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Research article

ON ASSESSING RISK FACTORS THAT CAUSE MORTALITY DUE TO MALIGNANT NEOPLASMS AMONG MEN LIVING IN INDUSTRIAL MONOTOWNS

G.I. Tikhonova, M.S. Bryleva

Izmerov Research Institute of Occupational Health, 31 Budennogo Ave., Moscow, 105275, Russian Federation

The paper dwells on examining mortality among men due to malignant neoplasms (MNs) in Russia and in Norilsk and Monchegorsk, two monotowns located in the Arctic zone with the only industry there being nickel production. Nickel is a well-known carcinogen.

Given rather small population numbers in these two towns, the authors calculated mortality due to MNs that was averaged over 8 years (2010–2017) for 5-year age groups and standardized mortality ratios (SMR) for employable and post-employable ages as per this nosology in general and specific MNs localizations as well.

Mortality was comparatively analyzed in two male populations in the following pairs: Monchegorsk and Russia, Norilsk and Russia; the analysis was based on data on climatic peculiarities in the towns, working conditions at industrial enterprises, ecological situation, and socioeconomic features including an existing situation in public healthcare.

Socioeconomic welfare and public healthcare quality were close to average Russian ones in Monchegorsk, but SMR for employable population was higher than on average in the country: due to MNs in general, by 34.7 %; nickel-specific MNs such as MNs of the lip, mouth, and throat, by 2.2 times; MNs in the stomach, by 1.5 times.

In Norilsk working conditions were similar to those in Monchegorsk but the environmental conditions were worse; still, mortality among employable population was lower: due to MNs in general, by 15.4 %; MNs of the lip, mouth, and throat, by 14.0 %; due to MNs in the stomach, by 39.3 %. In comparison with Russia as a whole, mortality due to MNs was also lower at employable age but higher by 21.6 % at post-employable one.

A decrease in MNs-related mortality and carcinogenic effects becoming apparent at older ages were achieved due to organizing up-to-date oncologic aid in Norilsk including high-tech diagnostic, treatment, and rehabilitation procedures as well as due to higher living standards in the town.

Key words: *mortality, malignant neoplasms, nickel, monotowns, risk factors, high-tech medical aid.*

In Russia malignant neoplasms (MNs) occupy either the second or the third rank place in the structure of mortality among adult men falling behind diseases of the circulatory system and in some years external causes of death[1]. The most unfavorable oncologic situation is usually in industrially developed regions where chemical enterprises, ferrous and non-ferrous metallurgy are located and where most people are exposed to technogenic risk factors including carcinogens [1–5].

National cancer control programs issued by the WHO point out that cancer is quite preventable in one third of cases; it can be successfully treated in another one third provided early diagnostics; palliative help results in a significant improvement of life quality for such patients in the remaining one third of cases [6].

Copper and nickel production in Russia is listed among carcinogenic ones[2] and IARC

Galina I. Tikhonova – Doctor of Biological Sciences, Head of the Laboratory for Social and Hygienic Research (e-mail: gtikhonova@yandex.ru; tel.: +7 (495)366-05-66; ORCID: https://orcid.org/0000-0002-1948-4450).

Maria S. Bryleva – Junior Researcher at the Laboratory for Social and Hygienic Research (e-mail: lms_18@mail.ru; tel.: +7 (495) 366-05-66; ORCID: https://orcid.org/0000-0001-7997-979X).

[1] Demografiya [Demography]. *The Federal State Statistic Service*. Available at: https://www.gks.ru/folder/12781 (September 06, 2019) (in Russian).

[2] GN 1.1.029-98. Perechen' veshchestv, produktov, proizvodstvennykh protsessov, bytovykh i prirodnykh faktorov, kantserogennykh dlya cheloveka [HS 1.1.029-98. A list of substances, products, production processes, household and natural factors that are carcinogenic to humans]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200007321 (September 06, 2019) (in Russian).

assigns nickel and its compounds to Group 1, that is, these compounds are undoubtedly carcinogenic to humans [7].

It is well known that in Russia adverse, hard, and dangerous work is mostly accomplished by men. In 2018 in Russia a share of men who had to face adverse and hazardous working conditions at their workplaces varied from 40 to 60 % depending on an economic activity. The most hazardous conditions at workplaces are usually in mining and in processing industries and this share is even higher in industrially developed regions where it can reach 70–80 %. We should also note that in Russia mortality among people of employable age is typical exactly for men [8].

