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Research article

## MORTALITY AMONG ADULTS IN THE ARCTIC MACRO-REGION: DYNAMICS, STRUCTURE AND FEATURES

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*An expected increase in the number of workplaces in the Arctic macro-region will require a lot of available local workforce. However, currently the working age population is declining markedly there. Between 2014 and 2020, the population decreased everywhere, except the Yamal Nenets Autonomous Area; the decrease was the most apparent in the Arkhangelsk region, Murmansk region, and the Komi Republic. Fluctuations in the share of the working age population in the Arkhangelsk region and the Nenets Autonomous Area practically have the same dynamic as in the country as a whole (the decline equals 2–3 %). The greatest declines (5–7 %) were observed in the Magadan region, Chukotka, the Murmansk region and the Komi Republic.*

*Mortality rates in the Arctic macro-region tend to be higher than the national average rate due to uncomfortable Arctic climate, long distances between the settlements and basic healthcare facilities, and some other reasons. A current decline in mortality among the working age population has not reached its national average level yet. The major causes of elevated mortality in the Arctic macro-region include ischemic heart disease (in Chukotka, the Arkhangelsk region and the Murmansk region); stroke (in Karelia and the Komi Republic); external causes including accidental alcohol poisoning (in Karelia, the Komi Republic, and the Arkhangelsk region).*

*To protect health of the working age population, it is necessary to develop and implement regional programs aimed at reducing mortality due to the major causes, which differ from one region to another. These programs should consider the experience gained in the other Arctic regions. It is also necessary to implement more effective healthcare management systems. This includes development of specific models for various population groups with specific working conditions and lifestyle; development of private-public partnerships; making healthcare more available.*

**Keywords:** Arctic, demography, public health, mortality, working age population, prevention, working conditions and lifestyle, macro-region, natural and climatic conditions.

The development of the Arctic macro-region is a major task within the overall country development. Therefore, demographers, healthcare professionals, economists, sociologists and experts in other spheres have addressed the outstanding task of preservation of population size in these territories [1–4]. The population outflow from the Arctic is greater

than that from other Russian regions. Active migration from these territories began in the last decade of the 20<sup>th</sup> century. Between 2000 and 2018, the population declined from 11.6 to 9.9 million people, or almost by 15 % [5].

According to the RF President Order issued in 2014<sup>1</sup>, the Arctic zone in Russia includes the whole territory of the Murmansk

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region, the Nenets Autonomous Area, the Yamal Nenets Autonomous Area and Chukotka as well as some parts of the Arkhangelsk region (58 %), the Komi Republic (9 %), Yakutia (7 %) and Karelia (6.5 %). Since 2014, some other territories in Yakutia and Karelia have been added to the Arctic zone. To estimate mortality rates among the working age population in the Arctic zone, we used a concept of 'macro-region', that is, a geographical area that comprises different regions with similar natural and climatic conditions due to their close proximity to the Arctic Circle. The data on mortality rates are generally more reliable on the regional rather than on the municipal level, because the regional authorities regularly review and validate these data according to the issued death certificates. This is why we used the regional level data on mortality among the Arctic populations. Besides, specialized healthcare, including high-tech one, is available mostly in the regional capitals in the Arctic zone and we should consider this fact when interpreting data on mortality rates and other health indicators in the Arctic.

The demographic processes in the Russian Arctic zone have been described in detail in the monograph coauthored by several authors and edited by Professor V.V. Fauzer [3]. Still, mortality rates among the working age population as well as some territory-specific differences have not been sufficiently investigated. Some studies established that mortality rates in small industrial towns (Apatity, Kandalaksha, Kirovsk, and Monchegorsk) in the Murmansk region were higher than those in Murmansk city [6]. Very interesting results were reported in a study that compared mortality rates in two cities with highly uncomfortable climate, Yakutsk (population 340,000) and Nizhnevartovsk (population 250,000). Mortality due to cardiovascular diseases in the age group between 20 and 44 years was higher in Nizhnevartovsk than that in Yakutsk. The authors explained this finding by a higher share

of indigenous people in Yakutsk because the latter are genetically better adapted to cold. Another factor that contributed to such difference could be traditional diets of Yakut people. However, mortality rates due to cerebrovascular diseases (stroke) in the older age groups were higher in Yakutsk [7].

Some quite unexpected results were reported in a study that addressed the high mortality rates due to external causes. It was based on data collected in 2011–2016 and provided by the Unified Interdepartmental Information and Statistics System (UIISS). Arctic territories covered by this study included Yakutia and the Magadan region where total mortality and mortality due to circulatory system diseases (CSD) went down whereas mortality due to external causes did not decline. Moreover, mortality due to external causes surpassed the CSD-related mortality by 5.8 % in 2016 for the first time and reached 227 cases per 100,000. Thus, the external causes became the main contributor to the total mortality [8], which has never been observed in any other territory.

Spatial heterogeneity in mortality rates is quite common for the Arctic macro-region; it can occur even within the same region [9, 10]. However, there were no studies focusing on the whole Arctic territory. Meanwhile, spatial differences in mortality rates in Russia remain a major topic for the demography studies which predict the socioeconomic situation in the country<sup>2</sup> [11, 12]. Without such analysis, it is impossible to identify the most problematic areas with the greatest mortality rates among the working age population, and to develop future projections of the demographic indicators.

It is in the Arctic that health of the working age population becomes a crucial issue since the target is to create 180,000 workplaces in the macro-region by 2030. These workplaces cannot be filled only by the shift workers. Besides, the shift workers have a lot of specific health problems as a separate group of the working age population. Specific psychology tests applied to this group concluded

<sup>2</sup> Shchur A.E. Mortality differentiation by regions, cities of different population sizes and rural areas in Russia: the abstract of the thesis ... for the Candidate of Social Science degree. Moscow, 2022, 24 p. (in Russian); Shkol'nikov V.M. Geograficheskie faktory prodolzhitel'nosti zhizni [Geographical factors of life expectancy at birth]. *Izvestiya AN SSSR. Seriya geograficheskaya*, 1987, no. 3, pp. 35–44 (in Russian).

that the shift workers in the Arctic should be intellectually developed, able to give subjective health self-assessments and take care of themselves [13]. It is not evident that it will be possible to find such specifically eligible shift workers since their satisfaction with work in shifts has been declining—over recent years. High wages is their only incentive [14] but in future, when oil and gas production will go down, this advantage will also disappear.

**Materials and methods.** Mortality rates among population, including working age people (aged 15–64 years) were taken from the annual reports issued by the Russian Statistical Service (Rosstat). In particular, Table C51 ‘Distribution of deceased citizens as per sex, age, and causes of death’ summarizes the data on average population numbers in 2000–2021. Age-specific mortality rates were calculated for several major causes of death and for total

mortality. To remove any influence of the differences in age structures among the regions, regional mortality rates were compared based on calculated standardized mortality rates according to the International Classification of Diseases, the 10<sup>th</sup> Revision (ICD-10). The European standard population (1976) was taken as the reference population in this study. The temporal trends in mortality rates were estimated by linear regression analysis using IBM SPSS Statistics 21 software. The differences between the analyzed trends were considered statistically significant at  $p \leq 0.05$ . There were substantial fluctuations in the cause-specific mortality rates in the Nenets Autonomous Area, Yamal Nenets Autonomous Area, Chukotka and Magadan region. For this reason, and considering small population sizes in these regions, we did not report the results for these regions in Tables 1 and 2.

