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POPULATION HEALTH AS A TARGET FUNCTION AND CRITERION FOR ASSESSING EFFICIENCY OF ACTIVITIES PERFORMED WITHIN "PURE AIR" FEDERAL PROJECT

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We took several cities (Bratsk, Krasnoyarsk, Norilsk, and Chita) included as priority ones into the "Pure air" federal project as an example and showed that it was not sufficient to only aim at reducing gross emissions of pollutants and apply it as a criterion to assess efficiency of air-protecting activities performed in a city. Health risk calculations, and comparative analysis of risk assessment and medical statistical data on population applying for medical aid, combined with the results of profound targeted examinations, revealed that medical and demographic losses (additional population mortality and morbidity) occurred due to a significant number of chemical admixtures, including those, who were not included into a list of pollutants which had to be reduced. Consequently, air-protecting activities don't necessarily result in relevant improvement of a sanitary-hygienic and medical-demographic situation. Residual health risks still remain high.

We showed that there were several significant aspects related to developing and working out in detail complex regional action plans within the "Pure air" federal project. They were a necessity to constantly and profoundly inform a wide circle of people who make decisions on ambient air protection about adverse impacts exerted by specific components in emissions on population health and actual medical and demographic losses on a territory; to assess whether it was technically possible to achieve recommended emission levels and to discuss it with economic entities in order to work out optimal decisions as regards orientation and urgency of specific activities in the sphere; to integrate assessments of air-protecting activities efficiency with prospect city-planning in a region, and to include compensatory medical and prevention activities into regional action plans that should help achieving acceptable health risks levels.

Key words: *"Pure air" federal project, sanitary-hygienic situation, ambient air pollution, risk, population health.*

Strategic documents adopted in the RF, including The RF President Order dated May 07, 2018 No. 204[1, 2], set priority goals for the country development; medical and demographic

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[1] On the Concept for the long-term social and economic development of the Russian Federation up to 2020 (together with The Concept for the long-term social and economic development of the Russian Federation up to 2020): The RF Government Order dated November 17, 2008 No. 1662-r (last edited on September 28, 2018). *KonsultantPlus*. Available at: http://www.consultant.ru/document/cons_doc_LAW_82134/ (date of visit September 13, 2019).

[2] On national goals and strategic tasks regarding The RF development up to 2024: The RF President Order dated May 07, 2018 No. 204. *Garant*. Available at: https://www.garant.ru/products/ipo/prime/doc/71837200/ (date of visit September 13, 2019).

issues are obviously among the most significant ones. They concern population life expectancy, an increase in population number, a decrease in mortality among employable population caused by cardiovascular system diseases, malignant neoplasms, etc. These priorities have been selected quite relevantly as unfavorable demographic trends unavoidably exert negative influence on the RF status in the world, make the country lag behind technological leaders and prevent any rise in life quality and living standards [1, 2].

Activities that should be implemented within national projects, including "Ecology" national project, are supposed to help achieving necessary positive dynamics of population life expectancy and decrease in population mortality and morbidity. "Ecology" national project doesn't have a direct priority as regards reducing population health risks, improving medical and demographic parameters, or providing citizens with more comfortable living environment[2]. The project is oriented at overall decrease in negative technogenic impacts on the environment. Thus, "Pure air" federal project[3], which is an integral part of "Ecology" national project, fixes a key task to *"…decrease ambient air contamination in large industrial centers, including not less than a 20 % decrease in total emissions of pollutants into ambient air in the most contaminated cities"*

The project fixes also priority territories where issues related to ambient air contamination are the most pressing. They include such cities as Bratsk, Krasnoyarsk, Norilsk, Lipetsk, Magnitogorsk, Nizhniy Tagil, Novokuznetsk, Omsk, Chelyabinsk, Cherepovets, and Chita. Approximately 6.4 million people live there. All these territories suffer from high or elevated ambient air contamination.

As planned, approaches to optimal planning and implementation of air protection activities are to be tested in 12 priority cities; they should allow achieving a fundamental improvement in the existing situation. Should these approaches be considered efficient, they can be also applied in other cities and on other territories in the country[4].

A decrease in overall emissions of pollutants into the atmosphere undoubtedly seems to be a most significant task as it is a relevant tool for preserving natural chemical structure of ambient air or atmospheric heat balance. However, it is only secondary next to reducing adverse impacts on population health, especially on densely populated territories such as large industrial cities.

Results obtained via large-scale and long-term research, including works recognized by the World Health Organization, prove that ambient air contamination produces adverse effects on population mortality and morbidity. Relevant scientific works confirm that additional death cases may occur among population due to respiratory organs diseases and cardiovascular system diseases caused by ambient air being contaminated with fine-dispersed dust [3–5], and sulfur dioxide [6]. Benzpyrene, benzene, compounds of chromium, lead, nickel, cadmium, and arsenic, and polycyclic hydrocarbons cause additional cancer cases when they are introduced with inhaled air [7–9]. Various diseases occur in the respiratory organs under exposure to elevated concentrations of nitrogen dioxide, hydrogen chloride, hydrogen sulfide, ammonia, toluene, xylol, phenol, and some other admixtures [10–16].

As per results of macroanalysis, in the RF only in 2018 there were approximately 2.4 thousand additional death cases caused by ambient air contamination (respiratory organs diseases and malignant neoplasms). Effects produced by ambient air contamination are likely to result in about 863.55 thousand disease cases among children and adults; these diseases occur in the respiratory organs, circulatory system, musculoskeletal system, connectivity tissue, and blood and blood-making organs; there are also certain disorders in the immune mechanism, nervous sys-

[3] The Profile of "Ecology" national project. Approved on December 24, 2018. Available at: https://rg.ru/2018/05/08/president-ukaz204-site-dok.html (date of visit October 02, 2019).

[4] The Profile of "Pure air" federal project. Available at: https://rg.ru/2018/05/08/president-ukaz204-site-dok.html (date of visit October 02, 2019).

tem, endocrine system, digestive organs, and neoplasms[5].

When population health becomes a criterion for assessing efficiency of measures taken within "Pure air" federal project, lists and parameters of air-protecting activities should be well-defined and well-substantiated. A simple reduction in overall emissions by a fixed volume is not always efficient without taking into account actual hazards caused by this or that component for people's lives and health; so, it can't always lead to a substantial increase in population life quality and make a sanitary-hygienic situation conform to fixed standards [17].

Plans which are designed within a project are not fixed once and for all; they can be adjusted, specified, and supplemented. Thus, it seems truly vital to get a better insight into algorithms and procedures for assessing efficiency of suggested activities according to medical and demographic criteria. However, it doesn't mean that ecological, technical and/or technological criteria applied in such assessments should be neglected.

Our research goal was to test a mechanism for assessing sufficiency and efficiency of activities implemented within "Pure air" federal project as per health-related criteria[6].

Data and methods. We achieved our research goal via step-by-step finding solutions to the following tasks thus making an overall algorithm:

– assessing ambient air quality in areas where people permanently lived in priority cities;

– assessing population health risks;

– splitting up unacceptable risks into components and assessing contributions made by specific pollutants into overall existing risks;

– comparing risk levels with population morbidity in order to determine whether risk assessments are consistent with the existing medical and demographic situation on a particular territory;

– analyzing regional sets of air-protecting activities regarding effects expected to be produced by them being relevant to risk factors structure;

– working out recommendations on improvements that are to be made in activities implemented within "Pure air" federal project.

We tested the algorithm in Krasnoyarsk, Norilsk, Bratsk, and Chita; we applied health risk assessment methodology as our basic methodical instrument for assessing whether implemented activities were sufficient and yielded expected results. The methodology was supplemented with comparative analysis of the results obtained via the assessment and medical statistical data as well as data obtained via specific research.

To assess population exposure, we took air quality monitoring data collected over a long-term period at stationary monitoring posts belonging to Rosgidromet state ecological monitoring network and posts included into Rospotrebnadzor's social and hygienic monitoring system.

We calculated lifetime carcinogenic risk taking an upper 95 % -limit of average annual long-term (2014–2018) concentration of a specific admixture as contamination level; all analyzed admixtures were measured at monitoring posts located in examined cities. Non-carcinogenic risk was calculated basing on the same initial data but it was given with hazard quotients and indexes (Hazard Index, HI)[7].

When calculated health risks were considered to be "unacceptable", we split them up into specific components and assessed contributions made by each substance into an overall health risk level. It was done in order to determine substances that made the most significant contribution into health risks; so, should their ground concentrations be reduced, it would produce the most considerable effects regarding population health improvement.

We compared calculated risk levels with

[5] On sanitary-epidemiologic welfare of the population in the Russian Federation in 2018: the State Report. Moscow The Federal Center for Hygiene and Epidemiology, 2018, 246 p.

[6] Economic aspects related to such activities were excluded from the present work; we also didn't perform any conformity assessment to check whether examined activities could be considered the best available ones as per technological parameters.

[7] P 2.1.10.1920-04. The Guide on assessing population health risks under exposure to chemicals that pollute the environment. Moscow, The Federal Center for State Sanitary and Epidemiologic Surveillance of the RF Public Healthcare Ministry, 143 p.

data on population mortality and morbidity taken from the official medical statistics[8], and with results obtained via in-depth research performed on selected territories.

We assessed contents and structure of regional air-protecting activities as per "Complex plans of activities aimed at reducing pollutants emissions…" in regions approved by the Deputy Head of the Russian Federation Government on December 28, 2018.

Basic results. We analyzed results obtained via long-term instrumental measuring within Rosgidromet ecological monitoring and Rospotrebnadzor's social and hygienic monitoring system; the analysis revealed that there was a wide range of chemical admixtures registered in ambient air on territories where people permanently lived in the examined cities. Thus, in Bratsk, 29 chemicals were registered in significant concentrations, and some of them were even higher than hygienic standards. Seven chemicals were carcinogens (benzpyrene; benzene; compounds of nickel, lead and chromium; formaldehyde; ethyl benzene).

Even more pollutants were registered with instrumental methods in Krasnoyarsk; there were totally 37, 5 out of them being carcinogenic. 15 admixtures were registered and measured by Rosgidromet and Rospotrebnadzor in Norilsk; in Chita, 21 admixtures.

Practically all the measured admixtures produce well-proven adverse effects on health under short-term and/or long-term exposure.

Table 1 gives some average annual concentrations of chemicals registered in 2014–2018 in Bratsk. It also contains exposure criteria (reference concentrations); should they be exceeded, adverse effects on population health and target organs and systems are likely to occur. If population is exposed to concentrations that exceed reference ones, functional disorders in these target organs or systems are to be expected.

Population health risks calculated on the basis of field observation results were assessed as unacceptable ones as per various violations of hygienic standards practically on all the examined territories. Table 2 contains health risks parameters and characteristics[9] in Bratsk.

Table 1

Concentrations of chemicals with proven adverse effects on health under long-term exposure fixed at monitoring posts included into ecological and social and hygienic monitoring systems in Bratsk in 2014–2018

Chemical	Concentration, mg/m^3			Target organs and systems
	Average annual long-term	95-% provision	RfC	
Nitrogen dioxide	0.0408	0.0512	0.040	Respiratory organs, blood
Nitrogen oxide	0.060	0.078	0.060	Respiratory organs
Benzpyrene	2.0E-06	4.1E-06	1.0E-06	Respiratory organs, immune system, development, carcinogen
Benzene	0.036	0.053	0.030	Respiratory organs, development, blood, immune system, central nervous system, reproductive system, cardiovascular system
Particulate matter	0.086	0.148	0.075	Respiratory organs, mortality
Phenol	0.064	0.095	0.006	Cardiovascular system, kidneys, central nervous system, respiratory organs
Hydrogen sulfide	0.002	0.004	0.002	Respiratory organs

[8] Datasets issued by the Department for Monitoring, Analysis, And Strategic Development of Public Healthcare of the RF Public Healthcare, and the Central Scientific Research Institute for Public Healthcare Organization and Informatization of the RF Public Healthcare Ministry.