Sanitary-hygienic conditions are the most significant factor that influences mortality levels in industrial monotowns. This includes working conditions at an enterprise where a considerable part of a male population are employed (a city-forming enterprise) and environmental conditions that are influenced by an economic activity performed at this enterprise which is a dominating economic entity in a given monotown. But still, population mortality is influenced by a whole set of living conditions including climate, geographic conditions, socioeconomic and other features that can mitigate or, on the contrary, aggravate consequences of industrial activities.

Given all that, **our aim** was to assess contribution made by leading risk factors into mortality due to MNs among male population in industrial monotowns.

Materials and methods. We selected two industrial monotowns located in the Arctic zone in Russia where copper and nickel production was located. These monotowns were Monchegorsk (Murmansk region) located on the Kola Peninsula and Norilsk (Krasnoyarsk region) located on Taimyr.

We examined industrial, ecological, climatic and geographic and socioeconomic features of Monchegorsk and Norilsk and comparatively analyzed mortality due to oncologic diseases in these two monotowns and in Russia as a whole.

Occupational environment at enterprises located in the examined cities was analyzed based on data taken from state reports on sanitary-epidemiologic welfare of population in Murmansk region and Krasnoyarsk region; reports on sustainable development issued by "Norilsk Nickel" Group of Companies in 2010–2017; data obtained through studies performed by the North-Western Scientific Center for Hygiene and Public Health; etc. [9–13].

Ecologic situation in the towns was examined based on data provided by Murmansk regional office on hydrometeorology and monitoring over environmental pollution, the Committee on use of natural resources and ecology in Murmansk region, Taimyr Center on hydrometeorology and environmental monitoring and official annual statistical data bulletins issued by Rosgidromet in 2010–2017.

Socioeconomic features of Monchegorsk and Norilsk in 2010–2017 were examined based on official statistical annual reports and Rosstat databases as well as on data taken from reports available at official web-sites, *monchegorsk.gov-murman.ru* for Monchegorsk, and *norilsk-city.ru* for Norilsk. Additional data on public healthcare systems were taken from official web-sites of medical organizations in the examined towns.

Mortality among male population in the examined towns was analyzed based on the following statistical data:

– Sex and age population structure in 2010–2017;

– Number of death cases (Statistical Form C-51 "Distribution of deceased as per sex, age, and causes of death in 2010–2017).

Data on mortality among men of post-employable age provided by Murmansk statistical service were limited to an age group 70 and older and this was taken into account when statistical analysis was performed.

Since population number was relatively small in the towns and significant fluctuations in mortality levels were possible in some years, we calculated mortality rates due to MNs among adult males that were averaged over 8 years (2010–2017):

– for 5-year age groups (15–19, 20–24, ..., 85+) due to all MNs;

– mortality rates standardized as per age;

– for employable age (15–59);

– for post-employable age (Monchegorsk and Russia, 60–70+; Norilsk and Russia, 60–85+).

Standardized rates were calculated for MNs in general, MNs of respiratory organs and MNs of digestive organs as well as for leading MNs localizations that were specific for exposure to nickel according to literature data: MNs of lip, oral cavity, and pharynx; MNs of trachea, bronchus, and lung; MNs of stomach [7, 10, 12–18].

Standardization was performed with direct method. Age structure of male population in Russia determined in the Census-2010 was taken as a standard.

Results. Monchegorsk and Norilsk are located in the Polar Regions practically at the same latitude (67° n.l. for Monchegorsk and 69° n.l. for Norilsk); however, climatic conditions differ greatly in these two towns. Climate is milder in Monchegorsk due to close proximity to Gulfstream and average temperature in winter doesn't drop below –18 °C. Norilsk had more severe subarctic climatic conditions with temperature falling down to –53 °C in winter, higher wind speed and longer polar day and night.

Enterprises belonging to "Norilsk Nickel" Group of Companies are city-forming ones in both towns. In Monchegorsk a metallurgic plant is located where only finished products are manufactured. An enterprise located in Norilsk deals with the whole production cycle and includes several plants where ores are mined and refined as well as several powerful metallurgic plants.