Table 1

Statistically significant ( $p < 0.05$ ) descending trends in cause-specific mortality among the population in the Arctic macro-region and Russia as a whole in 2000–2021

Region	Men		Women	
<b>All-cause mortality</b>				
	Trend	95 % CI	Trend	95 % CI
Nenets Autonomous Area	-65.2	-82.6 ÷ -47.7	-42.7	-52.2 ÷ -33.2
Yamal Nenets Autonomous Area	-31.5	-41.7 ÷ -21.3	-21.8	-27.1 ÷ -16.4
Chukotka	-66.0	-94.4 ÷ -37.5	n/a	
Karelia	-58.7	-74.6 ÷ -42.7	-26.2	-34.1 ÷ -18.2
Komi Republic	-56.2	-70.1 ÷ -42.4	-27.2	-34.5 ÷ -19.8
Arkhangelsk region	-59.8	-72.7 ÷ -46.8	-26.1	-32.2 ÷ -19.9
Murmansk region	-54.5	-68.7 ÷ -40.2	-22.7	-30.2 ÷ -15.2
Magadan region	-71.0	-81.0 ÷ -61.1	-27.5	-33.1 ÷ -21.9
Yakutia	-46.2	-54.5 ÷ -38.0	-25.1	-30.6 ÷ -19.7
Russian Federation	-45.3	-54.6 ÷ -36.1	-17.8	-23.2 ÷ -12.4
<b>Circulatory system diseases</b>				
Nenets Autonomous Area	-49.3	-63.1 ÷ -35.6	-41.9	-47.9 ÷ -35.9
Yamal Nenets Autonomous Area	-19.4	-25.6 ÷ -13.1	-19.5	-21.7 ÷ -17.3
Chukotka	n/a		n/a	
Karelia	-40.4	-46.8 ÷ -34.0	-24.9	-28.6 ÷ -21.2
Komi Republic	-34.4	-41.4 ÷ -27.4	-21.3	-24.6 ÷ -18.1
Arkhangelsk region	-36.8	-41.9 ÷ -31.6	-19.8	-22.7 ÷ -17.0
Murmansk region	-37.4	-43.8 ÷ -31.1	-20.4	-23.1 ÷ -17.6
Magadan region	-40.7	-47.7 ÷ -33.7	-24.9	-28.5 ÷ -21.2
Yakutia	-22.6	-28.1 ÷ -17.0	-16.4	-19.4 ÷ -13.3
Russian Federation	-31.7	-35.7 ÷ -27.6	-19.7	-21.9 ÷ -17.6
including				
Ischemic heart disease				
Nenets Autonomous Area	-35.6	-46.3 ÷ -24.8	-18.7	-22.1 ÷ -15.3
Yamal Nenets Autonomous Area	n/a		n/a	

End of the Table 1

Region	Men		Women	
Chukotka	n/a		n/a	
Karelia	-20.6	-24.6 ÷ -16.6	-9.4	-11.5 ÷ -7.3
Komi Republic	-15.4	-19.4 ÷ -11.5	-9.4	-11.5 ÷ -7.3
Arkhangelsk region	-15.6	-17.6 ÷ -13.5	-3.4	-4.9 ÷ -1.9
Murmansk region	-17.5	-20.6 ÷ -14.4	-5.3	-6.5 ÷ -4.1
Magadan region	-16.8	-23.1 ÷ -10.5	-6.6	-8.9 ÷ -4.3
Yakutia	-8.1	-11.3 ÷ -4.9	-4.0	-6.0 ÷ -1.9
Russian Federation	-15.0	-17.1 ÷ -12.8	-7.0	-8.1 ÷ -5.9
<b>Strokes</b>				
Nenets Autonomous Area	n/a		-13.5	-16.1 ÷ -10.9
Yamal Nenets Autonomous Area	n/a		-9.1	-11.1 ÷ -7.1
Chukotka	n/a		n/a	
Karelia	-19.1	-21.6 ÷ -16.6	-15.7	-17.2 ÷ -14.2
Komi Republic	-17.9	-20.6 ÷ -15.1	-14.5	-16.4 ÷ -12.6
Arkhangelsk region	-17.6	-21.2 ÷ -14.0	-14.4	-17.4 ÷ -11.5
Murmansk region	-16.5	-19.7 ÷ -13.3	-12.3	-14.6 ÷ -10.0
Magadan region	n/a		-6.4	-8.2 ÷ -4.6
Yakutia	-4.6	-5.7 ÷ -3.5	-4.1	-4.8 ÷ -3.3
Russian Federation	-12.5	-13.9 ÷ -11.1	-9.9	-10.9 ÷ -8.9
<b>External causes</b>				
Nenets Autonomous Area	-20.0	-24.4 ÷ -15.5	-4.8	-6.2 ÷ -3.3
Yamal Nenets Autonomous Area	-8.9	-10.3 ÷ -7.4	-2.8	-3.3 ÷ -2.3
Chukotka	-11.1	-15.8 ÷ -6.5	n/a	
Karelia	-19.4	-22.4 ÷ -16.4	-5.0	-5.6 ÷ -4.4
Komi Republic	-17.0	-19.3 ÷ -14.7	-4.6	-5.5 ÷ -3.8
Arkhangelsk region	-16.6	-19.0 ÷ -14.1	-3.8	-4.4 ÷ -3.2
Murmansk region	-9.7	-12.0 ÷ -7.4	-2.0	-2.6 ÷ -1.3
Magadan region	-12.7	-15.3 ÷ -10.2	-3.9	-4.8 ÷ -3.0
Yakutia	-13.1	-13.9 ÷ -12.2	-2.7	-3.0 ÷ -2.4
Russian Federation	-13.1	-14.5 ÷ -11.7	-3.1	-3.4 ÷ -2.8

Table 2

Statistically significant ( $p < 0.05$ ) descending trends in case-specific mortality among the working age population (aged 15–64 years) in the Arctic macro-region and Russia as a whole in 2000–2021

Region	Men		Women	
<b>All-cause mortality</b>				
	Trend	95 % CI	Trend	95 % CI
Nenets Autonomous Area	-61.6	-70.1 ÷ -53.1	-16.4	-20.6 ÷ -12.2
Yamal Nenets Autonomous Area	-28.7	-33.0 ÷ -24.5	-8.8	-10.5 ÷ -7.1
Chukotka	-35.1	-47.5 ÷ -22.7	n/a	
Karelia	-58.2	-71.7 ÷ -44.7	-14.9	-20.0 ÷ -9.8
Komi Republic	-51.4	-62.2 ÷ -40.6	-15.6	-20.3 ÷ -10.9
Arkhangelsk region	-59.2	-70.5 ÷ -47.8	-14.6	-18.4 ÷ -10.9
Murmansk region	-47.9	-59.5 ÷ -36.2	-12.3	-16.1 ÷ -8.4
Magadan region	-42.5	-48.8 ÷ -36.1	-11.1	-15.2 ÷ -7.1
Yakutia	-39.4	-44.1 ÷ -34.7	-12.8	-14.9 ÷ -10.7
Russian Federation	-40.8	-47.4 ÷ -34.1	-9.4	-12.2 ÷ -6.6
<b>Circulatory system diseases</b>				
Nenets Autonomous Area	-33.1	-37.9 ÷ -28.2	-11.9	-14.5 ÷ -9.2
Yamal Nenets Autonomous Area	-12.1	-13.6 ÷ -10.5	-5.0	-5.7 ÷ -4.3

