skin; urinary bladder; rectum, rectosigmoid junction, and anus. The morbidity rates identified for four following

Table 4

Standardized mortality and morbidity rates for the most common cancer sites in the Irkutsk blast and in the RF, 2018

Cancer sites	Rate per 100,000 people				Mortality / morbidity ratio		Share of differences in the rates (of the RF)
	mortality		morbidity				
	Irkutsk oblast	RF	Irkutsk oblast	RF	Irkutsk oblast	RF	
Esophagus	3.12	2.65	4.64	3.18	0.67	0.83	19.3
Stomach	11.86	9.94	19.45	13.55	0.61	0.73	16.9
Colon	8.5	7.73	17.87	15.58	0.48	0.50	4.1
Rectum, rectosigmoid junction, and anus	5.92	5.66	13.7	11.63	0.43	0.49	11.2
Liver and intrahepatic bile ducts	4.41	3.66	4.49	3.31	0.98	1.11	11.2
Pancreas	8.52	6.59	9.95	7.02	0.86	0.94	8.8
Larynx	1.5	1.58	3.29	2.91	0.46	0.54	16.0
Trachea, bronchi, and lungs	25.99	19.08	36.82	23.64	0.71	0.81	12.5
Skin melanoma	1.65	1.44	4.99	4.73	0.33	0.30	-8.6
Other malignant neoplasms of skin	0.47	0.48	33.33	27.46	0.01	0.02	19.3
Female breast	16.01	14.02	63.26	51.63	0.25	0.27	6.8
Cervix uteri	8.87	5.07	25.18	15.8	0.35	0.32	-9.8
Corpus uteri	3.9	3.98	18.7	18.79	0.21	0.21	1.5
Ovary	5.8	4.92	13.97	11.14	0.42	0.44	6.0
Prostate	17.68	12.11	62.06	41.45	0.28	0.29	2.5
Kidney	3.1	4.02	15.42	10.01	0.20	0.40	49.9
Urinary bladder	2.01	2	7.66	6.41	0.26	0.31	15.9
Brain and other and unspecified parts of central nervous system	3.54	3.61	4.92	4.45	0.72	0.81	11.3
Thyroid	0.43	0.37	8.34	6.36	0.05	0.06	11.4
Lymphoid and hematopoietic tissue	6.4	6.39	18.43	14.16	0.35	0.45	23.0
Total MNs:	**129**	**108.6**	**320.2**	**246.77**	0.40	0.44	**8.5**

cancer sites were less than 15 % higher than the national average: colon; larynx; brain and other and unspecified parts of central nervous system; skin melanoma.

The mortality rates that were higher in the Irkutsk region than the national average were identified for the following 12 cancer sites: cervix uteri; prostate; trachea, bronchi, and lungs; pancreas; liver and intrahepatic bile ducts; stomach; ovary; esophagus; thyroid; skin melanoma; female breast; colon. The highest difference between the mortality rate in the Irkutsk oblast and the national average was identified for cervix uteri cancer (75 % higher than the national average); prostate cancer (46 % higher in the Irkutsk oblast than the national average); trachea, bronchi, and lungs cancer (36.2 % higher).

Maximum mortality / morbidity ratios, both in the Irkutsk oblast and the RF in general, are typical for malignant neoplasms of liver and intrahepatic bile ducts (0.98 and 1.11 respectively), which indicates high cancer fatality rate together with ineffective detection; probably, in some cases the disease is diagnosed in the RF after a patient's death. High ratios were also identified for the following cancer sites: pancreas (0.86 and 0.94); trachea, bronchi, and lungs (0.71 and 0.81); brain (0.72 and 0.81); esophagus (0.67 and 0.83); stomach (0.73 and 0.61). Although the cancer mortality and morbidity rates tend to be higher in the Irkutsk oblast than the national average over the analyzed 10 years, their ratios are still lower than in the RF in general for most cancer sites. And although the difference is rather low if we take total MNs (8.5 %), it can reach 15–50 % for such cancer sites as kidney, lymphoid and hematopoietic tissue, esophagus, other skin MNs, urinary bladder, stomach, and larynx.