Water-soluble nickel compounds in workplace air are a major source of carcinogenic hazards at metallurgic enterprises. Average nickel concentrations during a shift amounted to 6–37 MPC in Monchegorsk [9–11].

Workers employed at metallurgic plants in Norilsk are exposed to nickel compounds with average shift concentrations varying from 3.1 to 34 MPC and to arsenic oxide, up to 2.3 MPC [12–13].

Besides, workers employed at mining and refining enterprises where copper and nickels ores are processed are also exposed to carcinogenic factors including nickel dust in average shift concentration being from 3 to 8 times higher than MPC and benzopyrene, 1.3 MPC (cargo handling machinery operators) [12].

The most hazardous working conditions are usually at metallurgic enterprises. Nickel and its compounds are the most significant risk factors that can cause MNs among workers employed at such enterprises in both monotowns. Nickel penetrates the body predominantly through the airways, gastrointestinal tract and skin[3] [17].

Exposure to nickel didn't have any significant difference at different enterprises; hence, we can assume that occupational carcinogenic hazard was equal at all workplaces.

We analyzed ecological situation in Monchegorsk to reveal that emissions from stationary sources contained dust, sulfur dioxide, carbon oxide, nitrogen dioxide, as well as such carcinogens as benzopyrene and formaldehyde. Average annual concentrations were higher than MPC only for formaldehyde (up to 2.5 MPC)[4]. In 2018 45.7 tons overall were emitted into ambient air in Monchegorsk[1]. But at the same time cyclones that are typical for the Kola Peninsula make for pollutants dispersion. Complex atmosphere pollution index (IZA 5), all major pollutants taken into account, didn't ex-

[3] Vrednye veshchestva v promyshlennosti. T. 3. Neorganicheskie i elementorganicheskie soedineniya: spravochnik [Adverse chemicals in industry. Volume 3. Non-organic and elemental-organic compounds: reference book]. In: N.V. Lazarev, E.N. Levina eds. Leningrad, Khimiya, 1977, 608 p. (in Russian).

[4] O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Murmanskoi oblasti: Gosudarstvennyi doklad [On sanitary-epidemiologic welfare of the population in Murmansk region: The State Report]. Murmansk, The Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing. Murmansk regional office Publ., 2010–2018 (in Russian).

ceed 5.2[3, 5] in 2010–2017 and pollution was estimated as "elevated"[6].

Ambient air in Norilsk is excessively polluted with adverse chemicals belonging to the 1st and 2nd hazard categories and they are detected in air in the town 350 days a year, 80 % of them in concentrations reaching 5 MPC[7]. Hygienic standards are violated as per contents of sulfur dioxide, phenol, nitrogen dioxide and oxide, copper, and cobalt that are detected in concentrations varying from 1.3 to 4.2 MPC. Average annual ambient air pollution with carcinogens was by 9.5 times higher than permissible levels for formaldehyde and by 7.5 times higher for nickel in residential areas in the town[8]. Overall, in 2018 1,798.5 thousand tons were emitted into ambient air in Norilsk. Adverse chemicals are accumulated in ambient air due to a peculiar relief since the town is located in a hollow surrounded by mountain ranges on the south-west and north-east with their height being 500–900 meters. IZA 5 varied from 4.19 to 31.4 and pollution was estimated either as "high" or "extremely high"[5].

Therefore, environmental pollution can be considered a risk factor of developing MNs in the examined towns. This pollution is significantly higher in Norilsk due to the peculiar relief and substantial production scales; the town is usually among three the most polluted urban settlements in Russia[6].

Having analyzed socioeconomic features we revealed that in 2018 average monthly wages in Russia amounted to 43,724 rubles; they were approximately by 30 % higher in Monchegorsk and amounted to 59,734 rubles; and they were almost two times higher in Norilsk and amounted to 93,129 rubles.[1]. Other socioeconomic features indicated that standard of living was slightly higher in Monchegorsk than in Russia on average according to most parameters whereas it was substantially higher in Norilsk. For example, a share of people with their incomes being lower than living wage amounted to 12.9 % in Russia; 10.8 % in Monchegorsk; and 6.6 % in Norilsk, almost two times lower than on average in the country. Unemployment rate was 4.8 % in Russia, 2.2 % in Monchegorsk, and 0.8 % in Norilsk; capital investments per capita amounted to 119.8 thousand rubles, 171.2 thousand rubles, and 524.9 thousand rubles accordingly[1].