End of the Table 2

Region	Men		Women	
Chukotka	n/a		n/a	
Karelia	-22.4	-27.1 ÷ -17.8	-7.4	-9.5 ÷ -5.3
Komi Republic	-20.0	-24.6 ÷ -15.3	-8.7	-10.7 ÷ -6.7
Arkhangelsk region	-24.8	-29.5 ÷ -20.1	-8.0	-9.7 ÷ -6.3
Murmansk region	-26.2	-31.6 ÷ -20.7	-9.3	-11.0 ÷ -7.6
Magadan region	-18.3	-22.2 ÷ -14.4	-6.8	-8.9 ÷ -4.8
Yakutia	-14.0	-16.6 ÷ -11.5	-6.5	-7.5 ÷ -5.4
Russian Federation	-16.2	-18.8 ÷ -13.6	-5.8	-6.7 ÷ -4.9
<b>External causes</b>				
Nenets Autonomous Area	-26.5	-33.0 ÷ -20.1	-5.7	-7.1 ÷ -4.3
Yamal Nenets Autonomous Area	-11.3	-12.9 ÷ -9.8	-2.7	-3.2 ÷ -2.2
Chukotka	n/a		n/a	
Karelia	-26.6	-30.6 ÷ -22.5	-6.4	-7.3 ÷ -5.6
Komi Republic	-22.7	-25.8 ÷ -19.6	-6.1	-7.2 ÷ -5.0
Arkhangelsk region	-23.0	-26.5 ÷ -19.5	-4.9	-5.7 ÷ -4.1
Murmansk region	-14.4	-17.8 ÷ -11.0	-2.2	-3.0 ÷ -1.4
Magadan region	-13.8	-16.7 ÷ -10.9	-3.9	-4.9 ÷ -2.9
Yakutia	-17.0	-18.0 ÷ -15.9	-3.2	-3.5 ÷ -2.9
Russian Federation	-17.5	-19.4 ÷ -15.6	-3.7	-4.1 ÷ -3.3

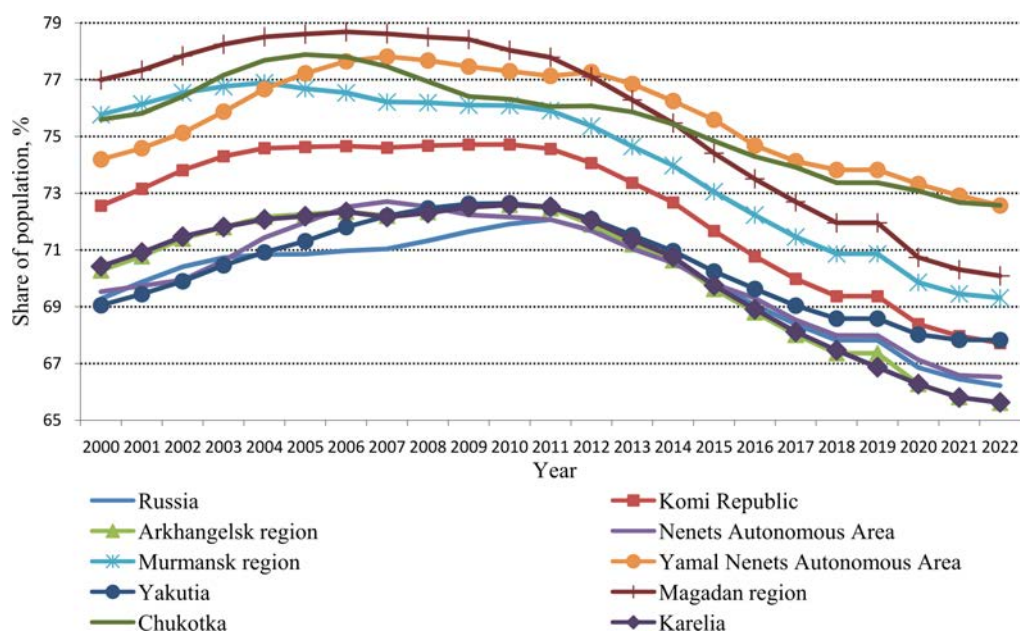


Figure 1. The shares of people aged 15–64 years (the working age population) in the total population in the regions included in the Arctic macro-region and in Russia over 2000–2022

**Results.** The working age population is declining steadily in the Arctic macro-region. This obviously leads to deficit in local workforce. Population outflows occurred in all Arctic regions between 2014 and 2020, except the Yamal Nenets Autonomous Area. The greatest reductions in population occurred in the Magadan region (6.8 %), the Komi Republic (5.9 %) and the Arkhangelsk region excluding the Nenets Autonomous Area (4.9 %). The av-

erage population loss in all other Arctic regions was 4 % [15]. Figure 1 shows the dynamics of the working age population in the Arctic regions. The trends in the Arkhangelsk region and the Nenets Autonomous Area are similar to those observed in the national level (the decline by 2–3 %) but the declines are greater in the Magadan region, Chukotka and the Komi Republic (5–7 %). Despite this substantial decline in the share of the working age

population, this share remains the highest in these regions and exceeds 73 %. In future, the established trend is likely to continue depending on the socioeconomic situation in each Arctic region.

**Dynamics and specific features of the all-cause mortality.** During the first two decades of the 21<sup>st</sup> century, the trends in mortality identified in the Arctic macro-region were generally similar to those identified in Russia as a whole but the rates were different (Figure 2). In the Yamal Nenets Autonomous area, the standardized mortality rate (SMR) for all-cause mortality among

men was 10 % lower than the national average. The same rate was greater by  $\geq 20\%$  than the national average, in Chukotka, the Magadan region, the Komi Republic, and Karelia. The same was true for the Nenets Autonomous Area, the Arkhangelsk region and the Murmansk region where the SMR for all-cause mortality among men was by 10–15 % higher than the national average and it was close to the national average only in Yakutia (where it was 3 % higher). Notably, the spread in estimated mortality rates in the analyzed territories somewhat diminished over the last two decades.