[9] Criteria for health risk assessment given with HI and accepted in conformity with MG 2.1.10.0156-19 "Assessment of ambient air quality and health risk analysis in order to substantiate managerial decisions taken in the sphere of providing ambient air quality and sanitary-epidemiologic welfare of the population", approved by the RF Chief Sanitary Inspector on December 02, 2019.

Xylol	0.06	0.08	0.1	Central nervous system, respiratory organs, kidneys, liver
Toluene	0.03	0.05	0.4	Central nervous system, respiratory organs, development
Sulfur dioxide	0.03	0.081	0.05	Respiratory organs, mortality
Carbon disulfide	0.15	0.7	0.7	Central nervous system, development
Carbon oxide	1,8	2,5	3,0	Blood, cardiovascular system, development, central nervous system
Formaldehyde	0.0032	0.005	0.003	Respiratory organs, eyes, immune system
Non-organic poorly soluble fluorides	0.018	0.038	0.013	Skeletal system, respiratory organs
Fluoric gaseous compounds	0.021	0.048	0.03	Skeletal system, respiratory organs
Aluminum compounds		0.005	0.005	Respiratory organs, body weight
Methyl mercaptan	0.0006	0.00012	0.001	Respiratory organs, central nervous system
Lead	3.2E-06	4.2E-06	5.0E-05	Central nervous system, blood, development, reproductive system, hormonal system, kidneys
Manganese	2.1E-05	3.4E-05	5.0E-05	Central nervous system, blood, development, reproductive system, hormonal system, kidneys
Nickel	2.8E-05	3.3E-05	5.0E-05	Respiratory organs, blood, immune system, central nervous system
Chromium	0.00004	0.00008	0.0001	Respiratory organs

Table 2

Population health risks (hazard indexes or HI) under chronic inhalation exposure to chemicals contained in ambient air in Bratsk

Target organs or system	Average HI in the city	HI range	Risk characteristic	Priority risk factors
				chemical
Respiratory organs	12.46	0.85–23.62	High	Particulate matter
				Formaldehyde
				Chlorine
				Nitrogen dioxide
				Sulfur dioxide
Immune system	9.95	5.08–25.43–	High	Formaldehyde
				Benzene
				Nickel compounds
Central nervous system	3.57	0.47–8.21	Alerting, and in some city zones, high	Aluminum compounds
				Phenol
Development	5.16	0.22–20.81	Alerting, and in some city zones, high	Benzene
				Carbon oxide
				Ethyl benzene
Blood system	2.74	0.87–6.22	In some city zones, high	Benzene
Liver	1.50	1.76–2.28	Acceptable	Phenol
Kidneys	1.59	1.00–2.65	Acceptable	Phenol
Cardiovascular system	1.89	1.02–2.56–	Acceptable	Lead compounds
				Phenol

Calculated individual lifetime carcinogenic risk was expected to be up to 3.44E-0.4 in Bratsk; such a risk is considered to be unacceptable and can result in 1.2 additional cancer cases caused by ambient air pollution alone. Chromium and nickel compounds in ambient air make the greatest contribution into carcinogenic risks.

Therefore, a lot of various chemical admixtures make certain contributions (major ones on certain territories in the city) into population health risks occurrence in Bratsk; such admixtures are both commonly spread (dusts, carbon oxide, nitrogen oxide, and sulfur oxide) and specific ones (heavy metals compounds, phenol, aromatic hydrocarbons, and formaldehyde).

In Krasnoyarsk, "high" health risks (HI>6.0) were determined to cause untimely deaths, diseases in the respiratory organs, central nervous system, immune system, neuroendocrine system, blood and blood-making system, development disorders, etc.

In Norilsk and Chita, high health risks existed as regards respiratory organs diseases, development processes, blood system, etc.

Given that risks are somewhat probabilistic and calculated, we performed reconnaissance assessment of population morbidity in the examined cities exactly as per the same nosologies with predicted risks causing them being assessed as unacceptable.

We determined that it was well-grounded to expect health risks turning into actual registered diseases cases.

Thus, for example, in Bratsk where risks causing respiratory organs diseases were considered to be unacceptable and were assessed as high, morbidity with respiratory organs diseases among children has recently been equal to approximately 1.700 cases per 1,000 children. It is 1.21.3 times higher than on average in the region and 1.4–1.5 times higher than on average in the country. Chronic bronchitis among children in Bratsk is registered 2.6 times more frequently among children and 1.9 times more frequently among adults than in the region on average. Bronchial asthma (asthmatic state) is 1.6 times more frequently first diagnosed among teenagers in Bratsk than in the region on average. Nervous system diseases and congenital malformations are 1.2–1.4 times more frequently registered in Bratsk than in the region on average, etc.

In-depth medical and biological examinations of population also confirm that risks related to ambient air contamination turn into additional morbidity cases [18, 19]. Thus, urine and blood taken from children in Bratsk contain those chemical admixtures that were considered priority risk factors on the territory such as benzpyrene, chromium, aluminum, nickel, fluorides, etc; such admixtures were either absent or their concentrations were authentically lower in biological media of children from a reference group. We detected authentic dependences between these chemicals in children's bodies and a number of health disorders that were similar to expected ones. Examined children more frequently suffered from respiratory organs diseases, predominantly chronic inflammations in the upper respiratory tracts (2.9 times more frequently than in a reference group); functional disorders in the vegetative and central nervous system were 5.5 times more frequent than in a reference group. We also detected development disorders as congenital malformations of the heart and kidneys which were 1.5 times more frequent than in a reference group; small anomalies in kidneys development were 1.6 times more frequent than in a reference group.

Statistical, epidemiologic, and targeted medical and biological research that are now being accomplished in Krasnoyarsk and Norilsk, allow obtaining results, though fragmented, that are similar in their essence to above-mentioned ones. Besides, data are well consistent with sanitary-hygienic and medical-biological research that has been previously accomplished on these territories [20–25].

Therefore, risks calculation, and comparative analysis of risk assessment results that were compared with medical statistic data on population applying for medical health and results of in-depth targeted medical examinations on certain territories confirm that it is vital and relevant to work out air-protecting

activities taking into account health-related criteria.

Such an approach will allow not only reducing gross emissions but also providing improvement in medical and demographic situation on a territory and preserving population health as a most significant resource for the development of the state. Reduced emissions of carcinogens and chemicals that cause additional morbidity with cardiovascular system diseases should lead to a decrease in number of disease cases with high fatality rate; it fully corresponds to goals fixed within "Demography" national project. A decrease in environmental pollution with substances that are hazardous for the endocrine system can make its contribution into a reduction in overall number of health disorders related to human hormonal state etc.

But still, analysis of activities that are to be implemented in their initial form doesn't allow assessing their sufficiency and consistency with population health criteria.

Most activities planned within "Pure air" federal project are not strictly bound to specific emission sources. Documents do not fix actual decrease in emission power (g/sec), and there are no other parameters to measure changes in emission volumes.

Thus, in Bratsk there is a range of planned activities that are aimed at reducing emissions by more than 126.5 thousand tons per year; but less than 2 % of this planned potential reduction is technologically substantiated. "Irkutsenergo" PLC plans to reduce emissions from smoke chimneys 0001/0002 at the Heat and Power Plant No.7 due to switching this object from solid fuel (coal) to gas and installing more efficient electrical filters (solid particles emissions reduced by 156.4 tons per years; sulfur dioxide, by 1,202.2 tons per year); the company also plans to reduce emissions from smoke chimneys No. 1 and 2 at the Heat and Power Plant No.6 due to modernized electrical filters and multicyclone devices in the central section (emissions of solid ash particles are to be reduced by 709 tons)[10].

Action plans don't contain any substantiation for potential decrease in emissions of chemicals that are fundamentally significant for minimizing adverse effects produced on population health; such chemicals are metal compounds (aluminum, lead, and nickel), aromatic hydrocarbons (benzene, xylol, and toluene), phenol, hydrogen sulfide, etc. The largest emissions sources in Bratsk including "RUSAL. Bratsk Aluminum Plant" PLC, "Ilim Group in Bratsk" PLC, and "Mechel" Bratsk Ferroalloy Plant plan to adjust their environmental activities within complex ecological expertise aimed at granting these enterprises ecological licenses in 2021–2022[11].

By October 1st, 2019 in Krasnoyarsk only 2.7 % reduced emissions (6,704.343 tons per year) have specific technological substantiation. Emission sources with their aerodynamic and ecological properties to be changed have been determined. Activities that are to be implemented in Krasnoyarsk are aimed at reducing emissions of nitrogen dioxide, nitrogen oxide, benzpyrene, sulfur dioxide, tarry substances, carbon oxide, solid fluorides, hydrogen fluoride, and several dusts. Having assessed efficiency of these activities, experts revealed that their implementation would result in a decrease in health risks under chronic exposure for almost 4.8 thousand people. The greatest risks reduction will be achieved regarding damage to the skeletal system with fluorides being a risk factor for it, as hazard index HI will fall from 2.4 to 1.3. However, a decrease as per priority risk groups (respiratory organs, central nervous system, and blood system) amounts to not more than 0.5 % off the initial level. Health risks remain "high| for all the exposed city population even after implementation of planned activities.

Obtained results don't allow making certain conclusions on achieving acceptable health

[10] The Letter by "Irkutsenergo" PLC dated September 27, 2019 No. 116-35/2680-2598.

[11] The Letter by "RUSAL Bratsk Aluminum Plant" PLC No. RB-out-19-45-0199 dated September 27, 2019, the Letter by "Ilim Group in Bratsk" PLC No. FB-25300-329 dated September 27, 2019. The Letter by "Mechel" Bratsk Ferroalloy Plant No. 2679 dated October 01, 2019.

risks if other activities included into complex plans have similar efficiency.

Special attention should be paid to issues related to a necessity to regulate emissions of fine-dispersed particles which are solid fractions in dust and gas mixtures with particles sizes being less than 10 μm (PM10) and 2.5 μm (PM2.5). Fine-dispersed particles are registered in ambient air in many cities, including their concentrations that are much higher than reference ones which are safe for health. Thus, for example, in Krasnoyarsk 12 out of 44 day samples (27.3 %) taken from April to October 2019 within social and hygienic monitoring activities contained particulate matter in concentrations exceeding hygienic standards with their level sometimes being up to 4.7 average daily MPC. Occurrence of fine-dispersed particles in emissions from both stationary and mobile pollution sources has also been proved by specific research [26–29]. At the same time, fine-dispersed particles nowadays are practically never identified or estimated when emissions from ambient air pollution sources are inventoried. Consequently, PM10 and PM2.5 are not included into ecological standardizing and are not considered a specific risk factor that should be reduced via implementing air-protecting activities. Accordingly, it is impossible to assess sanitary-hygienic and medical-demographic consequences caused by pollution with PM or efficiency of activities aimed at environmental protection.