We paid special attention to quality of medical aid and public healthcare systems in the examined cities when analyzing their socioeconomic features. According to official parameters related to public healthcare systems, there were only slight differences between Monchegorsk, Norilsk, and Russia as a whole: number of doctors per 10 thousand people amounted to 54.9, 50.9, 47.5 accordingly; nurses per 10 thousand people, 146.6, 189.5, 103.8; in-hospital beds, 84.2, 70.1, and 80.5 per 10 thousand people accoridngly[1]. However, when it comes down to population health preservation and mortality reduction, such factors as high-tech diagnostic and treatment techniques, professional skills and staffing are becoming more and more important. All this is necessary for efficient use of complicated unique equipment, especially regarding two nosology categories which are the leading causes of death, namely diseases of the circulatory system and MNs. Given that, we accomplished more profound analysis of oncologic aid provision in the examined monotowns.

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[5] Murmanskoe upravlenie po gidrometeorologii i monitoringu okruzhayushchei sredy [Murmansk office on hydrometeorology and environmental monitoring]. Available at: http://kolgimet.ru/ (June 13, 2019) (in Russian).

[6] RD 52.04.186-89. Rukovodstvo po kontrolyu zagryazneniya atmosfery (utv. Goskomgidrometom SSSR 01.06.1989, Glavnym gosudarstvennym sanitarnym vrachom SSSR 16.05.1989) [Guide 52.04.186-89. Guide on control over ambient air pollution (approved by the USSR Goskomgidromet on June 01, 1989, and the USSR Chief Sanitary Inspector on May 16, 1989)]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: http://docs.cntd.ru/document/1200036406 (February 24, 2021) (in Russian).

[7] O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Krasnoyarskom krae: Gosudarstvennyi doklad [On sanitary-epidemiologic welfare of the population in Krasnoyarsk region: The State Report]. Krasnoyarsk, The Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, Krasnoyarsk regional office Publ., 2010–2018 (in Russian).

[8] Taimyrskii tsentr po gidrometeorologii i monitoringu okruzhayushchei sredy [Taimyr center on hydrometeorology and environmental monitoring]. Available at: http://www.meteorf.ru/about/structure/cgms/3154/ (June 30, 2019) (in Russian).

In Monchegorsk there is only a primary oncologic aid office operating in the central town hospital; a diagnosis can be verified and any treatment can be provided only in Murmansk Regional Oncologic Dispensary which isn't either equipped with x-ray and endoscopic devices. Rospotrebnadzor, Gospozhnadzor, and Roszdravnadzor point out in their directions that the central town hospital doesn't have enough oncologists in the staff and its premises are unsatisfactory. The situation makes it next to impossible to detect MNs at early stages and can result in advanced oncologic diseases and, accordingly, higher lethality [19].

Medical aid is of different quality in Norilsk. Norilsk hospital is the only one in the Polar Regions which is located in a multistoried building and equipped with 1,000 beds. Its oncologic division has up-to-date high-tech equipment and there are highly qualified oncologists in the staff; all this provides complex and instant diagnostics of malignant neoplasms and sparing therapy for patients including low-invasive surgery etc. Medical and preventive programs are being implemented in the town including oncologic screening with its main focus on diseases that are typical for exposure to nickel: chronic and pre-cancer gastrointestinal disorders, neoplasms of lip, oral cavity and pharynx. There is a center for outpatient oncologic aid which is opened in Norilsk municipal polyclinic within the Regional project "Fighting against oncologic diseases". People who are older than 40 can have an annual medical check-up there [20].

Therefore, most parameters that describe socioeconomic welfare of population as well as quality of public healthcare were close to average country levels in Monchegorsk whereas they were substantially higher in Norilsk.

Demographic issues are known to be closely connected with economic and social development. There are the same demographic issues in Monchegorsk as in the country in general, namely declining population and young people migrating to larger cities, and this results in intense "population ageing"; the issues are further aggravated with low birth rates and high mortality levels, especially among males of employable age. In Russia, in 2018 overall mortality rate was 12.0 ‰ and higher than birth rate which was only 11.0 ‰. The difference between mortality and birth rates was even greater in Monchegorsk where they were 12.6 ‰ and 9.0 ‰ accordingly[1].