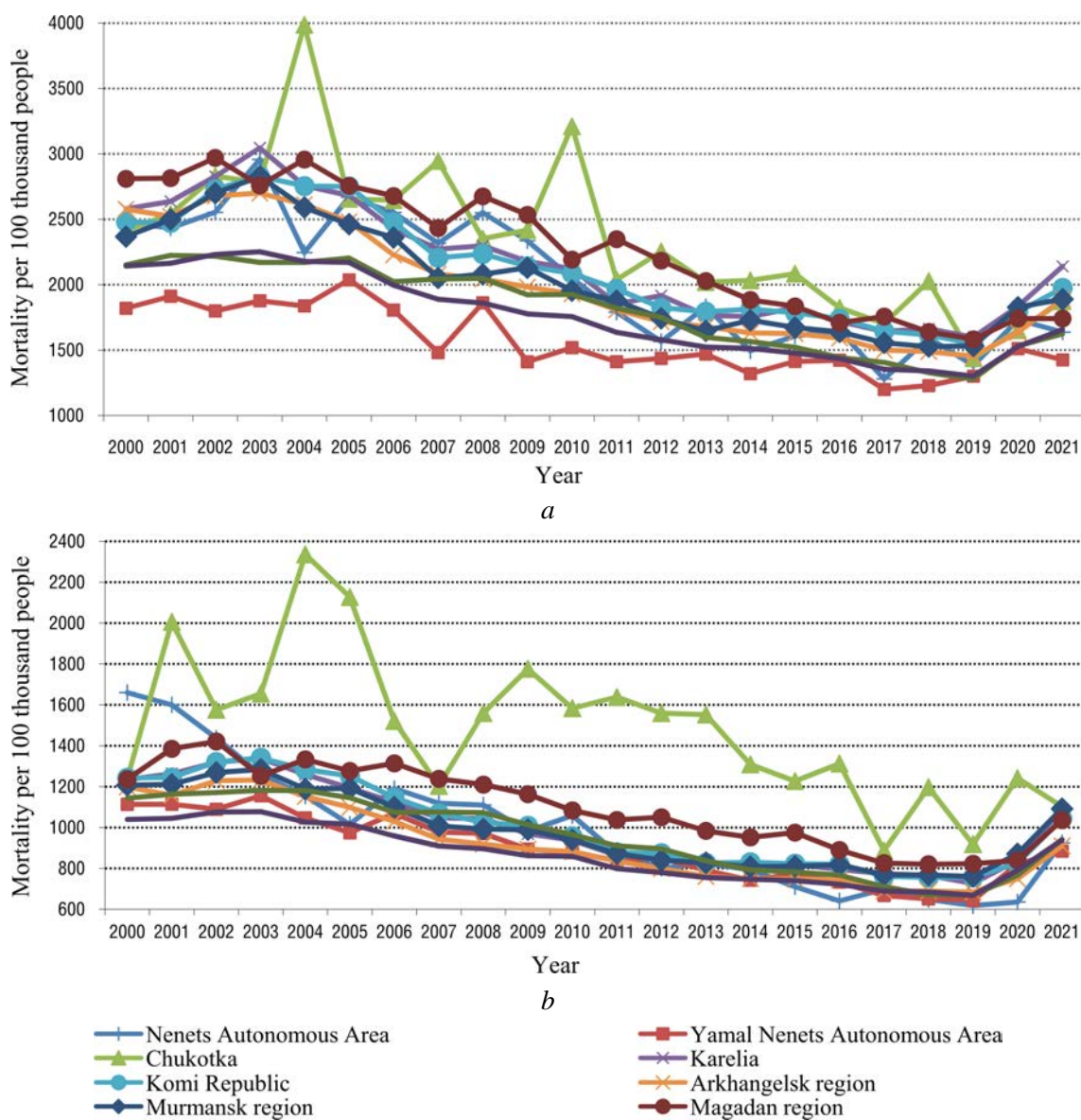


Figure 2. Dynamics of standardized mortality rates for all-cause mortality among men and women in the Arctic macro-region and in Russia as a whole per 100,000 people in 2000–2021: a) men, b) women

The situation with female population is somewhat different. The SMR for all-cause mortality among women in the Yamal Nenets Autonomous Area is the nearest to the national average, being 3.3 % higher than that. The greatest differences between the regional SMR and the national average were identified in Chukotka (where it was 50 % higher) and in the Magadan region (where it was 33 % higher). This indicator was also higher in the Nenets Autonomous Area, Karelia, the Komi Republic, and Yakutia; the difference varied between 10 and 15 % on average. This difference was 5.5 % higher in the Arkhangelsk region. Interestingly, the SMR for all-cause mortality among women in the Arkhangelsk region was even lower than the national average in 2020 and 2021, by 5.3 and 3.1 % accordingly. The diversity between the regional mortality rates among women was smaller than that for men. By 2021, the regional mortality rates among women generally converged, and the spread became smaller.

In general, mortality among men tends to be higher than that among women, both in Russia as a whole and in the Arctic macro-region. The SMR for all-cause mortality among men is almost two times higher than that among women. This difference is smaller only in Chukotka (it is 50 % there). This is caused primarily by relatively higher mortality among women in this region compared to the other regions.

Table 1 summarizes the trends in all-cause and cause-specific mortality in the Arctic macro-region and in the country as a whole in 2000–2021. Non-significant trends are marked 'n/a' (mostly in the Nenets Autonomous Area and Chukotka). A decline in all-cause mortality rates among men in the Arctic is generally more pronounced than the national average trend. The only exception is the Yamal Nenets Autonomous Area where this decline was 33 % smaller than the national average. The decline in all-cause mortality among women in the Arctic was greater than the national average, especially in the Nenets Autonomous Area and Chukotka. All-cause mortality among men decreased faster than

that among women, both in Russia as a whole and in the Arctic macro-region.

In general, the trends in mortality of the working age population (people aged 15–64 years) in the Arctic macro-region were similar to those identified for the country as a whole, with certain exceptions (Figure 3). Thus, the SMR among people aged 15–64 among both men and women in the Yamal Nenets Autonomous Area in 2000–2021 was almost 25 % lower than the national average rate, whereas in Chukotka and Karelia, the SMR among men of the working age was more than 30 % higher than that among women.

The difference between the regional SMR and the national average rate was the greatest in Chukotka (where it was 50 % higher) and the Magadan region (where it was almost 33 % higher) both for women and men. Mortality among men and women of the working age was also higher than the national average in the other Arctic regions as well.

The declining trends in mortality among men aged 15–64 were a bit lower in the Yamal Nenets Autonomous Area and Chukotka than the national average. The same trends in the Magadan region and Yakutia were quite similar to the national average. On the contrary, mortality among the working age population in the other regions went down faster than the national average. Mortality rates among women of the working age declined faster in all Arctic regions than the national average, the Yamal Nenets Autonomous Area being the only exception.

In general, the structure of cause-specific mortality among the working age population in the Arctic is similar to that identified in the country: circulatory system diseases (CSD), neoplasms and external causes account for about 80 %. It is noteworthy that the share of these three major groups of causes in the Arctic macro-region is higher than that in Russia as a whole, primarily, among men. The share of the external causes in the Arctic is more than two times higher than that in Russia as a whole, whereas the share of CSD is significantly lower than the national average.