Conclusion. Undoubtedly, it is not enough to simply list priority chemical admixtures and determine what decrease in their levels should be achieved. There are other important aspects related to developing and detailing complex regional action plans within “Pure air” federal projects. They are:

– a necessity to constantly and fully inform a wide circle of people who are to make decision on air protection in priority cities included into the federal project; such people should be provided with relevant data on adverse effects produced by specific components in emissions on population health;

– population health parameters being a target function and a key criterion in assessing efficiency of planned air-protecting activities;

– assessment and discussion with economic entities whether recommended emission levels are technically achievable; working out optimal solutions on targets and urgency of specific activities;

– supplementing complex activity plans with documents that contain specific technical description of air-protecting activities (giving exact information on emission sources and on pollutants emissions of which should be reduced, masses of pollutants emissions from each source before and after planned activities have been implemented (g/sec, tons/year) etc.;

– assessment of possibility (or, on the contrary, impossibility) to achieve combined reduction in a set of admixtures that are technologically interconnected;

– integration of efficiency assessments for air-protecting activities with prospect town planning on territories;

– in case acceptable health risk levels can’t be achieved due to technical and/or technological limitations medical and prevention activities are to be included into compensatory action plans; such activities are fixed by the Federal Law issued on July 26, 2019 No. 195-FZ “On accomplishing an experiment on fixing quotas for pollutants emissions…”[12].

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SOCIAL AND ECONOMIC DETERMINANTS AND POTENTIAL FOR GROWTH IN LIFE EXPECTANCY OF THE POPULATION IN THE RUSSIAN FEDERATION TAKING INTO ACCOUNT REGIONAL DIFFERENTIATION

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The article contains results of the research on a correlation between social and economic determinants and life expectancy of the RF population. The research is quite relevant at present as it is consistent with the goals set within the demographic policy in the RF, including searching for efficient tools aimed at solving tasks set in it and achieving its targets. Our research goal was to examine social and economic determinants and potential for a growth in life expectancy of the RF population taking into account regional differentiation.

We analyzed world experience in examining effects produced by social and economic factors on life expectancy. Correlation-regression analysis allowed us to detect that economic parameters, lifestyle-related ones, and parameters reflecting education and home comforts were the most significant modifiers (R^2=0.06–0.43). We showed that aggregated changes in these parameters equal to 10.0 % could result in 460.5 days increase in life expectancy (1.3 years longer). The greatest contribution was made by population employment/unemployment taking into account their education (115.29 days); home comforts available in housing (86.9 days); economic parameters (74.09 days); psychosocial stress (54.58 days); alcohol drinks sales (49.57 days); basic food products consumption (46.23 days). These data are fully consistent with the already known results obtained by domestic and foreign researchers in the field and efficiently complement them. Our research results indicate that the current social policy that is being implemented in the RF is quite relevant as it is aimed at reducing social and economic inequality and eliminating a social gradient as regards health of various population groups. We are also sure it is necessary to perform further research in the sphere.

Key words: *life expectancy, social and economic factors, social gradient, demographic policy, population, life quality, morbidity, mortality, factor analysis, cluster analysis.*

Nowadays in the Russian Federation life expectancy at birth (LEB) amounts to 72.6 years (2017); it is equal to 67.51 among males; and to 77.64, among females. This gender-related discrepancy between men and women in the country (10.13) is unprecedented against the average world one (4.81) and the European one (6.67). According to the UN annual research "Life Expectancy Index 2018" Russia occupies the 116th place among 191 analyzed

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countries [1]. Life expectancy in 32 countries has already exceeded 80 years; however, it has not yet reached 70 in 63 countries. Contemporary forecasts made by the UN predict that, taking into account an average population mortality scenario in the RF, LEB in the country is likely to grow [2]. To a great extent it will depend on life quality improvement and an increase in living standards that are determined by such socioeconomic parameters as welfare, healthcare, education, employment, and lifestyle. According to the Clauses 2 and 7 of the RF Constitution, a person is the highest value for the state and the latter is obliged to create favorable conditions for his or her development and life[1]. Relevant policy in the economic and social spheres will provide a steady growth in LEB in the RF.

Implementation of the demographic policy in the RF is aimed at increasing population life expectancy, reducing mortality, birth rate growth, regulating internal and external migration, preserving and improving population health, and a consequent improvement in the demographic situation in the country. In this relation, The RF President Order issued on October 9, 2007 No. 1351 "On approval on The Concept of the demographic policy in the Russian Federation up to 2025"[2] is well-grounded and relevant to the existing demographic situation; moreover, it is quite feasible and can truly provide an increase in population life quality in the RF. It fixes a wide range of tasks thus giving an opportunity to find solutions to priority problems including those aimed at securing population growth up to 145 million people and an increase in life expectancy of the RF population to 75 years up to 2025.

A basic instrument that would allow implementing of the above-mentioned Order is the RF Government Order issued on April 14, 2016 No. 669-r[3]. This document states that life expectancy should reach 74 years by 2020; it also fixes there should be an increase in some other demographic parameters (population number, birth rate coefficient, and migration growth). All the implemented activities are aimed at reaching target quantitative parameters via improved population life quality and it has a key significance for the steady growth in population number in the country.

The RF President Message to the Federal Assembly issued on March 01, 2018 [3] stresses that it is important to preserve the country population including creation of favorable conditions for development, self-realization, and creative work for each person as it will help securing well-being for each citizen and the society as a whole. The state policy that is being implemented at the moment, including approval on new RF national projects (NP) entitled[4]: "The Human Capital", "Comfortable Living Environment", and "Economic Growth", is now aimed at achieving a strategic goal that is the RF becoming a member of a pool that includes "80 plus" countries.

"Healthcare"[5] and "Demography"[6] are basic national projects that cover issues related to a growth in LEB. These two NPs fix different ways how to achieve LEB target levels but still

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they supplement each other quite harmoniously. "Healthcare" NP solves the given task via developing primary medical and sanitary aid, providing medical organizations with highly qualified personnel, public healthcare digitalization, and implementation of innovative medical technologies into everyday medical practices. It all should eventually result in achieving target parameters related to a decrease in population mortality caused by circulatory system diseases and malignant neoplasms, including mortality among employable population. The main focus of the project is on solving issues related to secondary prevention such as preventing disease complications, disability among patients, and preventing lethal outcomes of diseases.

In its turn, "Demography" NP has a target to achieve an increase in healthy life expectancy up to 67 years; it solves issues related to improving life quality via stimulating citizens to make conscious decisions regarding their own health and, above all, via creating conditions for that. This project focuses on primary prevention aimed at preventing occurrence and effects produced by risk factors that can cause a disease. And here main efforts are aimed at supporting motherhood and childhood, improving life quality of elderly people, and creating stimuli for citizens of all ages to pursue healthy lifestyle.

At present a lot of attention is paid to examining possible ways how to increase and predict life expectancy, especially its healthy and active period [4, 5]. In economically developed countries experts mostly try to find ways how to achieve a maximum possible increase in person's life together with preserving his or her basic physical and cognitive abilities. On the contrary, in developing countries it is still vital to increase LEB as an integral population parameter of population mortality. The difference between research performed in developed countries and developing ones is explained via current stages in society development according to the epidemiologic transition theory [6]. Developed countries are now at the fourth stage in this transition with all the properties that are typical for it: low population mortality, high LEB, chronic diseases prevalence in morbidity structure including aging-associated diseases such as Alzheimer's disease, senile asthenia, etc. At the same time in developing countries population suffer from diseases caused by industrialization and urbanization such as circulatory system diseases, oncologic diseases, environmentally induced diseases, and injuries. In some countries mass infections and hunger are still vital issues that need to be resolved [7]. Some researchers insist there was another stage in the process that occurred in Russia in 1990; the stage was called "a period of health deterioration and social upheavals" [8]. The stage was characterized with doubled diseases burden when deteriorated economic and social conditions led to an increase in mortality caused by infectious diseases, alcoholism, and injuries on the backgrounds of degenerative diseases; also a lot of diseases tended to occur at younger ages during that period.

Given all the above-mentioned, there are different ways how to increase LEB. For developed countries, a key issue here is to find causes of degenerative aging-associated diseases and ways how to treat them [9, 10]. For developing countries, and the RF as well, the problem can be solved via drawing on experience accumulated by advanced countries as well as economic transformations aimed at improving life quality and reducing population mortality and morbidity [11].

Differences that exist in stages in epidemiologic transition are also confirmed by how fast LEB grows in different countries. Over the last 70 years LEB in developed countries has increased by 15.0 % – 20.0 %, growth rates being less than 1 % over the recent years. Over the same time period, LEB in developing countries has increased by more than 60.0 %, and growth rates annually have exceeded 2 % over the recent years. In the middle of the last century (1950es) LEB amounted to approximately 70 years in developed countries and it didn't exceed 55 years in developing ones [2]. Besides, in developed countries processes related to mortality reduction and, consequently, a growth in LEB were consistent and planned, and in developing countries a similar growth

in LEB can result in accelerated demographic aging of a country population and disease burden being doubled; it requires completely different approaches to planning managerial activities [12, 13].

Such properties of a demographic process are rather generalized; a basic role in this case belongs to a state policy aimed at resolving given demographic tasks. For example, in 1960–1970es LEB in the RSFSR (Russia) was similar to that in the Western Europe. Over the next 20 years the parameter stagnated in the country, and in 1990es political, economic, and social transformations and consequent changes in structure and dynamics of population mortality and morbidity led to a decrease in LEB, especially among males and employable population. However, at present when the shock therapy on the country economy was completed and political and social stricture in the country is rather stable, changes in LEB have become positive and it has started to grow. In 2017 the parameter was equal to 72.7 years for the whole population [14], and, according to current data, in amounted to 73.7 years in the first half of 2019 [15]. Over the same period life expectancy has also been growing in other countries and "80 plus" pool of countries gradually accepts new members. This example shows how changes in social and economic factors can influence population life expectancy.

The existing situation in the USA is quite different. The country has the highest GDP in the world and the highest expenses on public healthcare, both in absolute and relative values. But despite all that, life expectancy has not yet exceeded 80 years, and it has been steadily declining over the recent years. In scientific literature the phenomenon is now called 'the American paradox" [16]. Recent research that focused on life expectancy and population mortality in the USA reveled that an increase in overall mortality was mostly caused by such reasons as drugs overdose, alcohol abuse, suicides, and injuries. A basic risk group is low-educated employable men and women that live in rural areas or economically unfavorable regions [17]. Other research has revealed that the USA have the lowest ratio between expenses on social services and expenses on healthcare among all OECD countries [18–20].

We have discussed how socioeconomic determinants influence population life expectancy on the examples of events and situations in Russia and the USA; life quality and living standards that have direct influence on population lifestyle seem to make the most significant contribution into diseases occurrence and an increase in number of death cases.

In particular, "INTERHEART", a well-known examination on risk factors causing cardiovascular diseases (CVD) that account for the greatest number of death cases all over the world, revealed that there were several reasons that made the primary contribution into CVD occurrence and deterioration; they are dislipoproteinemia, smoking, hypertension, diabetes, abdominal obesity, psychosocial factors, low consumption of vegetables and fruit, and low physical activity [21]. All the above-mentioned reasons are modified risk factors and each of them often depends on a person's social and economic status; and these statuses can be quite different due to a social gradient in a society [22].