Demographic situation in Norilsk is quite different from that typical for the Arctic zone and Russia in general. The town has "young" population with a higher share of employable population, 68.7 %, and in 2018 it was higher than in Monchegorsk and in Russia by 10.6 % and 12.7 % accordingly.[1] The town is quite attractive for economically active population and a lot of people migrate there, predominantly young ones. But still, population increases mostly due to natural growth since in 2018 overall birth rate in Norilsk amounted to 13.1 ‰[1].

All these occupational and non-occupational factors can influence not only overall demographic parameters but also mortality due to oncologic diseases.

Given difference in age structure occurring due to both natural and mechanic population flows, we comparatively analyzed sex and age mortality rates for 5-year age groups as well as mortality rates standardized as per age separately for employable people (aged 15–59) and people of post-employable age (60 and older). Thus we eliminated impacts by differences in age structure of male population in the examined towns when identifying mortality levels.

To assess influence exerted by occupational activities on health, we compared mortality among male population in Monchegorsk and Russia since socioeconomic development and quality of public healthcare systems in this town were quite similar to those existing in Russia and a major difference was a carcinogenic copper and nickel production located there.

To assess influence exerted by socioeconomic and other non-occupational factors, we compared mortality in Norilsk and Monchegorsk where copper and nickel productions were located with comparable working condi-

tions at workplaces; but still, two towns were quite different regarding living standards and quality of public healthcare systems; more adverse climatic conditions in Norilsk were also taken into account.

Figure 1 shows mortality rates due to MNs average over 2010–2017 for specific age groups of employable male population (aged 15–59) in Monchegorsk, Russia, and Norilsk.

Analysis revealed that mortality rates were higher in Monchegorsk than in Russia or Norilsk practically in all age groups (Figure 1). On the contrary, mortality rates in most age groups in Norilsk were lower not only than in Monchegorsk but also than on average in Russia.

The highest mortality rates in two age groups of people older than 60 were also detected in Monchegorsk (Figure 2).

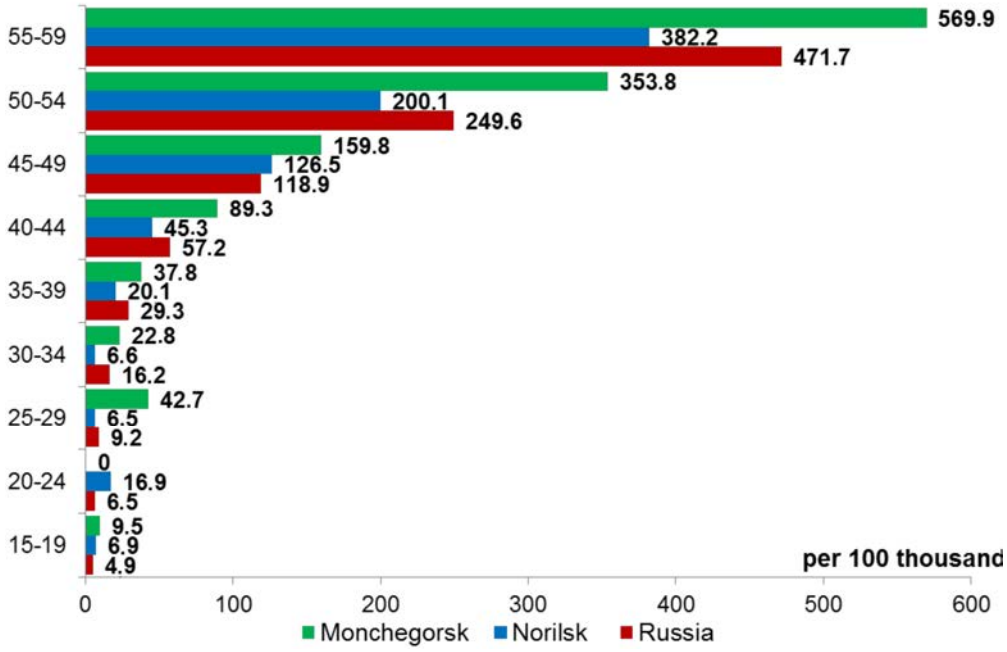

Figure 1. Mortality due to MNs among employable male population in Monchegorsk, Norilsk, and Russia as per 5-year age groups on average in 2010–2017 per 100 thousand people of a respective age