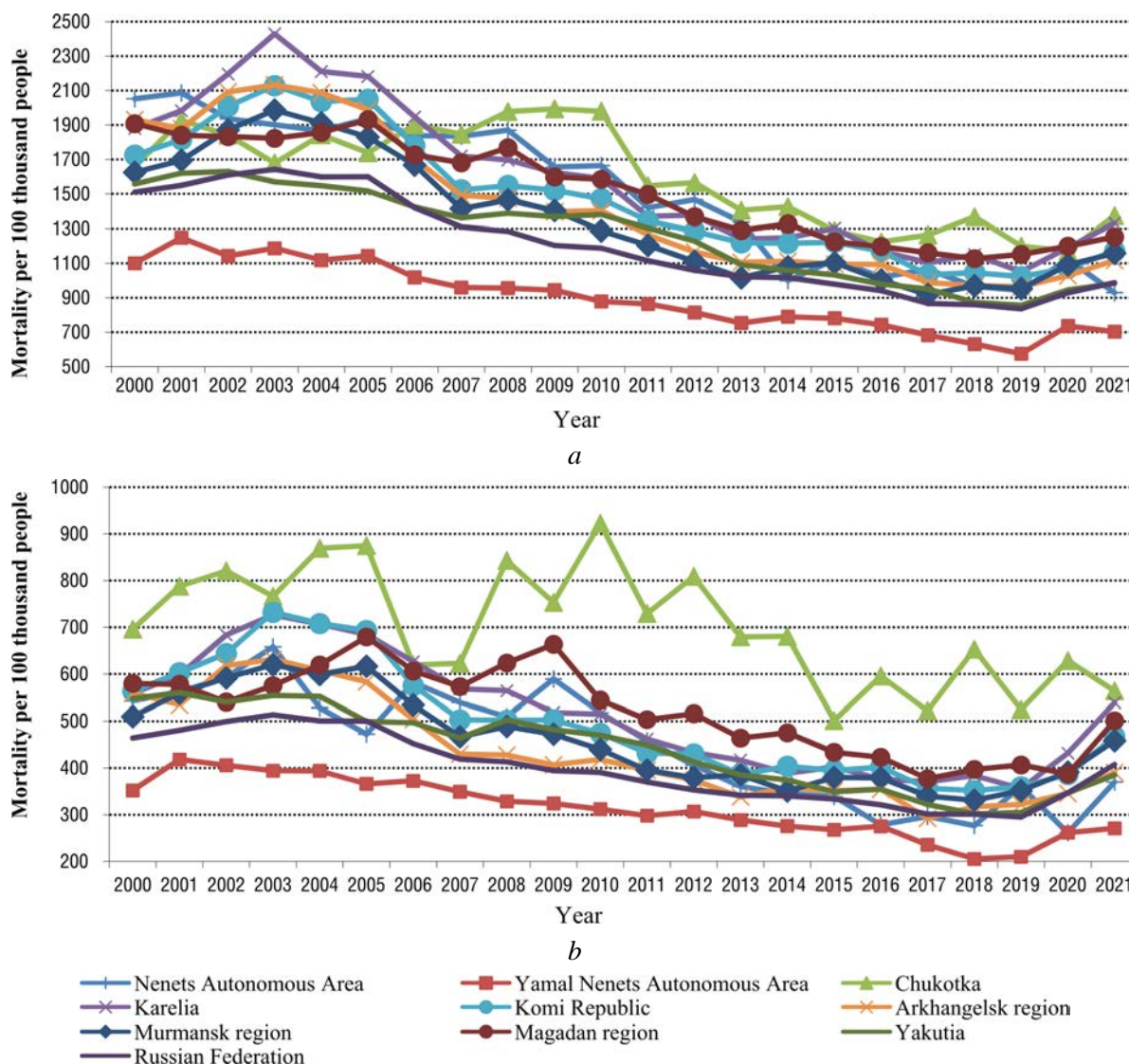


Figure 3. Dynamics of standardized mortality rates for all-cause mortality among men and women aged 15–64 years in the Arctic macro-region and in Russia as a whole per 100,000 people, in 2000–2021: a) men, b) women

**Dynamics and specific features of cause-specific mortality.** During the period 2000–2021, mortality among men due to CSD in the Arctic macro-region was generally higher than the national average rate, with the exception of the Yamal Nenets Autonomous Area. For example, this mortality rate was more than 30 % higher in the Murmansk region and Chukotka; more than 20 % higher in the Arkhangelsk region, Magadan region and Karelia; 15 % higher in the Komi Republic and the Nenets Autonomous Area. The SMR for the circulatory system diseases in Yakutia was almost the same as the national average rate, and this indicator in the Yamal Nenets

Autonomous Area was 10 % lower than the national average rate.

Regarding the trends in CSD mortality rate, it went down in each analyzed region until 2019. After that, it increased again in 2020 and 2021 during the developing COVID-19 pandemic. Thus, the highest statistically significant decreases in CSD-caused mortality compared with the national average level during the analyzed period – were identified for both men and women in the Nenets Autonomous Area, Karelia, and the Magadan region. The decreases in CSD mortality rate were slightly greater than that for the national average rate in the Komi Republic, Arkhangelsk



region, and the Murmansk region. The same decrease among men was 50 % smaller than the national average in the Yamal Nenets Autonomous Area and SCD mortality rate for women in this region was equal to the national average. The CSD-caused mortality among men and women in Yakutia went down slower than in Russia on average.

Ischemic heart disease and strokes account for about 80 % of all CSD-related deaths among men and women both in Russia as a whole and in the Arctic macro-region. In 2000–2021, the SMR due to ischemic heart disease in all analyzed regions was higher than the national average rate, except in Yakutia for men and women, in the Yamal Nenets Autonomous area for men and in Karelia and the Komi Republic for women. The SMR due to ischemic heart disease was lower in these four regions than the national average rate. At the same time, the SMR due to ischemic heart disease among men in the Arkhangelsk region, Murmansk region, and Chukotka was almost 30 % higher than the national average rate. The greatest deviations from the national average in the SMR due to ischemic heart disease for women were observed in Chukotka (by 50 %) and the Nenets Autonomous Area (by 33 %). It should be noted that the statistical reports contain large uncertainties when it comes down to registering deaths due to this cause; in addition, there are certain problems related to healthcare availability in these regions [16].

The inter-regional differences in mortality caused by strokes in the Arctic are very similar for men and women. The SMR due to strokes in Karelia, the Komi Republic and the Murmansk region was almost 50 % higher than the national average rate. Conversely, this indicator in Yakutia, the Yamal Nenets Autonomous Area and Chukotka was significantly lower than the national average rate.

We observed a common tendency in the mortality caused by ischemic heart disease and strokes among men and women in the Arctic regions: the higher SMR in a specific region, the more apparent the declining trend was.

The inter-regional differences in mortality caused by neoplasms among men and women in the Arctic macro-region were generally less

pronounced. However, the SMR due to neoplasms among men and women was almost 33 % higher in the Magadan region compared to the national average rate. The same indicator among men in Karelia and the Komi Republic was 20 % higher than the national average rate. The smallest deviations in this indicator from the national average rates were observed among men in Yakutia and among women in the Arkhangelsk region.