Inequality in education, incomes, and occupational status has its effects on difference in mortality and morbidity in population groups that are different as per these parameters [23, 24]. Besides, education is a significant component here as a level of future incomes will depend on it. Education also influences a person's awareness about risk factors and possible ways to preserve and improve his or her health. There are several research works revealing that mortality tends to be lower among well-educated people and LEB tends to be higher in countries with a higher fraction of educated people [25–29].

Together with education, population incomes also have significant influence on LEB. First of all, cash that is available to households allows people to buy more qualitative products and services and create favorable conditions for life and rest [30, 31]. According to some data, children who live in families with low social and economic status are more prone to cardiovascular system diseases in their adult

life including ischemic heart disease (IHD) and cardiac infarction [32]. Insufficient incomes produce grave effects on males' health as men are more prone to various deviant behaviors such as alcohol intake, smoking, violence and injuries [33].

A person's lifestyle is known to make the greatest contribution into his or her health state [34]. Smoking, alcohol intake, insufficient consumption of vegetables and fruit, and high prevalence of obesity leads to a decrease in LEB among population as a whole [35–38]. Factors related to social tension or psychosocial stress such as unlawful actions including murders, divorces, and unemployment also exert negative influence on population mortality and LEB [39].

We should stress that all the abovementioned risk factors are fully modified and basically depend on relevant state policy regarding economy, social security, and public healthcare both in a country as a whole and on a regional level. Such policy should be based on well-predictable parameters and, among other things, on applying modern techniques for assessing health risks [40].

A regional aspect in demographic issues is especially relevant for the RF as there are substantial differences between the regions in the country as regards both social and economic parameters and life expectancy; in 2017 the difference between the maximum and the minimum LEB in the RF regions amounted to more than 15 years (66.1 in Chukotka Autonomous Area and 81.59 in Ingushetia).

Despite numerous research works that focused on searching for a correlation between social and economic status and LEB both in the RF and abroad, it is still unclear how social and economic determinants influence public and individual health. But at the same time, even given uncertainties in estimations, such factors can be significant proxy-variables that allow predicting LEB taking into account differentiated nature of spatial and time distribution that is typical for social and economic risk factors.

Our research goal was to examine regionally differentiated social and economic determinants and a potential for a growth in life expectancy in the RF related to such determinants.

Data and methods. In our research we considered a hypothesis that there was a direct or inverse regular cause-and-effect correlation between life expectancy at birth (whole population, males, and females as dependent variables) and social and economic determinants (risk factors as independent variables, predictors or regressors). To build up and analyze regression models, we took statistical data collected in 2010–2017 in 85 RF regions; all the data were obtained from official sources such as reports issued by the Federal State Statistics Service (economic parameters, basic food products consumption, alcohol sales, education, employment and unemployment, housing conditions, psychosocial stress, and indirect parameters showing physical activity of population); statistical reports issued by Rospotrebnadzor No. 18 "Data on sanitary situation in RF regions" (a fraction of children who had hot meals at least once a day). Totally, our analysis included 85 socioeconomic parameters that were combined into several groups: public healthcare; economic parameters; basic food products consumption; alcohol sales; a fraction of children who have hot meal at least once a day; employment; parameters related to housing conditions; psychosocial stress; indirect parameters showing physical activity of population; population structure.

We calculated model parameters and checked their adequacy with standard regression analysis applying Statistica 10.0 software package for statistical data analysis. Statistical hypotheses regarding regression coefficients in case parameters were distributed normally were checked with Student's t-test. Models adequacy was checked with dispersion analysis performed with Fischer's test and significance level being 0.05.

To examine occurrence of numerous correlations between socioeconomic parameters and a decrease in initial data dimensions, we applied exploratory factor analysis; we built correlations as per the following chain: "socioeconomic parameters – generalized factors – LEB". Sequential creation of correlation variables matrix, factors extraction via least-square procedure and finding eigenvalues of factors

with consequent Kaiser Criterion application (eigenvalues criterion) allowed us to reduce a number of factors up to 20. To obtain values for burdens of variables on factors, we applied orthogonal rotation that allowed excluding mutual influences produced by factors. These approaches allowed us to calculate quantitative changes in LEB under preset changes in examined socioeconomic parameters.

Our algorithm for creating correlations as per "socioeconomic parameters – generalized factors – LEB" chain included the following basic stages:

– setting predicted socioeconomic parameters via making changes into initial values by a scenario per cent (for example, 10 %, 5 %, or 1 %);

– calculating a difference between predicted and actual value of a socioeconomic parameter;

– recovering data for specific data series as per an algorithm that is given below;

– calculating mean values of a parameter and standard deviation for observation series;

– calculating standardized difference between predicted and actual value of a socioeconomic parameter;

– calculating changes in generalized factors associated with changes in a socioeconomic parameter, taking into account multiple regression coefficient "socioeconomic factors - life expectancy";

– summing up all the values of changes in LEB obtained at the previous stage associated with changes in a socioeconomic parameter;

– ranking all the socioeconomic parameters as per their contributions made into changes in LEB.

The difference between predicted and actual values of a socioeconomic parameter was calculated as per the formula (1):

$$\Delta D = D' - D, \qquad (1)$$

where ΔD is the difference between a predicted and actual value of a socioeconomic parameter; D' is a predicted value of a socioeconomic parameter; D is an actual value of a socioeconomic parameter.

When performing factor analysis, we recovered missing data in an observation series according to the following algorithm: if there were no data in an examined year as regards a given parameter in a specific RF region, we took data collected in the previous year; should there be no data collected in the previous years, we took an average value for an observation series.

We calculated average values and standard deviations for each filled (recovered) data series. The standardized difference between predicted and actual values of socioeconomic parameters was determined as per the following formula (2):

$$\Delta d = d' - d = \\ = \frac{D' - \overline{D}}{D_s} - \frac{D - \overline{D}}{D_s} = \frac{D' - D}{D_s} = \frac{\Delta D}{D_s}, \qquad (2)$$

where Δd is the standardized difference between a predicted and an actual value of a parameter; d' is a standardized predicted value of a parameter; d is a standardized actual value of a parameter; $\overline{D}$ is an average value of a parameter with recovered data; D_s is a standard deviation in a parameter with recovered data.

We calculated changes in generalized factors associated with changes in a socioeconomic parameter as per the following formula (3):

$$\Delta F_i = \Delta d \cdot k_i, \qquad (3)$$

where ΔF_i is a change in the i-th generalized factor associated with a change in a socioeconomic parameter; k_i is a factor coefficient for the i-th generalized factor (determined as per factor analysis results).

A change in life expectancy associated with a change in a socioeconomic parameter was determined via summing up all the products of changes in generalized factors multiplied by relevant "socioeconomic parameters – LEB" multiple regression coefficients as per the following formula (4):

$$\Delta Z = \Delta F_i \cdot b_i, \qquad (4)$$

where ΔZ is a change in life expectancy associated with a change in a socioeconomic parameter given in years; b_i is a coefficient before the i-th factor in "socioeconomic factors – LEB" multiple regression.

Exploratory factor analysis allowed obtaining a factor burden matrix that totally included 20 factors. Cumulative per cent of explained variance amounted to 81.9 %. Formulas (3) and (4) were applied to calculate quantitative changes in LEB associated with a change in each examined socioeconomic parameter. We give an example of calculating a change in life expectancy depending on a 10.0 % change in values of socioeconomic parameters; in this calculation parameters that led to an increase in LEB were raised by 10.0 %, and those that decreased LEB were reduced by 10.0 %. To perform aggregated analysis, we combined all the examined socioeconomic parameters into several factor groups: economic parameters; basic food products consumption; alcohol sales; education; employment and unemployment; housing conditions; psychosocial stress; indirect parameters showing physical activity of population.

We divided RF regions into several clusters according to their socioeconomic parameters and LEB applying a multi-dimensional statistical procedure, namely cluster analysis with k-medians clustering. Parameter values in clusters were compared as per their average cluster values.

Basic results. Linear correlation-regression analysis allowed us to obtain 201 authentically significant models. We analyzed influence exerted by socioeconomic determinants on LEB of female population and revealed the most significant factors as per explained variance coefficient; these factors given in the descending order are as follows: a number of registered crimes per 100,000 people (a_x = -0.002; b = 79.16; $p < 0.05$; r = -0.36; R^2 = 0.13); a fraction of employed population with high education (a_x = 0.16; b = 71.03; $p < 0.05$; r = 0.25; R^2 = 0.063); consumption of vegetables and melons in kg/year per 1 consumer (a_x = 0.042; b = 71.64; $p < 0.05$; r = 0.23; R^2 = 0.053); specific weight of housing equipped with centralized water supply (a_x = 0.056; b = 71.38; $p < 0.05$; r = 0.22; R^2 = 0.049). LEB of male population was primarily influenced by a number of registered crimes per 100,000 people (a_x = -0.004; b = 70.74; $p < 0.05$; r = -0.66; R^2 = 0.43); marriages to divorces ratio (a number of divorces per 1,000 marriages) (a_x = -0.009; b = 69.93; $p < 0.05$; r = -0,34; R^2 = 0.11); consumption of vegetables and melons in kg/year per 1 consumer (a_x = 0.069; b = 57.93; $p < 0.05$; r = 0.4; R^2 = 0.16); consumer expenses per capita, rubles per month (a_x = 0.0002; b = 62.02; $p < 0.05$; r = 0.3; R^2 = 0.09); a fraction of employed population with high education (a_x = 0.314; b = 55.33; $p < 0.05$; r = 0.52; R^2 = 0.28). The most significant models for LEB of the overall population were a number of registered crimes per 100,000 people (a_x = -0.003; b = 75.41; $p < 0.05$; r = -0.65; R^2 = 0.42); consumption of vegetables and melons in kg/year per 1 consumer (a_x = 0.062; b = 64.23; $p < 0.05$; r = 0.41; R^2 = 0.17); a fraction of employed population with high education (a_x = 0.26; b = 62.56; $p < 0.05$; r = 0.5; R^2 = 0.25); specific weight of housing equipped with centralized water supply (a_x = 0.082; b = 63.89; $p < 0.05$; r = 0.39; R^2 = 0.16).

Cluster analysis allowed us to distribute all the RF regions into 4 major groups (clusters) that had their specific socioeconomic parameters; the 1st cluster was made up of 2 regions; the 2nd, 6 regions; the 3rd, 31 regions; and the 4th, 46 regions (Figure 1).

The 1st cluster includes two RF regions, the Nenets Autonomous Area and the Yamal Nenets Autonomous Area. Average LEB value for this cluster amounts to 72.53±1.01 years and is among the highest ones in the country. This cluster has high values of socioeconomic parameters such as investments into fixed assets (average cluster value is 2,623,477 rubles) and gross regional product (4,745,909 rubles) per capita; but at the same time average registered unemployment in this cluster is comparatively high (1.7 %). Provision with doctors (50.2 per 10,000 people) and places in hospitals (85.25 per 10,000) is higher in this cluster than in the country on average (47.5 and 80.5 per 10,000 people respectively).

We have analyzed basic food products consumption[7] and revealed that people living

[7] Here and hereinafter quantity of food products consumed by population and given in kilograms per year per 1 consumer (kg/year per 1 consumer) was estimated basing on recommendations given by the RF Public Healthcare Ministry, The Order No. 614 dated August 19, 2016. “On Approval on the Recommendations on rational standards for food products consumption that conform to contemporary requirements to healthy nutrition”.