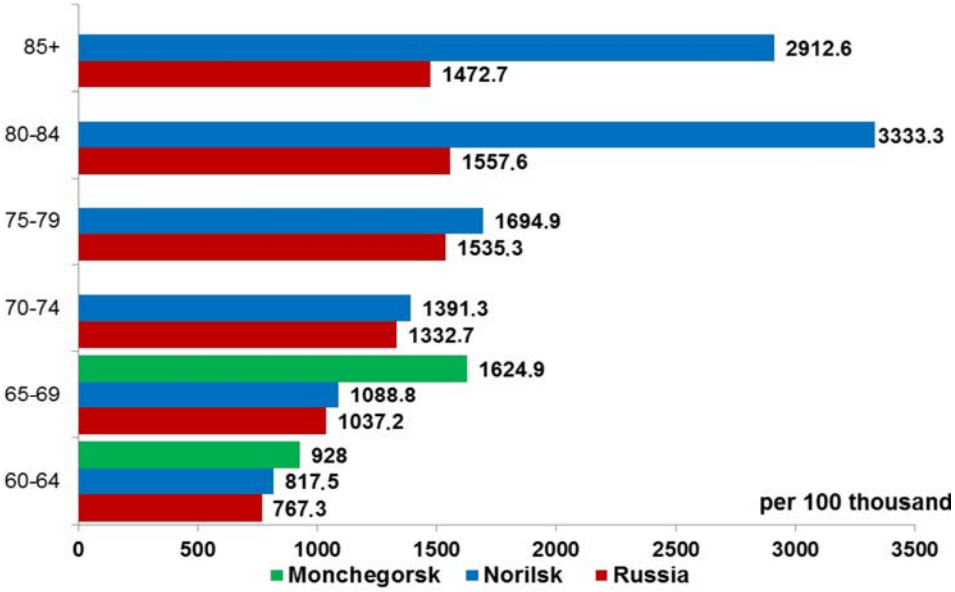

Figure 2. Mortality due to MNs among post-employable male population in Monchegorsk, Norilsk, and Russia as per 5-year age groups on average in 2010–2017 per 100 thousand people of a respective age

Table

Standardized mortality rates due to MNs among male population of employable and post-employable age in Monchegorsk, Norilsk, and Russia per 100 thousand people of a respective age

Territory	All MNs	MNs of respiratory organs	MNs of trachea, bronchus and lung	MNs of digestive organs	MNs of stomach	MNs of lip, oral cavity and pharynx
	Employable age (15–59)					
Monchegorsk	133.8	37.0	32.5	42.2	15.9	16.4
Norilsk	84.0	25.7	22.3	31.1	6.6	6.5
Russia	99.4	30.9	26.8	33.4	10.8	7.5
	Post-employable age (truncated data 60–70+)					
Monchegorsk	1204.6	317.3	298.9	441.3	156.3	73.6
Russia	1134.1	329.1	297.0	427.5	135.4	41.9
	Post-employable age (60–85+)					
Norilsk	1367.9	414.2	387.3	476.9	138.9	43.9
Russia	1124.7	331.6	299.1	422.5	134.2	42.4

The difference between mortality rates in Russia and Norilsk changed in groups of people of post-employable age. Mortality was higher in Norilsk than in Russia in all older age groups with maximum difference being reached for people older than 80.

Mortality rates among male population were standardized as per age separately for employable and post-employable age groups. The results are shown in Table.

Standardized mortality rate due to MNs among employable male population was by 34.7 % higher in Monchegorsk than in Russia (133.8 and 99.4 per 100 thousand men of employable age accordingly). Mortality due to MNs of respiratory organs was also by 19.7 % higher; MNs of trachea, bronchus and lung were by 21.5 % higher. Maximum difference was detected for malignant neoplasms typical for exposure to nickel: MNs of stomach, by 1.5 times higher than in Russia; MNs of lip, oral cavity and pharynx, by 2.2 times higher (Table).