High mortality due to external causes in Russia is known to be a major reason for the differences in life expectancy at birth between Russia and the developed countries. Mortality due to external causes was higher than the national average in nearly all Arctic regions. The greatest deviations in this indicator from the national average rate were recorded in Chukotka (70 % for men and 160 % for women) and in the Nenets Autonomous Area (50 % for both sexes). On the contrary, the SMR due to external causes among men and women was 10 % lower than the national average in the Yamal Nenets Autonomous Area and the Murmansk region. This indicator in the other Arctic regions was 20–40 % higher than the national average rate.

Suicides, homicides and injuries accounted for approximately 50 % of all deaths due to external causes among men and for 40 % of those among women, both in Russia as a whole and in the Arctic macro-region. This share was considerably higher in the Murmansk region (70.4 % among men and 66.9 % among women) in 2000–2021. During the analyzed period, the SMR due to suicides, homicides and injuries was higher in all Arctic regions (except the Yamal Nenets Autonomous Area) than the national average rate. The highest SMRs among men were identified in Chukotka (70 % higher than the national average), in the Nenets Autonomous Area and the Magadan region (50 % higher). The highest SMRs among women were identified in Chukotka (160 % higher than the national average), the Magadan (60 % higher) and Murmansk regions (50 % higher).

The highest SMRs due to accidental alcohol poisoning among men were observed in

the Komi Republic (120 % higher than the national average), in the Arkhangelsk region (twice as higher), and in Karelia (80 % higher). The SMR due to accidental alcohol poisoning among women was 3 times higher in the Komi Republic than the national average; 2.7 times higher in Chukotka; and 2.3 times higher in Karelia. At the same time, the SMR due to this cause was lower than the national average for men and women in the Yamal Nenets Autonomous Area and Yakutia.

In 2000–2021, mortality from respiratory diseases in the Magadan region was 70 % higher for men and 110 % higher for women than the respective national averages (by 1.7 times among men and by 2.1 times among women). The same indicators in Chukotka were 60 % higher for men and 180 % higher for women than the respective national averages. Respiratory disease mortality among men in the Komi Republic was 20 % higher than the national average rate, and the same increase was observed among women in the Yamal Nenets Autonomous Area. Until 2019, the SMR due to respiratory diseases had been declining both in Russia as a whole and in the Arctic macro-region after that, it increased again in 2020–2021, most likely, due to the COVID-19 pandemic.

Mortality from gastrointestinal diseases among men was higher than the national average in one-half of the analyzed regions. The SMR due to this cause among women was higher than the national average in all the analyzed regions. The highest rates were identified in Chukotka (80 % higher), the Magadan region and the Komi Republic (50 % higher).

**Spatial differences in mortality among the working age population.** Inter-regional comparisons were used to identify the areas with the greatest problems and the principal causes contributing to elevated mortality rates among the working age population. The most favorable situation was observed in the Yamal Nenets Autonomous Area, a relatively wealthy and economically developed region with a lar-

ger proportion of the young population and modern cities (Nadym, Noviy Urengoy, Tarkosale, shift settlements). The Arkhangelsk region and Yakutia also fared well in this respect, with its well-developed public healthcare system, high-tech medical equipment, and the Regional Center for Cardiovascular Pathologies. These regions have large differences in the age-specific population structure. Thus, in the Yamal Nenets Autonomous Area, people aged 65 years and older accounted for 4.7 % in the total regional population in 2021 whereas this share was 9.3 % in Yakutia and 16.7 % in the Arkhangelsk region. On the other hand, the regions with the highest mortality rates include Chukotka, the Nenets Autonomous Area, the Komi Republic, Karelia, the Murmansk region, and the Magadan region. Better medical services offered by the centers for cardiovascular pathologies in these regions may lead to a decrease in the mortality caused by strokes and other cardiovascular diseases.

A very interesting situation is with mortality rates due to neoplasms. In the Arkhangelsk region and Yakutia, it is only slightly different from the average country level (probably, due to successful functioning of the university oncology department and oncological hospitals). This mortality rate is somewhat higher than on average in the country in all the other regions. It is in the Arkhangelsk region and Yakutia, with their long histories of successful public healthcare, and in the two Autonomous Areas (the Yamal Nenets and the Nenets) that the lowest mortality rates are registered among the working age population of the Arctic macro-region. But if these two Autonomous Areas and Yakutia have the highest human development index (HDI<sup>3</sup>) and are in the first quartile among all the RF regions, then in the Arkhangelsk region this index is relatively low due to the low income level. Probably, the low mortality rates have been achieved in this region due to the effective regional public healthcare system, the

<sup>3</sup> Индекс человеческого развития в России: региональные различия [The Human Development Index in Russia: regional differences]: the analytical report. *The Analytical Center of the RF Government*, 2021. Available at: [https://ac.gov.ru/uploads/2-Publications/analitika/2022/\\_2021\\_long.pdf](https://ac.gov.ru/uploads/2-Publications/analitika/2022/_2021_long.pdf) (December 22, 2022) (in Russian).

whole medical society, and the Northern Medical Institute.

Mortality rates due to the external causes are rather difficult to interpret. This mortality rate is the lowest in the Yamal Nenets Autonomous Area and the Murmansk region; the highest mortality from the external causes was observed in Chukotka, the Nenets Autonomous Area, and the Magadan region. Unfortunately, such a common cause of death as accidental alcohol poisoning in the autonomous republics and autonomous areas of the Arctic macro-region is twice as higher as the national average. Mortality rate due to this cause is lower than the national average only in the Yamal Nenets Autonomous Area and Yakutia.

**Discussion.** What actions can be taken to reduce additional mortality among the working age population in the Arctic macro-region? An extremely important article that outlines the most vital tasks in the organization of public healthcare on this territory [17] addresses '*multi-aspect peculiarities*' of the Arctic and postulates the necessity to implement specific improvements in public healthcare for different population groups with specific working conditions and lifestyles. Such actions can be tentatively divided into several groups.

First, we should improve healthcare provided for the working age population and people living in industrial cities. Corporate healthcare is the most developed in the Arctic macro-region, especially in the oil and gas, mining and metallurgy companies. Comparative analysis of mortality among men in Norilsk and Monchegorsk in 2010–2017 provided a valuable example of the results of an effective modernization of the regional healthcare system. In Norilsk, an interregional hospital with 1000 beds was built and equipped with the most up-to-date high-tech medical equipment with the financial support from Nor-nickel LLC. Several specialized healthcare programs were implemented for effective treatment of specific diseases, healthcare and

prevention became more available and some other measures were taken. Nothing like that has been implemented in Monchegorsk. As a result, all-cause mortality went down in Norilsk, mortality rates due to circulatory system diseases and some other causes there became approximately 10 % lower than those in Monchegorsk<sup>4</sup>.

Approximately 10,000 people work for Gazprom Dobycha Nadym LLC in the Yamal Nenets Autonomous Area. This company has created a powerful network of occupational and preventive medicine. This network now includes 32 treatment and prevention facilities that use a three-stage rehabilitation system with sanatorium-resort therapy. As a result, the incidence rates among shift workers went down considerably [18]. Local residents can also use the services offered by these treatment and prevention facilities if needed.