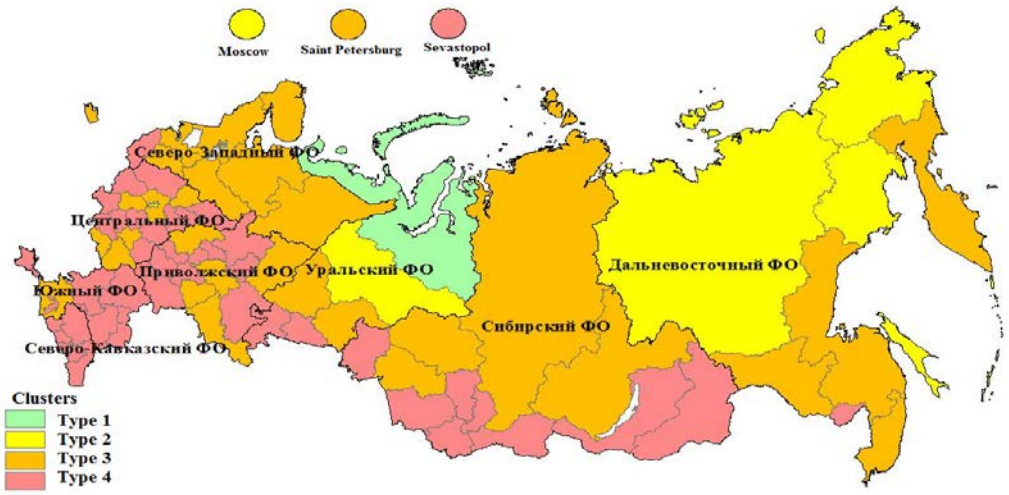

Figure 1. RF regions distributed into 4 clusters as per socioeconomic parameters

in this cluster don't consume sufficient quantities of vegetables (86.65 kg/year per 1 consumer, the standard being 140 kg/year) and fruit (67.25 kg/year per 1 consumer, the standard being 100 kg/year); at the same time, fish and fish products (36.15 kg/year per 1 consumer, the standard being 22 kg/year) and sugar and confectionary (38.3 kg/year per 1 consumer, the standard being 24 kg/year) are consumed in quantities that exceed recommended standards. This cluster has one of the highest alcohol sales volumes (vines and low-alcohol drinks) per capita (9.5 and 0.95 liter per capita accordingly). Population structure in the cluster is characterized with high specific weight of young (24.4 %) and employable (60.55 %) population. Housing conditions such as a specific weight of housing equipped with centralized water supply (80.6 %) and sewage (75.15 %) are poorer than on average in the country (82.4 % and 77.6 % respectively). A specific weight of housing that has central heating is the highest among all the clusters and it is most probably due to climatic conditions and geographic locations of the regions. At the same time a specific weight of dilapidated housing is the highest in the cluster and amounts to 6.05 %. Besides, the crime rate is also the highest in this cluster as it amounts to 1,645.5 registered crimes per 100,000 people. Therefore, high LEB in the cluster is mostly due to economic parameters and factors that could probably result in a decrease in LEB are high crime rate, alcohol consumption, and poor housing conditions.

The 2nd cluster consists of 6 RF regions; they are Moscow City, the Khanty-Mansi Autonomous Area, Yakutia, Magadan region, Sakhalin, and Chukotka Autonomous Area. Average cluster LEB amounts to 71.51±1.65 years. Economic parameters in the cluster including average cash incomes per capita (53,400.0 rubles per month) and consumer expenses (32,280.67 rubles per month) are higher than on average in the country (31,422.0 and 23,806.0 rubles per month respectively). Average cluster unemployment is the lowest (4.3 % on average annually) as per data obtained via sampling examinations of employable population. The cluster also has the highest values of healthcare-related parameters; for example, a number of medical personnel with all specialties amounts to 61.25 $^{0}/_{000}$ per 10,000 people. People living in the 2nd cluster don't consume sufficient quantities of vegetables and melons (85.6 kg/year per 1 consumer), potatoes (46.9 kg/year per 1 consumer), eggs (210 eggs/year per 1 consumer), milk and milk products (239.4 kg/year per 1 consumer), and butter (10.7 kg/year per 1 consumer). Alcohol sales for several types of alcohol drinks (vodka and liquor, sparkling wines, beer and beer-based drinks) per capita are also among the highest in the country (9.48 l, 2.2 l, and 57.5 l per capita respectively).

The cluster has the highest fraction of urban population (84.17 %) and the highest divorce

rate among married families (634.8 divorces per 1,000 marriages). Housing conditions such as specific weight of housing equipped with centralized water supply (87.43 %) and sewage (86.1 %) are the best among clusters. This cluster also has comparatively high crime rate (1,579.3 per 100,000 people) and a rather big share of housing that can be considered dilapidated (2.77 %). Therefore, factors that allow keeping LEB at its existing level are economic parameters that are higher than in the country on average, low unemployment rate, as well as high value of healthcare-related parameters. Risk factors in the cluster are high alcohol sales per capita, divorces rate, and crime rate.

The 3rd cluster comprises 31 RF regions, namely Belgorod, Voronezh, Kaluga, Lipetsk, Moscow (region), Yaroslavl, Karelia, the Komi Republic, Arkhangelsk, Vologda, Kaliningrad, Leningrad (region), Murmansk, Novgorod, Saint Petersburg (city), Krasnodar, Tatarstan, Perm, Nizhniy Novgorod, Orenburg, Samara, Sverdlovsk (region), Tyumen, Krasnoyarsk, Irkutsk, Novosibirsk, Tomsk, Kamchatka, Primorye, Khabarovsk, and Amur regions. Average cluster LEB amounts to 71.68 ± 0.26 years. A peculiar feature of the cluster is that most analyzed parameters correspond to their average country values. For example, economic parameters such as cash incomes per capita (30,410.23 rubles per month) and gross regional product per capita (454,838 rubles) are similar to average country values (31,422.0 rubles per months and 472,161.9 rubles accordingly). Registered unemployment is the lowest among all clusters (1.05 %). Healthcare-related parameters are also quite comparable with average country ones; for example, number of doctors with all specialties amounts to 48.8 $^{0}/_{000}$ per 10,000 people (47.5 $^{0}/_{000}$ on average in the country).

Basic food products consumption is, in general, in conformity with standards recommended by the RF Public Healthcare Ministry (potatoes are consumed in a quantity equal to 59.5 kg/year per 1 consumer; in the RF, 59.4 kg/year per 1 consumer; fruit and berries, 73.1 kg/year per 1 consumer, in the RF, 73 kg/year per 1 consumer). Alcohol sales are also comparable with average country levels (cognac, 0.84 l, in the RF, 0.7 l; sparkling wines, 1.3 l, in the RF, 1.2 l). Population in the cluster has a rather high share of people who are beyond their employable age (elderly ones, 25.5 %). Housing conditions in the 3rd cluster are also comparable to average country ones (housing equipped with centralized water supply accounts for 81.1 %, in the RF, 82.4 %). Crime rate (1,561 $^{0}/_{0000}$) and divorces among married families (614.1 per 1,000 marriages) are higher than on average in the country (1,402.0 $^{0}/_{0000}$ and 582.0 ‰ accordingly). Therefore, LEB in the cluster is supported by low registered unemployment and basic food products consumption being the closest to recommended standards among all clusters. Risk factors are crime rate and divorces rate among married families.

The 4th cluster includes 46 RF regions, namely Bryansk, Vladimir, Ivanovo, Kostroma, Kursk, Orel, Ryazan, Smolensk, Tambov, Tver, Tula, Pskov, Adygei Republic, Kalmykia, Crimea, Astrakhan, Volgograd, Rostov, Sevastopol, Dagestan, Ingushetia, Kabardino-Balkaria, Karachai-Cherkess, North Ossetia, Chechnya, Stavropol, Bashkortostan, Mari (y) El Republic, Mordovia, Udmurtia, Chuvashia, Kirov, Penza, Saratov, Ulyanovsk, Kurgan, Chelyabinsk, Altai Republic, Buryatia, Tyva, Khakassia, Altai region, Transbaikalia, Kemerovo, Omsk, and the Jewish Autonomous Region. Average cluster LEB amounts to 72.39 ± 0.36 years. Economic parameters and healthcare-related parameters in the regions in this cluster are among the lowest in the RF (cash incomes per capita amount to only 22,605.37 rubles per month). Basic food products consumption, excluding bread and groceries (106.12 kg/year per 1 consumer with the standard being 97 kg/year per 1 consumer), corresponds to average country levels. Alcohol sales per capita are the lowest in this cluster (vodka, 4.58 l; wines, 5.32 l per capita). Specific weight of urban population is rather low in these regions (64.9 %) as well as fraction of employable population (55.1 %). Housing conditions are the poorest among all clusters (only 76.19 % of the overall housing is

equipped with centralized water supply). But at the same time the crime rate is the lowest in the cluster (1,379.1 $^{0}/_{0000}$) as well as divorces rate (578.37 ‰).

Therefore, LEB in the cluster remains at the same level due to low crime and divorces rates, low share of dilapidated housing as well as the lowest alcohol sales among all clusters. Risk factors that can cause a decrease in LEB are low economic parameters, low healthcare-related parameters, and poor housing conditions.

Exploratory factor analysis allowed us to reveal predicted quantitative changes in life expectancy at birth (for the overall population) associated with changes in socioeconomic parameters; it confirmed the results of previously performed correlation-regression and cluster analysis. The Table contains the results of 10.0 % scenario changes in socioeconomic parameters. For example, should there be a change in healthcare-related parameters such as a 10.0 % increase in a number of medical personnel per 10,000 people, and, accordingly, a 10.0 % decrease in a burden on public healthcare workers (a number of people per 1 doctor), it will lead to 8.3 days increase in LEB of the overall population (Table).

Table

Potential for a growth in life expectancy of the RF population determined by a socioeconomic factor (a scenario envisages a 10.0 % change in independent variables)

Groups of parameters	Increase ↑ / decrease ↓ in a parameter	Parameter	An increase in LEB given in days
Healthcare-related parameters	↑	A number of doctors with all specialties per 10,000 population, people (taken at the end of a year)	8.29
	↓	Burden on public healthcare workers (taken at the end of a year, number of people per 1 doctor) *	8.2
Economic parameters	↑	Consumer expenses per capita, rubles per month	28.12
	↑	Average cash incomes per capita, rubles per month	13.17
	↓	A specific weight of population with their cash incomes being lower than the living wage (per cent of the total population in a region), %	13.37
	↑	Gross regional product per capita, rubles	3.77
	↑	Investments into fixed assets per capita (given in actual prices)	1.97
	↓	Unemployment rate as per data obtained via sampling examinations of employable population (average annual), %	0.51
	↓	Registered unemployment rate as per data provided by the Federal Service on Labor and Employment (taken at the end of a year), %	0.4
	↑	Living wage (Employable population), rubles	4.73
	↑	Living wage (children), rubles	1.5
	↑	Living wage (retired), rubles	3.29
	↑	Living wage (overall population), rubles	3.26
Basic food products consumption in households	↓	Basic food products consumption in households (meat and meat products; kg/year per 1 consumer)	3.87
	↑	Basic food products consumption in households (eggs, units; kg/year per 1 consumer)	3.68
	↑	Basic food products consumption in households (bread and groceries; kg/year per 1 consumer)	2.95
	↑	Basic food products consumption in households (vegetable oil and other fats; kg/year per 1 consumer)	0.88
	↑	Basic food products consumption in households (potatoes; kg/year per 1 consumer)	12.55
	↑	Basic food products consumption in households (vegetables and melons; kg/year per 1 consumer)	11.32
	↑	Basic food products consumption in households (milk and milk products; kg/year per 1 consumer)	11.05