Our analysis of mortality based on truncated data for post-employable age also revealed that mortality rates due to all MNs for male population were by 6.2 % higher in Monchegorsk than in Russia. The greatest difference was detected for MNs of target organs for exposure to nickel, MNs of stomach by 15.4 % and MNs of lip, oral cavity and pharynx by 1.7 times.

In Norilsk age mortality rates and standardized mortality rates for employable males were lower over the 8-year period, both in comparison with Russia and Monchegorsk.

Lower mortality rates were detected for specific MNs localization as well. Mortality rate among employable men due to MNs of respiratory organs, MNs of trachea, bronchus and lung included, was by one third lower in Norilsk than in Monchegorsk and almost by 17 % lower than in Russia. Mortality due to MNs of digestive organs was by 26.2 % and 6.9 % lower among employable population in Norilsk than in Monchegorsk and Russia accordingly; mortality due to MNs of stomach was by 2.4 and 1.6 times lower accordingly. Mortality due to MNs of lip, oral cavity and pharynx was by 2.5 times lower than in Monchegorsk and by 14.0 % lower than on average in Russia.

Results and discussion. Long-term examination of mortality due to MNs in Monchegorsk revealed higher mortality rates due to the nosology than on average in the country regardless of similar socioeconomic development and demographic features and similar quality of public healthcare in this town and in Russia in general.

Similar results are described by other foreign and domestic researchers indicating there are high risks of developing MNs both for workers employed at copper and nickel produc-

tion and for people living in settlements where such productions are located [15, 16, 21–23].

Elevated oncologic morbidity among workers employed at nickel production has been mentioned by V.P. Artyunina, G.P. Chashchin and others [21]. According to these authors when nickel concentration is by multiple times higher than MPC, oncologic incidence grows by more than 3 times among workers employed at such enterprises in comparison with population in general; the greatest difference is usually detected for lung cancer [21].

G.I. Tikhonova, T.Yu. Gorhakova and A.N. Churanova [23] analyzed mortality rates among employable male population in towns located in Murmansk region depending on an economic activity performed at city-forming enterprises. It was established that mortality rates among male employable population were higher in Monchegorsk than in Murmansk, a city without any large industrial enterprises. Mortality due to all MNs was by 17.1 % higher; due to MNs of respiratory organs, by 8.5 % higher; MNs of digestive organs, by 26.7 % higher; MNs of lip, oral cavity and pharynx, by 80.2 % higher [23].

There was a study on morbidity with malignant neoplasms among workers dealing with electrolysis at a nickel production plant in Port-Colborne (Ontario, Canada) over a period from 1930 to 1992; it revealed an elevated risk of MNs of nasal cavity and nasopharynx regardless of levels of exposure to nickel and its compounds [15].

M. Pavela, J. Uitti, and E. Pukkala [16] examined oncologic incidence among workers employed at nickel and oil processing productions in Harjavalta, Finland. They examined MNs incidence among 1,115 people who were exposed to nickel. A reference group was made up of 194 people who were not exposed to this metal at their workplaces. Overall examination period was 45 years, from 1967 to 2011. The authors revealed that exposure to nickel compounds was a basic reason for elevated risks of nasal cavity cancer and lung cancer among workers employed at nickel production. Overall number of cancer cases amounted to 251 among men (Standardized incidence rate (SIR) amounted to 1.05, 95 %) and to 12 among women (SIR 1.22, 95 %). 14 cases of lung cancer (SIR 2.01, 95 %) and 3 cases of nasal cavity cancer (SIR 26.7, 95 %) were detected at workplaces where exposure to nickel was the highest [16].

V. Ciannameo with colleagues [22] examined a correlation between exposure to nickel and mortality in a cohort made up of 2,991 Italian workers dealing with galvanizing. The research results revealed that exposure to nickel compounds could result in elevated risks of lung cancer even if this occupational exposure didn't exceed maximum permissible concentration. They also revealed a correlation between exposure to nickel and developing MNs of digestive organs and MNs of kidneys [22].

Therefore, we revealed higher mortality rates due to MNs among employable population in Monchegorsk who were predominantly employed at a city-forming nickel production enterprise and these results are well in line with those obtained by other Russian and foreign researchers. We can conclude that elevated mortality due to cancer among adult male population as a negative health outcome results from occupational and ecological risks caused by economic activities performed at a city-forming enterprise.