The second group of actions involves improvements of publicly funded healthcare programs aimed at prevention of lethal diseases. Such programs are already being implemented, and their effectiveness is monitored by the federal and regional authorities. For example, several regional cancer prevention programs contain certain quantitative targets with respect to expected reductions in mortality rates and increases in early cancer detection rates to be achieved by 2024. These projects also have other goals such as establishment of outpatient healthcare centers, primary oncological consulting rooms, and implementation of other measures aimed at reducing cancer incidence and mortality. Unfortunately, there are not enough projects preventing deaths from the external causes that contribute significantly to the mortality structure.

The third group of actions considers development of public-private partnerships in the public health sector. Such partnerships make health management much more effective, facilitate rapid implementation of business plans and make medical aid more available.

<sup>4</sup>Bryleva M.S. Sotsial'no-gigienicheskoe issledovanie smertnosti naseleniya promyshlennykh monogorodov Arktiki [Social and hygienic examination of mortality among population in industrial monotowns in the Arctic]: the abstract of the thesis ... for the Candidate of Biological Sciences degree. Moscow, 2021, pp. 17–18 (in Russian).

Fourth, the availability of healthcare services should increase greatly everywhere in the Arctic macro-region. This can be achieved by wider implementation of air ambulance services, mobile medical teams, and optimization of transportation routes using the traffic graph technique [19]. The fifth task is to attract highly qualified healthcare professionals to the region. Sixth, priority development targets should include distant medical technologies and medical services tailored for the specific and the most susceptible population groups such as indigenous populations, seamen, shift workers, and some others. Corporate healthcare has a lot to offer in the sphere. For example, the Center for Corporate Public Healthcare was established in cooperation with the Tomsk Medical University. This Center actively develops new methods of remote telemedicine, medical evacuation, and provision of emergency medical aid to the hard-to-reach Arctic settlements, shift camps, offshore oil platforms, ships and the like.

Elevated mortality caused by the exposure to low air temperatures is a specific problem in the Arctic macro-region. In Yakutia, deaths due to the exposure to extreme cold was the second largest contributor to deaths from all external causes before 2015. In the Arctic, more people die from freezing injuries (the ICD-10 code X31 “Exposure to excessive natural cold”) than from traffic accidents.

Improvement of public healthcare influences the overall health status of the Arctic residents more than that in any other region of the RF. Still, the state of public health depends upon many other factors, primarily socioeconomic ones. Quantitative health risk assessment of these factors (income, poverty, unemployment, bad housing, natural and climate conditions, toxic environmental pollution, be-

havioral and personal aspects) have been addressed in many studies, including our previous research in the Arctic macro-region [20]. The health effects produced by a reduction in the number of hospital beds in the rural areas in Yakutia were considered in [21].

Excessive mortality among the working age population is both a social and economic problem. Different statistical techniques have been applied to estimate economic losses caused by elevated population morbidity and mortality. Here are some examples. Based on the *Rospotrebnadzor* Guidelines (MR 5.1.0095-14)<sup>5</sup>, the total economic loss due to the excessive morbidity and mortality in the Komi Republic in 2014–2019 was estimated as 1.5 % of the regional GDP. This loss was mainly attributed to circulatory system diseases, neoplasms and exposure to harmful environmental factors [22]. A similar estimate was produced in a study of economic costs of primary hypertension. The total economic loss due to this disease was estimated as 870 billion Rubles or 1 % of the Russian GDP. Substantial losses are also associated with mortality caused by ischemic heart disease, strokes, and chronic obstructive pulmonary disease (COPD) [23]. Economic losses associated with all causes of death in the country were equal to 1 trillion Rubles or 3 % of the Russian GDP [24].

The number of years of potential life lost (YPLL) also serves as an estimation of the premature deaths. High mortality rates among people under 65 years of age indicate that the public management is not very effective in the socioeconomic sector. The assessments provided for specific territories showed how huge economic losses really were. For example, a study in Vologda region reported the loss of 64,875 billion Rubles due to the premature deaths among the working age population, or

<sup>5</sup>MR 5.1.0095-14. Raschet fakticheskikh i predotvrashchennykh v rezul'tate kontrol'no-nadzornoj deyatel'nosti ekonomicheskikh poter' ot smertnosti, zaboлеваemosti i invalidizatsii naseleniya, assotsirovannykh s negativnym vozdeystviem faktorov srede obitaniya: metodicheskie rekomendatsii; utv. rukovoditelem Federal'noi sluzhby po nadzoru v sfere zashchity prav potrebiteli i blagopoluchiya cheloveka, Glavnym gosudarstvennym sanitarnym vrachom Rossiiskoi Federatsii A.Yu. Popovoi 23 oktyabrya 2014 g. [Calculation of actual economic losses and those prevented due to control and surveillance activities in case such losses are caused by mortality, incidence and disability among population associated with exposure to harmful environmental factors: methodical guidelines; approved by A.Yu. Popova, the Head of the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, the RF Chief Sanitary Inspector, on October 23, 2014]. Moscow, the Federal Center for Hygiene and Epidemiology of Rospotrebnadzor, 2015, 60 p. (in Russian).

about 20 % of the gross regional product in 2018 [25].

Economists also use the public utility and actuarial method to estimate economic losses caused by excessive population mortality. This method is used to estimate both short-term and long-term economic losses. For example, the excess mortality during the severe heat wave in Moscow in 2010 was estimated as 11,000 additional deaths, which was equivalent to 7–12.3

billion rubles or 1.23–1.57 % of Moscow GRP [26]. In 2018, when the Wet-Bulb Globe Temperature (WBGT) index rose above 24 °C, the worldwide losses in labor productivity grew up to 5 % (Watts et al., 2020) [27].