Alcohol sales	↓	Alcohol sales to population (cognac)	5.67
	↓	Alcohol sales to population (beer and beer-based beverages, liters per capita)	14.19
	↓	Alcohol sales to population (wines (without sparkling wines and champagne, liters per capita)	10.86
	↓	Alcohol sales to population (vodka and liquors, liters per capita)	10.32
	↓	Alcohol sales to population (sparkling wines and champagne, liters per capita)	6.57
	↓	Alcohol sales to population (low alcohol drinks (ethyl spirit contents not exceeding 9 %), liters per capita)	1.96
Children provided with hot meals	↑	Hot meals (lunch) provided for students at vocational education establishments, %	12.13
	↑	Hot meals (breakfast and lunch) provided for schoolchildren studying at 1–11 grades, %	2.92
Employment/ unemployment among population with various education	↑	A share of employed people aged 15–72 with high education, %	36.02
	↑	A share of employed people aged 15–72 with general secondary education, %	7.33
	↑	A share of employed people aged 15–72 with vocational education, %	5.37
	↑	A share of employed people aged 15–72 without general secondary education, %	0.03
	↑	A share of unemployed people aged 15–72 with high education, %	28.32
	↓	A share of unemployed people aged 15–72 with basic secondary education, %	13.68
	↓	A share of unemployed people aged 15–72 with vocational education, %	11.89
	↓	A share of unemployed people aged 15–72 with vocational education for highly qualified workers and clerks, %	7.01
	↓	A share of unemployed people aged 15–72 with general secondary education, %	2.56
	↓	A share of unemployed people aged 15–72 without basic secondary education, %	3.08
Housing conditions	↑	Specific weight of housing equipped with sewage, %	18.9
	↑	Specific weight of housing equipped with central heating, %	37.4
	↑	Specific weight of housing equipped with centralized water supply, %	29.97
	↓	Specific weight of dilapidated housing, %	0.63
Indirect parameters showing physical activity of population	↓	Swimming pools (number of people per 1 swimming pool)	0.87
	↓	Open-air sport facilities (playgrounds and fields) number of people per 1 facility)	6.6
Psychosocial stress	↓	Marriages to divorces ratio (number of divorces per 1,000 marriages)	29.38
	↓	A number of registered crimes per 100,000 people	25.2
Population structure	↑	People younger than employable age, %	2.96
	↑	Males to females ratio (number of women per 1,000 men)*	103.98
		Всего	460,5

Note: * means that this parameter was not included when summing a an expected change in life expectancy given in days

We have analyzed economic parameters and revealed that combined effects produced by average cash incomes, consumer expenses, gross regional product, investments into fixed assets per capita, unemployment rate and other parameters (Figure 2) can result in 74.09 days increase in LEB of the overall population. We have also determined that unemployment rate and specific weight of population with incomes being lower than living wage lead to a decrease in LEB of the overall population (13.8 days), and a rise in average cash incomes per capita, gross regional product, and investments into fixed assets make it increase by 18.91 days on average

Parameters that characterize people's lifestyle include basic food products consumption, energy value of a daily ration consumed in households, alcohol consumption, and a number of children provided with hot meals. We have established that a 10.0 % increase in consumption of such products as eggs, bread and groceries, vegetable oil and other fats, potatoes, vegetables and melons, and milk and

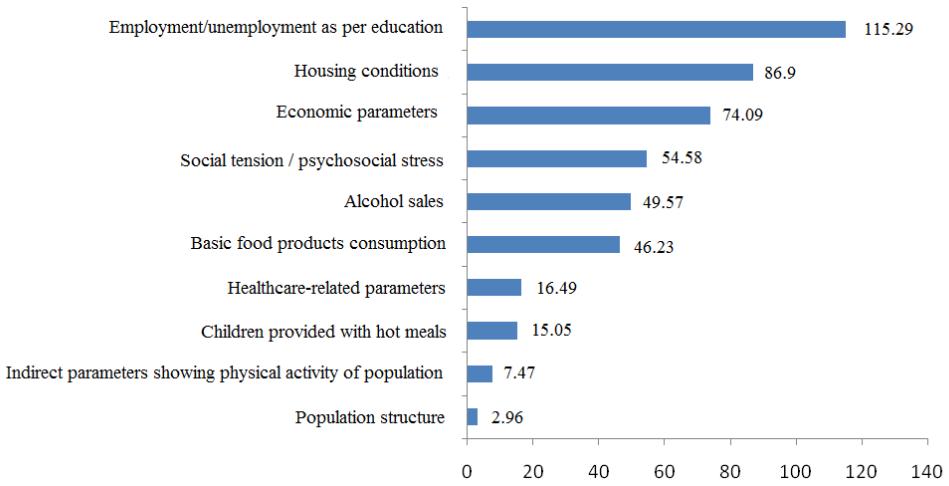

Figure 2. Predicted potential for a growth in life expectancy among the overall RF population determined by socioeconomic parameters (a scenario envisages a 10.0 % rise), days

milk products lead to a rise in life expectancy; an increase in consumption of meat and meat products, on the contrary, results in a fall in LEB of the overall population. Total predicted growth in LEB of the overall population due to changes in basic food products consumption amounts to 42.23 days (Table).

We have obtained an inverse correlation between alcohol sales and LEB of the overall population. A 10.0%-decrease in alcohol sales (most common alcohol drinks) makes LEB of the overall population grow by 49.57 days provided there are no any social consequences of such limitations.

There is a direct correlation between a number of children provided with hot meals, in particular, lunch provided for students attending vocational education establishments and breakfast and lunch provided for schoolchildren of 1–11 grades, and LEB of the overall population as a predicted growth in LEB amounts to 15.05 days.

We have analyzed parameters that characterize the social sphere (employment / unemployment taking into account education, housing conditions, indirect parameters showing physical activity of population, psychosocial stress, and population structure) and revealed that high education regardless of employment status leads to an increase in LEB of the overall population (Table). Besides, employed people with general secondary education, vocational education, and without basic secondary education increase LEB of the overall population whereas should they be unemployed, it results in a fall in it. An aggregated rise in LEB of the overall population caused by an increase in a number of employed people or their education level amounts to 115.29 days.

A 10.0%-increase in parameters that characterize housing conditions such as specific weight of housing equipped with centralized water supply, central heating and sewage makes LEB of the overall population rise by 86.27 days. A 10.0%-decrease in specific weight of dilapidated housing makes LEB of the overall population grow by 0.63 days.

Indirect parameters showing physical activity of population have been estimated via a number of people per 1 sport facility (swimming pools and open air grounds); they have a positive effect on LEB of the overall population (+7.47 days) should a number of sport facilities grow by 10.0 %.

We have determined that a 10.0%-decrease in divorces rate and in crime rate leads to a predicted rise in LEB of the overall population that is equal to 54.58 days.

We have analyzed parameters that characterize population structure and revealed that an increase in males to females ratio (a number of women per 1,000 men) and a share of people younger than employable age makes LEB of the overall population grow by 103.98 and 2.96 respectively. It is well known that mortality among younger people and among women

tends to be lower than among elderly people and men. And a vital task of the demographic policy in the country is to make a fraction of children grow.

Therefore, our calculations indicate that an aggregated increase in life expectancy of the overall RF population amounts to 460.5 days (1.3 years) provided there are relevant changes in the preset scenario conditions for analyzed socioeconomic determinants.

Discussion. Our research results have confirmed that there is a correlation between socioeconomic parameters and population life expectancy. We have shown that the most significant influence is exerted on LEB by economic parameters, lifestyle-related parameters, and parameters that characterize education and housing conditions. Obtained data are fully consistent with results obtained in other research in the sphere. Thus, it was established that an increase in number of people with high education would lead to a growth in LEB and it was probably due to better education providing a possibility to obtain more comprehensive information about potential health risks [24–29]. Besides, higher education often helps people get a more qualified, prestigious, and better-paid job and it makes their life quality higher. And if a share of population with poor education grows, it results in a decrease in LEB, especially if people with poor education are unemployed. Therefore, people with poor education run greater health risks and, consequently, greater risks of a decrease in their LEB.

Average cash incomes per capita and consumer expenses allow making conclusions on welfare among population. Incomes rise provides an opportunity to buy more qualitative food products and better services and allows people to improve their life quality and living standard. Such parameters as gross regional product and investments into fixed assets also make LEB grow and reflect overall welfare of population in a region [30–32]. Opportunities that allow people to realize their potential to a great extent depend on the above-mentioned economic parameters.

Factors related to lifestyle also have their significance, especially structure and energy value of nutrition and alcohol sales. Food products consumption that corresponds to recommended standards especially regarding vegetables, milk products, potatoes, and eggs can result in a considerable growth in LEB [41]. Therefore, issues related to food safety, providing population with high quality and safe food products, and informing population about healthy nutrition play a significant role in the policy aimed at improving the demographic situation in the country.

An inverse correlation between alcohol sales in the RF regions and LEB highlights the significance of any policy aimed at regulating distribution of such products. Measures taken by the state and aimed at limiting a period of time when alcohol can be sold, complete ban on alcohol sales on certain days, excise-duties rise, implementation of the Unified State Automated Information System (USAIS) and other targeted activities will make for further improvement of the situation in the sphere.

Equipping housing with centralized water supply, sewage, and central heating leads to a considerable growth in LEB of the overall country population as it is confirmed by the results obtained in other research in the sphere [42]. Probably, more comfortable housing conditions when people are provided with centralized water supply, sewage, and central heating also allow achieving a decrease in population morbidity.

To sum up, our research allows us to make the following **conclusions**:

– socioeconomic determinants exert significant influence on life expectancy and are different in different regions a per a level of their potentiating or inhibiting effects on LEB;

– an aggregated increase in life expectancy of the overall RF population due to relevant changes in present scenario conditions (10.0 %) for the analyzed socioeconomic determinants can amount to 460.5 days (1.3 years);

– the greatest influence is exerted on life expectancy by the following socioeconomic parameters: employment / unemployment (115.29 days); housing conditions (86.9 days); economic parameters (74.09 days); psychosocial

stress (54.58 days); alcohol sales (49.57 days); basic food products consumption (46.23 days).

Our research has covered influence exerted on life expectancy only by socioeconomic factors data on which are collected by official statistical authorities. We plan to focus our further research on examining impacts exerted on life expectancy of the RF population by other modifying environmental factors.

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HEALTH RISK ANALYSIS RELATED TO EXPOSURE TO AMBUENT AIR CONTAMINATION AS A COMPONENT IN THE STRATEGY AIMED AT REDUCING GLOBAL NON-INFECTIOUS EPIDEMICS

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The article dwells on the analysis of the latest world data indicating that ambient air contamination is one of the most significant risk factors causing non-infectious diseases. Adverse effects produced on health are the most evident among sensitive population groups (women, children, and elderly people).

It was noted that risk management with well-grounded choice on the most efficient activities aimed at its minimization was rather rare in Russia; it is a key problem related to practical implementation of health risk analysis methodology in the country.

We highlighted that health risk analysis methodology was successfully applied when "Pure air" federal project was implemented within "Ecology" national project.

We recommended basic stages in assessing efficiency of activities aimed at health risk management, reducing population morbidity and mortality, creating comfortable and favorable urban environment in 12 cities that participated in "Pure air" federal project.