We could expect even higher mortality rates due to MNs in Norilsk since working conditions at city-forming enterprises also involved risks of developing MNs and environmental pollution there was much higher than in Monchegorsk with higher contents of carcinogens and could be further aggravated by more adverse climatic conditions. This assumption was also confirmed by literature data on high oncologic incidence rates in Norilsk available in works by O.A. Ananina with colleagues [24], D.V. Goryaev and I.V. Tikhnova [25], V.V. Karasyov with colleagues [26], B.A. Revich [4].

But our analysis of socioeconomic development and quality of medical and preventive aid provided to population allows concluding that lower mortality due to MNs among male employable population in Norilsk in compari-

son with Monchegorsk is to a greater extent due to high efficiency of public healthcare organizations in the town. Revealing a disease at an early stage contributes greatly to reducing mortality due to neoplasms and the process is quite efficient in Norilsk due to oncologic screening programs aimed at making wider population groups have medical check-ups and due to greater attention paid by medical experts to MNs localizations typical for exposure to nickel. It is confirmed by extremely low mortality rates due to MNs of stomach and MNs of lip, oral cavity and pharynx among employable population; mortality rates among population of post-employable age due to these MNs localizations are similar to those on average in the country (mortality due to MNs of stomach is only by 3.5 % and due to MNs of lip, oral cavity and pharynx, by 3.6 % higher in Norilsk than on average in Russia). It is very important since mortality due to all MNs among population of post-employable age was by 21.6 % higher in Norilsk than on average in Russia.

Several works by Russian and foreign authors have also stressed it is important to improve oncologic aid in order to achieve higher quality of life and longer life expectancy for patients with malignant neoplasms [27–29].

Analysis of all the obtained results indicates that there is high risk of developing MNs both in Norilsk and Monchegorsk and, given all the examined hygienic characteristics, it can be higher than on average in the country but mortality due to this nosology usually occurs in older age groups. This detected regularity can be estimated as postponed realization of carcinogenic risks caused by technogenic factors but adjusted by more efficient public healthcare systems including up-to-date oncologic aid as well as by higher living standards.

So, our study on mortality due to oncologic diseases in Norilsk revealed that a medical component, that is, early diagnostics, timely and efficient treatment and following rehabilitation had the most significant influence on mortality due to MNs in an industrial monotown with carcinogenic productions, especially when it comes down to employable population.

Therefore, economic activities performed at a city-forming enterprise can produce negative effects on health of workers and town population but the same enterprise brings all social and economic welfare to population being a life source for a given monotown [23]. And occupational and ecological risks can be mitigated significantly in case business is socially responsible. This can give grounds for social-demographic and corporate policies aimed at health preservation and reducing mortality among workers and town population in industrial monotowns.

Conclusions:

1. Our social-hygienic study on mortality among adult male population in two industrial monotowns in Russia allowed differentiated estimation of consequences caused by exposure to factors related to economic activities performed by copper and nickel production enterprises. It was done through comparative analysis of mortality in Monchegorsk and Russia and non-occupational factors in comparing mortality in Norilsk and Monchegorsk.

2. Socioeconomic features and quality of public healthcare in Monchegorsk were comparable to average country parameters; but still, there were higher mortality rates due to all MNs and specific localizations typical for exposure to nickel revealed there among male population. It allows concluding that the detected differences correlate with exposure to adverse occupational factors and environmental pollution.

3. We established that mortality rates among male population were lower in all 5-year age groups in Norilsk in comparison with Monchegorsk despite comparable occupational factors at city-forming enterprises in these two towns and more adverse climatic conditions and more polluted environment in Norilsk. These lower mortality rates were due to higher quality of life in Norilsk including better availability of medical and preventive aid, high-tech diagnostics, treatment and rehabilitation provided for patients with malignant neoplasms.

4. Higher mortality rates due to MNs were detected in Norilsk in comparison with Russia for people of post-employable age as opposed to lower standardized mortality rates among men younger than 60; that is, carcinogenic health risks persisted though they turned into actual diseases at older ages. This indicates that hygienic activities aimed at improvement of working conditions and ecological situations should be considered a top priority.

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