Population cancer morbidity rates are established to also depend on the age structure of population [4]; to eliminate influence of the factor, rates are usually standardized when analyzed comparatively. MNs morbidity tends to grow in the Irkutsk oblast, including both the standardized and 'rough' rate. This fact provides a relevant trend in future research, namely, identification of cause-effect relations within the 'environmental factors – cancer prevalence' system.

D.G. Zaridze and others think [3] that cancer morbidity grows in Russia due to, among other things, growing prevalence of some risk factors. Use of highly sensitive screening technologies and early diagnostics also facilitate this growth in morbidity rates, cancer morbidity included [17]. Medium or even low MNs mortality rates have been established on territories with higher living standards, available and widely applied up-to-date techniques of early diagnostics and high-tech healthcare even though cancer morbidity rates were rather high there [18]. An inverse correlation has been identified between population mortality and the number of healthcare workers (doctors) and in-hospital 'cancer' beds per capita (Buryatiya) [7].

We have analyzed the existing negative situation in the Irkutsk oblast associated with high cancer mortality and morbidity among population. So, we assume that a high morbidity rate and its growth can be caused not only by more effective detection and growing morbidity in older age groups due to population ageing and longer life expectancy but also by an actual growth in morbidity due to exposure to carcinogenic factors.

Some carcinogenic risk factors can be considered manageable, both at the individual and group or population level. According to the World Health Organization materials and data obtained in Russian research works, a substantial share of deaths due to cancer (more than 30 %) is caused by manageable (modifiable) risk factors, including tobacco smoking, alcohol abuse, low physical activity, and insufficient consumption of fruit and vegetables [4, 17, 19]. In addition, environmental exposures, occupational ones included, can also act as carcinogenic risk factors [6, 8, 20]. However, we have not found any studies with their focus on influence exerted by the whole set of factors on cancer prevalence in the Irkutsk oblast. Given that, issues of establishing carcinogenic factors become vital for the region within development and implementation of primary cancer

prevention. The latter is achieved by reducing or eliminating adverse effects of factors manageable at the population, group, and individual levels. The aforementioned tasks are ranked as the priority ones to be tackled by the Sanitary Service, the Center for Hygiene and Epidemiology, and the East-Siberian Institute of Medical and Ecological Research.

Conclusion. Therefore, assessment of individual carcinogenic risks caused by potential chemical exposure gives evidence of the existing unacceptable risk levels in Bratsk, Shelekhov, Irkutsk, Angarsk, and Usolie Sibirskoe. Risks are assessed as acceptable in Sayansk, Cheremkhovo, and Ust-Ilimsk. At the same time, the highest average annual radon dose is detected in Ust-Ilimsk (7.34 mSv/year), which calls for the risk-based approach as a basis for periodical medical examinations of workers exposed to carcinogenic occupational factors in their workplaces and mass health examinations of population. Basically, MNs morbidity and mortality rates can be considered unfavorable among the population in the Irkutsk oblast. Their values, long-term trends taken in dynamics, and cancer mortality to morbidity ratios give evidence of sufficient healthcare provided for cancer patients in the Irkutsk oblast. Predictive values that were calculated by analyzing long-term trends in the rates are going to be within the following ranges in 2021: the standardized morbidity rate, within 270.9–329.8; the 'rough' morbidity rate, within 372.7–532.4 per 100,000 people living in the Irkutsk region; the 'rough' mortality rate, within 220.0–230.0 cases.

This study allowed identifying priority tasks for the development of targeted activities aimed at eliminating or reducing adverse effects produced by carcinogenic factors on human health.

Funding. The research was not granted any sponsor support.

Competing interests. The authors declare no competing interests.

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Received: 03.04.2023
Approved: 06.09.2023
Accepted for publication: 20.09.2023