The article also contains suggestions on a unified algorithm based on economic estimation of alternative health risk management techniques and ways to provide sanitary-epidemiologic welfare. The algorithm includes substantiating a necessity to perform examinations and health risk assessment under "basic" exposure, and determining priority problems; assessing residual health risks after each considered activity, assessing efficiency of technological, economic, and health-influencing activities; comparative health risk assessment; health risks ranking taking into account additional effects, as well as technological and economic efficiency; substantiating choice on the most optimal activities and presenting conclusions to decision-makers in the field; giving grounds for a decision being taken.

***Key words**: risk analysis, risk assessment, risk management, economic estimation, economic efficiency, population health, sanitary-epidemiologic welfare of the population, "Pure air" federal project, ambient air contamination.*

The most recent data obtained via epidemiologic research in Europe and all over the world indicate that ambient air contamination holds the second place as a risk factor causing non-infectious diseases (NID) after tobacco smoking [1]. Approximately 90 % people in the world have to inhale air with elevated contamination levels and it annually causes about 7 million untimely deaths or 1 death case out of 9 [2]. In 2016 ambient air contamination caused 5.6 million death cases due to NID [3]. World Health Assembly instructed the WHO to take on a leading role in fighting against most significant reasons for

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untimely death in the world. Up to 98 % of people living in large cities located in low-income countries can be exposed to ambient air contamination. For example, according to the WHO estimates, cities in Eastern Mediterranean area or in the South-East Asia with not only low incomes but also with average ones have ambient air contamination that is 5–10 times higher than standards recommended by the WHO.

The WHO publications issued over the last ten years give some data confirming that approximately 4.3 million people annually die due to poor air quality indoors; approximately 3 million people die due to outdoor air contamination. Up to 30 % death cases caused by most prevailing non-infectious diseases (strokes, lung cancer, and chronic obstructive pulmonary diseases) and 25 % death cases caused by cardiac infarction are associated with ambient air contamination; this environmental factor produces the most adverse effects on health of women, children, elderly people and low-income people [4–6].

Apart from ambient air contamination, drastic changes in meteorological parameters also exert their influence on NID prevalence.

Unfavorable weather conditions (heat, temperature inversions etc.) combined with substantial ambient air contamination produce the most hazardous effects as such a combination leads to an increase in additional death cases due to cardiovascular diseases and respiratory diseases [7–10].

Issues related to ambient air contamination and their effects on population health in the Russian Federation are obviously most urgent and require solutions at the state, regional, and municipal levels [11–14].

In order to improve the ecological situation in the country and reduce ambient air contamination in Russian cities, “Ecology” national project was developed and approved by the RF President Order in 2018. “Pure air” federal project is its integral part[1]. By 2024 all the activities that are to be implemented within “Pure air” federal project should result in a 20%-decrease in aggregated volumes of adverse emissions into the atmosphere against their levels in 2017 in Bratsk, Krasnoyarsk, Lipetsk, Mednogorsk, Nizhniy Tagil, Novokuznetsk, Norilsk, Omsk, Chelyabinsk, Cherepovets, and Chita. When implemented, “Pure air” federal project should enable reducing a number of cities with high and extremely high ambient air contamination, creating an efficient system for monitoring and control over ambient air quality, as well as following people’s satisfaction with ambient air quality which is also very important.

Another expected result of the project implementation is a fall in mortality and morbidity caused by ambient air contamination in cities that participate in “Pure air” federal project.

Some activities within “Pure air” federal project focus on consolidated calculations of emissions from stationary and mobile sources; apart from that, a complex action plan is to be drawn up for each city, the most significant emission sources such as enterprises or any other are to be identified, exposed areas are to be determined, and effects produced by air-protection activities are to be assessed.

However, multiple research works prove that it is not sufficient to only assess aggregated emissions if we want to develop an efficient policy aimed at making the environment cleaner and healthier [15, 16]. Only comprehensive and in-depth analysis of all the available data on sources of ambient air contamination, impacts exerted by priority contaminants, and, accordingly, population health risks allows assessing whether planned and implemented activities are truly efficient, including their assessment from economic point of view [17–20].

[1] The Profile of “Ecology” national project / approved by the Presidium of the RF President Council on strategic development and national projects, the meeting report No. 16 dated December 24, 2018. Available at: http://www.consultant.ru/document/cons_doc_LAW_316096/ (date of visit November 12, 2019)

Nowadays, health risk analysis methodology is an optimal approach to assessing whether nature-protecting and recovery activities are efficient and should they be somehow adjusted or supplemented [21].

Over the last 25 years health risk assessment methodology has been successfully applied in many regions in the RF in order to make well-grounded managerial decisions as regards providing ambient air quality and sanitary-epidemiologic welfare of the population. Health risk assessment allowed identifying leading risk factors in each particular research; determining population groups that were the most susceptible to adverse effects; ranking territories as per health risks both in the current situation and in probable future ones related to changes in economic activities, primarily industries and transport.

Accumulated experience indicates that most studies on health risk analysis that are performed in Russia mostly focus on its first stage or health risk assessment that allows determining whether calculated risk levels are acceptable or not [22–26]. And risk analysis in this case rarely covers any issues related to risk management together with substantiating the most efficient measures required to minimize it. This methodology can be applied successfully only provided that implemented activities are analyzed and this analysis is aimed at determining maximum possible reduction in risk level that can be achieved due to them with the minimum possible expenses required for their implementation.

At present there are some scientific and methodological documents[2, 3, 4, 5] that fix approaches to how to make economic estimations and substantiate decisions regarding health risk management under exposure to various environmental factors including ambient air contamination.

These documents provide a detailed insight into assessing cost efficiency as regards variable managerial decisions, in particular, when substantiating sizes of a sanitary-protection zone taking into account any planned reconstruction of industrial facilities; when planning how to rehabilitate health of people who live on contaminated territories, etc.

However, in order to optimize practical implementation of risk analysis within “Pure air” federal project, it is advisable to apply a unified algorithm based on economic estimation of different options for managing health risks and providing sanitary-epidemiologic welfare.

When investment projects are properly ranked, it provides valuable information for decision-makers who are responsible for choosing the best available ones; such choices are to be based on a combination of maximum possible economic efficiency of a project with maximum possible effects related to protecting people from exposure to chemicals that contaminate ambient air.

A step-by-step algorithm for assessing health risks and damage to health applied to substantiate ways to manage risks caused by exposure to ambient air contamination (assessing how efficient implemented activities are) contains the following stages: substantiating a necessity to perform examinations, health risk assessment under “reference”

[2] G 2.1.10.1920-04. Guide on health risk assessment under exposure to chemicals that pollute the environment. Moscow, The Federal Center for State Sanitary and Epidemiologic Surveillance of the RF Public healthcare Ministry, 2004, 143 p.

[3] MG 5.1.0030-11. Methodical guidelines for economic estimates and substantiating decisions regarding health risk management under exposure to environmental factors. *KODEKS: an electronic fund of legal and reference documentation*. Available at: http://docs.cntd.ru/document/1200088393 (date of visit December 01, 2019).

[4] MG 2.1.10.0033-11. Assessment of risks caused by effects produced on health by lifestyle-related factors. *KODEKS: an electronic fund of legal and reference documentation*. Available at: http://docs.cntd.ru/document/1200111974 (date of visit December 01, 2019).

[5] MG 2.1.10.0057-12. Assessment of risk and damage caused by climatic changes that influence morbidity and mortality among population groups who run elevated health risks. *KODEKS: an electronic fund of legal and reference documentation*. Available at: http://docs.cntd.ru/document/1200096653 (date of visit December 01, 2019).

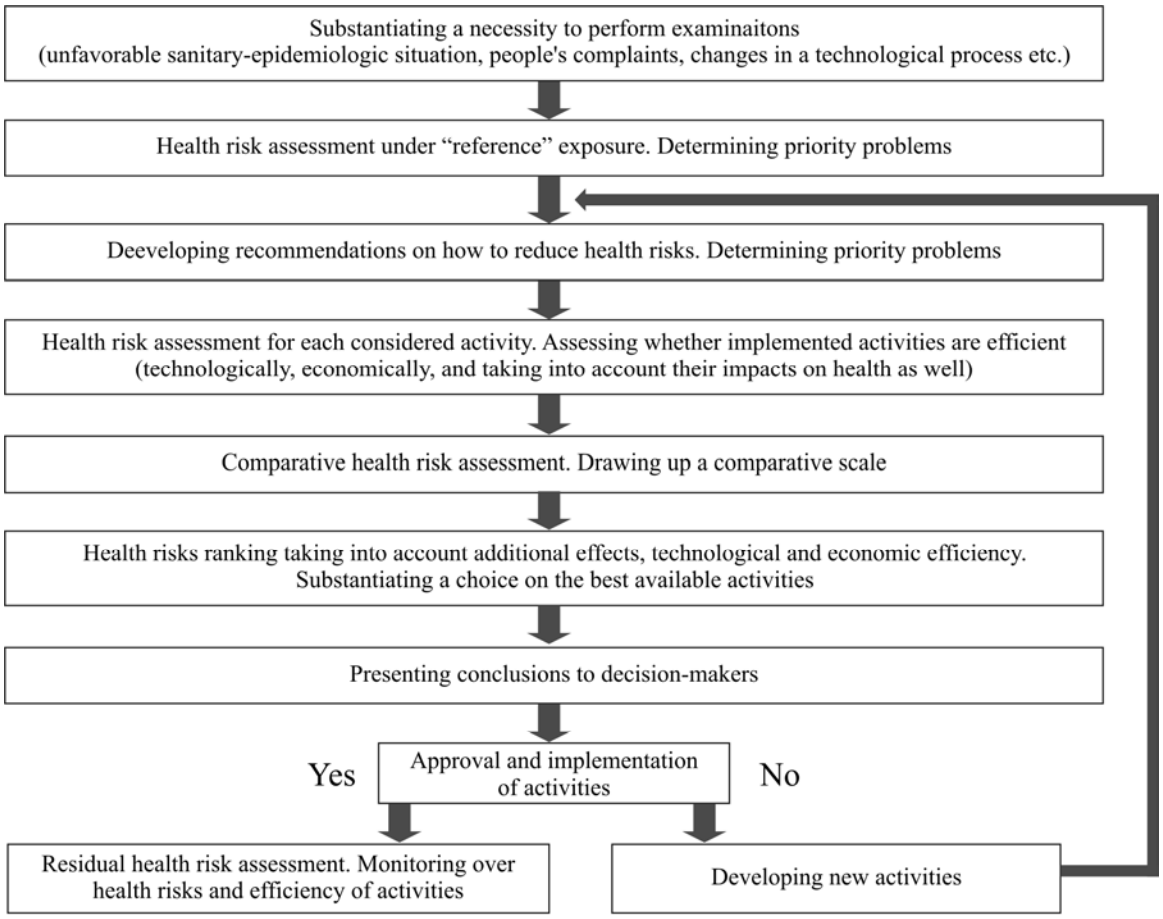

Figure. An algorithm for assessing health risks and damage to health for substantiating a choice on risk management techniques under exposure to ambient air contamination (assessing how efficient implemented activities are)

exposure, and determining priority problems; assessment of residual health risks after each considered activity, assessment whether implemented activities are efficient (technologically, economically, and taking into account their impacts on health as well); comparative health risk assessment; ranking health risks taking into account additional effects, technological and economic efficiency, substantiating a choice on the best available activities; providing decision-makers with all the conclusions that allow giving grounds for a taken decision (Figure).