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## References

1. Polovinkin V.N. Human resources – the main problem of the north development. *Arktika: ekologiya i ekonomika*, 2013, no. 4 (12), pp. 026–031 (in Russian).
2. Ivanter V.V., Lexin V.N., Porfiriev B.N. Arctic megaproject in the system of national interests and state administration. *Problemy analiz i gosudarstvenno-upravlencheskoe proektirovanie*, 2014, vol. 7, no. 6, pp. 6–24 (in Russian).
3. Fauzer V.V., Smirnov A.V., Lytkina T.S., Fauzer G.N. Russian and World Arctic: population, economy, settlement. In: V.V. Fauzer ed. Moscow, Politicheskaya entsiklopediya, 2022, 215 p. (in Russian).
4. Leksin V.N. Healthcare system in the Arctic zone of Russia. Known and emerging issues and solutions to them. *Rossiiskii ekonomicheskii zhurnal*, 2019, no. 4, pp. 3–20 (in Russian).
5. Mkrtychyan N.V. Population Migration Balance of the Russian North and the Arctic in the 2010s and its Structural Components. *Nauchnye trudy. Institut narodnokhozyaistvennogo prognozirovaniya RAN*, 2021, pp. 304–325. DOI: 10.47711/2076-318-2021-304-325 (in Russian).
6. Tikhonova G.I., Gortchakova T.Yu., Tchuranova A.N. Mortality among able-bodied population in industrial cities in accordance with specific enterprise forming a company city. *Medsitsina truda i promyshlennaya ekologiya*, 2013, no. 10, pp. 9–15 (in Russian).
7. Shopina O.V., Saltykova M.M., Balakaeva A.V., Bobrovnikskii I.P. Osobennosti smertnosti naseleniya v gorodakh Krainego Severa (na primere Nizhnevartovska i Yakutska) [Peculiarities of mortality in the cities of the Far North (on the example of Nizhnevartovsk and Yakutsk)]. *Analiz riska zdorov'yu – 2021. Vneshnesredovye, sotsial'nye, meditsinskie i povedencheskie aspekty. Sovmestno s mezhdunarodnoi vstrechei po okruzhayushchei srede i zdorov'yu RISE-2021: materialy XI Vserossiiskoi nauchno-prakticheskoi konferentsii s mezhdunarodnym uchastiem*. Perm, 2021, vol. 1, pp. 189–200 (in Russian).
8. Shchepin V.O., Shishkin E.V. The analysis of mortality of population of able-bodied age because of external causes. *Problemy sotsial'noi gigieny, organizatsii zdravookhraneniya i istorii meditsiny*, 2019, vol. 27, no. 3, pp. 222–226. DOI: 10.32687/0869-866X-2019-27-3-222-226 (in Russian).
9. Revich B.A., Kharkova T.L., Kvasha E.A., Bogoyavlensky D.D., Korovkin A.G., Korolev I.B. Demographic trends, labour force dynamics and health risks for the population of Russian Arctic. In: B.A. Revich, B.N. Porfir'ev eds. Moscow, Lenand, 2016, 304 p. (in Russian).
10. Revich B.A., Kharkova T.L., Podolnaya M.A. Mortality Dynamics and Life Expectancy of Population of Arctic/Subarctic Region of the Russian Federation in 1999–2014. *Ekologiya cheloveka*, 2017, no. 9, pp. 48–58. DOI: 10.33396/1728-0869-2017-9-48-58 (in Russian).
11. Shchur A., Timonin S. Center-peripheral differences in life expectancy in Russia: regional analysis. *Demograficheskoe obozrenie*, 2020, vol. 7, no. 3, pp. 108–133 (in Russian).
12. Russia's Population in 2017: 25rd Annual Demographic Report. In: S.V. Zakharov ed. Moscow, HSE Publ., 2019, 480 pp. (in Russian).
13. Korneeva Ya.A., Simonova N.N., Degteva G.N. Components of adaptative strategies as professionally important properties of specialists working on rotational basis in the North. *Ekologiya cheloveka*, 2011, no. 6, pp. 17–21 (in Russian).
14. Silin A.N. Sociological aspects of rotational employment in the northern territories of Western Siberia. *Economic and Social Changes: Facts, Trends, Forecast*, 2015, no. 4 (40), pp. 109–123. DOI: 10.15838/esc/2015.4.40.7

15. Fauzer V.V., Smirnov A.V., Lytkina T.S., Fauzer G.N. Challenges and contradictions in the development of the North and the Arctic: demographic dimension. *Arktika: ekologiya i ekonomika*, 2022, vol. 12, no. 1, pp. 111–122. DOI: 10.25283/2223-4594-2022-1-111-122 (in Russian).

16. Boytsov S.A., Zayratiants O.V., Andreev E.M., Samorodskaya I.V. Comparison of coronary heart disease mortality in men and women age 50 years and older in Russia and USA. *Rossiiskii kardiologicheskii zhurnal*, 2017, vol. 22, no. 6, pp. 100–107. DOI: 10.15829/1560-4071-2017-6-100-107 (in Russian).

17. Leksin V.N., Porfiriev B.N. The other Arctic: Experience in System Diagnostics. *Studies on Russian Economic Development*, 2022, vol. 33, no. 1, pp. 22–28. DOI: 10.1134/S1075700722010105

18. Mel'nikov I.V., Gerelishin I.Ya. Sistema sokhraneniya zdorov'ya i obespecheniya sanitarno-epidemiologicheskogo blagopoluchiya v Arktike na primere OOO «Gazprom dobycha Nadym» [The system of health protection and ensuring sanitary and epidemiological well-being in the Arctic on the example of Gazprom dobycha Nadym LLC]. *Problemy sokhraneniya zdorov'ya i obespecheniya sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Arktike: materialy III mezhdunarodnoi nauchno-prakticheskoi konferentsii*. St. Petersburg, 2021, pp. 265–271 (in Russian).

19. Shartova N.V., Grischenko M.Yu., Revich B.A. Geographical accessibility of health services based on open data in the Arkhangelsk region. *Sotsial'nye aspekty zdorov'ya naseleniya: online scientific journal*, 2019, vol. 65, no. 6, pp. 1. Available at: <http://vestnik.mednet.ru/content/view/1114/27/lang,ru/> (December 19, 2022) (in Russian).

20. Revich B.A. Determinants of public health in Arctic and Subarctic territories of Russia. *Studies on Russian Economic Development*, 2017, vol. 28, no. 1, pp. 39–47. DOI: 10.1134/S1075700717010099

21. Sleptsov S.S., Sleptsova S.S., Burtseva T.E. Mortality analysis of the working-age population of Yakutia. *Yakutskii meditsinskii zhurnal*, 2022, no. 1 (77), pp. 72–75. DOI: 10.25789/YMJ.2022.77.18 (in Russian).

22. Dmitrieva T.E., Fomina V.F. Ecological and economic assessment of public health in the Komi Republic. *Arktika: ekologiya i ekonomika*, 2021, vol. 11, no. 3, pp. 436–448. DOI: 10.25283/2223-4594-2021-3-436-448 (in Russian).

23. Balanova Yu.A., Kontsevaya A.V., Myrzamatova A.O., Mukaneeva D.K., Khudyakov M.B., Drapkina O.M. Economic Burden of Hypertension in the Russian Federation. *Ratsional'naya farmakoterapiya v kardiologii*, 2020, vol. 16, no. 3, pp. 415–423. DOI: 10.20996/1819-6446-2020-05-03 (in Russian).

24. Skvortsova V.I., Shetova I.M., Kakorina E.P., Kamkin E.G., Boiko E.L., Alekhan B.G., Ivanova G.E., Shamalov N.A. [et al.]. Reduction in stroke death rates through a package of measures to improve medical care for patients with vascular diseases in the Russian Federation. *Profilakticheskaya meditsina*, 2018, vol. 21, no. 1, pp. 4–10. DOI: 10.17116/profmed20182114-10 (in Russian).

25. Shabunova A.A., Duganov M.D., Kalashnikov K.N. Untimely death as a cause of economic losses in a region. *Zdravookhranenie Rossiiskoi Federatsii*, 2012, no. 3, pp. 26–30 (in Russian).

26. Porfiriev B.N. Economic evaluation of human losses from disasters. *Voprosy ekonomiki*, 2013, no. 1, pp. 48–68. DOI: 10.32609/0042-8736-2013-1-48-68 (in Russian).

27. Watts N., Amann M., Arnell N., Ayeb-Karlsson S., Belesova K., Boykoff M., Byass P., Cai W. [et al.]. The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. *Lancet*, 2019, vol. 394, no. 10211, pp. 1836–1878. DOI: 10.1016/S0140-6736(19)32596-6

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