Should such an algorithm be implemented, it will allow developing a possible scenario how to reduce risks caused by stationary and mobile sources of ambient air contamination; this scenario envisages any reduction in health risks to be achieved with least possible costs.

As we have already noted, ambient air contamination and its probable effects on population health are a truly pressing issue. We believe that "Pure air" federal project as an integral part of "Ecology" national project can be successfully implemented only if there are well-coordinated interdepartmental efforts to make targeted managerial decisions aimed at decreasing ambient air contamination, reducing health risks, and providing sanitary-epidemiologic welfare of the population.

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SCENARIO ASSESSMENTS OF CLIMATIC WARMING AND POPULATION MORTALITY IN RUSSIAN CITIES LOCATED IN THE SUB-ARCTIC REGIONS IN XXI CENTURY

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Climatic changes are the most apparent in the Arctic. Climatic forecasts indicate that warming is continuing on circumpolar territories. There is a vital task to determine attributive fraction of mortality caused by exposure to non-optimal temperatures within the given scenarios. We obtained a dependence of daily mortality on average daily temperatures within a non-linear model with a distributed lag. Daily temperature anomalies that were expected to occur by the middle and the end of the XXI century were calculated as per ensemble calculations of a regional climatic model by Voyekov's Chief Geophysical Observatory; the calculations were made with applying representative trajectories for greenhouse gases concentrations built by the Intergovernmental Expert group on Climatic Change: $RCP_{4.5}$ that led to moderate warming, and $RCP_{8.5}$ that led to the maximum warming. Warming in Russian cities located in the sub-Arctic regions would be accompanied with a general decrease in temperature-dependent mortality. A decrease in cold-induced mortality was more than enough to compensate for an increase in heat-induced mortality for all the examined sub-Arctic territories and warming scenarios. Therefore, the ultimate effect turned out to be quite favorable as mortality caused by all the natural reasons among people older than 30 would decrease by 4.5 % in Murmansk (95 % CI 1.1 – 7.9 %; by 3.1 %, in Arkhangelsk (1.1–5.1 %); and in Yakutsk, by 3.6 % (0.3–7.0 %) by 2090–2099 against 1990–1999 within $RCP_{8.5}$ scenario that involved strong radiation impacts on the climatic system. Expected relative decrease in mortality in Russian Arctic regions could be by several times higher than in the Northern Europe with confidence intervals of obtained assessments being rather similar to each other. These research works complement each other thus indicating that benefits and risks caused by global warming are going to be distributed unevenly.

Key words: *climatic changes, climatic warming, climatic models, population mortality, the Arctic, circulatory organs diseases, cerebrovascular diseases, respiratory organs diseases.*

It is impossible to imagine climatic scenarios, in spite of all their uncertainties, without concrete numerous assumptions on society development trajectories. Starting from 2014, the Intergovernmental Panel on Climatic Change (IPCC) have been summing these assumptions up and turning them into "representative trajectories for concentrations" of greenhouse gases. This work focuses on two scenarios related to radiation impacts on the climatic system, namely RCP4.5 that results in moderate warming and RCP8.5 that leads to the maximum warming in case there are no measures taken to impose any limitations on greenhouse gases emissions [1, 2].

Variable direct and indirect effects produced by climate on population health are most intensely examined on territories where climatic changes are the most apparent or have the greatest amplitude, including Russia. Over 1976–2018 average growth rate for average annual temperature in the Russian Federation amounted to 0.47 °C/10 years whereas globally temperature growth rate amounted to only 0.17–0.18 °C/10 years over the same period of time [3]. As our country's territory includes

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different climate zones, regional discrepancies in warming forecasts are also significant. We can expect discrepancies also in peculiar effects produced by climatic changes on mortality as it has already been detected in other big countries. For example, in Brazil impacts exerted by warming on mortality become more intense in equatorial regions as compared to those with moderate climate; the greatest growth in additional mortality is predicted in the former ones [4].

Russian Arctic and sub-Arctic territories are expected to experience much more rapid growth in surface temperatures than on average on dry land territories all over the world or in the country. For example, if we compare average annual temperature anomalies over 2000–2009 with 1951–1980, we can see there is a "polar amplification" effect as this anomaly in the Arctic already reaches 2 °C against global 0.6 °C [5]. Obviously, the phenomenon has occurred primarily due to changes in polar caps albedo caused by ice melting and peculiarities of high altitude jets in the atmosphere [6].

Foreign territories with sub-arctic climate are the northern Scandinavia, the biggest part of Alaska, and Canadian territories located to the north from 50° n.l. According to the RF legislation, natural and climatic factors are the most significant zoning criteria that are applied when a territory is considered to be a polar one (such territories include Murmansk and Yakutsk) or a territory is assumed to have similar climatic conditions as a polar one (for example, Arkhangelsk), low air temperature being the primary natural and climatic factor. Overall, 8.2 million people or about 5.8 % of the total RF population live on such territories. It is quite natural to expect that climate warming can create certain advantages for all these people, for example, a decrease in number of death cases as local climate will cease to be so harsh, or a growth in agriculture due to a warm season and vegetation period becoming longer[1].

Our research goal was to quantitatively assess what consequences changes in temperatures on polar territories could have for predicted mortality among population living there; to do that, we had to perform a direct evidential epidemiologic study on influence exerted by temperature on mortality. Such a study is possible only for a compactly living population with a considerable size that has been observed over a sufficient period of time. In other words, it is possible only in cities with their population exceeding 100 thousand people [7, 8].

Data and methods. *Predictive study layout*. In our research we applied conditional predictions of expected changes in average daily temperatures in Murmansk, Yakutsk, and Arkhangelsk in the 21st century; those predictions were obtained via ensemble calculations with a regional climatic model by A.I. Voyekov's Chief Geophysical Observatory of Rosgidromet. This regional climatic model has more significant resolution (25 km) against global ones and, therefore, is able to provide better insight into meso-scale climate changeability and its contribution into uncertainties in local estimations of future climatic changes. We took 1990–1999 decade as our basic period for a climate forecast; to describe dynamics of expected changes, we took two prediction periods, 2050–2059 (the middle of the 21st century) and 2090–2099 (the end of it). So, we examined two scenarios, RCP4.5 resulting in moderate warming and RCP8.5 leading to the maximum warming, and two prediction horizons for which we calculated expected changes in mortality caused by temperature changes on all days. We applied daily temperature anomalies with a relevant intra-ensemble standard deviation as our initial data when modeling future changes in mortality. Ensemble included 25 members for RCP4.5 scenario and 50 members for RCP8.5 scenario.

Mortality. Mortality was analyzed as per "climate-dependent" causes of death. 10 mortality parameters were taken into account in

[1] The second estimate report given by Rosgidromet on climatic changes and their consequences on the RF territory. The technical summary. Moscow, the Federal Service for Hydrometeorology and Environmental Monitoring, 2014, pp. 69–85. Available at: http://downloads.igce.ru/publications/OD_2_2014/v2014/pdf/resume_teh.pdf (date of visit November 03, 2019).

each city: five groups comprising possible causes of death (all natural reasons, all respiratory organs diseases, all circulatory system diseases with separately analyzed infarctions and strokes) in two age groups (people aged 30–64 and people aged 65 and older). Elderly people aged 65 and older are especially sensitive to changes in temperature caused by warming [9]. Overall number of examined death cases in both age groups is given in Table 1.

Table 1

Description of initial data applied to model mortality. Minimum and maximum average daily temperatures, internal nods in temperature splines (°C), overall examined number of deaths caused by all natural reasons over 1999–2016

City/parameter	Murmansk	Arkhangelsk	Yakutsk
T_{min}	-38	-37	-51
$T_{10\%}$	-10.9	-13.3	-37.9
$T_{75\%}$	8.5	10.3	12.0
$T_{90\%}$	12.9	16.3	18.6
T_{max}	25	27	28
Number of examined deaths caused by all natural reasons			
People aged 30–64	28,435	26,427	13,554
People aged 65+	33,137	44,213	14,597

Temperature curve for mortality and attributive risk. When working out a prediction for additional temperature-dependent mortality, we determined a correlation between everyday mortality and average daily temperatures during the basic period and an optimal temperature in case of which expected mortality is minimal (MMT, minimum mortality temperature). MMT value is a significant property of a population that depends not only on a local climate but also on peculiarities of people who live there (including ethnic ones). In some cities (Norilsk, for example) considerable migration makes determination of this value impossible.

To quantitatively describe impacts exerted by population exposure to non-optimal temperatures, we applied a relative increase in mortality or attributable fraction (*AF*) and an absolute increase in mortality or attributable number (*AN*). Both these values measure attributable risk and they have been calculated in this work because *AF* allows comparing different cities whereas *AN* gives data on absolute number of deaths in each city (for example, over a year). Attributable risk was determined on a reference day i with temperature T relative to a hypothetical situation should a temperature on this day being equal to MMT:

$$AF_T = 1 - \exp(-\beta_T); \quad AN_T = n\,AF_T, \qquad (1)$$

where β_T is a "log-risk" or a logarithm of a relative increase in mortality caused by a temperature rise from MMT to T, and n is overall mortality on a reference day i; let us give it as Mi under exposure to T. This definition can be generalized for delayed dependencies as they exactly occur in our case when average daily temperature in any preset "reference" day exerts its influence on daily mortality in a given city during a finite period with its duration being L+1 days (1 appears here due to a lag being calculated from a zero day, that is, a reference one). This generalization is obtained via considering a vector of past exposures $Ti...T_{i-L}$ and accordingly a "trail" of partial risks β (T_{i-l}, l), $l \in [0; L]$ which collectively characterize a delayed impact exerted by temperature on mortality during the overall period. Such generalization was first performed in the work [10] together with suggesting a technique to calculate attributable risk values. Therefore, a risk depends on two variables, namely temperature and lags, so the task is solved via building up a two-dimensional risks surface within a space of possible temperatures and lags. As here we speak about acute effects on health, the maximum possible lag doesn't exceed 2–3 weeks.

A model for mortality with a distributed lag. To calculate β (T_0)... β (T_L) values, we applied a non-linear mortality model with a distributed lag [11]. The model has become conventional for examining delayed dependencies between mortality and meteorological parameters and concentrations of pollutants. Our initial data were data on daily mortality provided by the Federal State Statistic Service; the data

were taken for each examined city and distributed as per causes of death and ages over 1999–2016; we also took meteorological data on average daily temperatures over the same period collected by the All-Russian Scientific Research Institute of Hydrometeorological Information.

Let us determine time series of average daily temperature and mortality over a period during which we model a temperature-dependent component in mortality as vectors consisting of 6,576 (a number of days in 1999–2016) time-ordered observed average daily temperatures $T_{obs}^{\rightarrow}$ and daily mortality $M_{obs}^{\rightarrow}$. The first vector is an 'exposure vector", and the second one, accordingly, is a "response". In this case, dependence between mortality and temperature taking into account that exposure is delayed and distributed over time is given with a two-dimensional surface *s* in a space of temperatures and lags:

$$\log\left[E(M_{obs}^{\rightarrow})\right] = \\ = \alpha + s\ (T_{obs}^{\rightarrow};\ \theta) + f(i;\beta) + I(dow;\gamma). \qquad (2)$$

The equation (2) is supposed to contain Poisson's function for everyday mortality distribution; hence, there is a log-link function, and the rest two summands indicate that mortality apparently depends on time, that is, on a number of day *i* and a day of the week *dow* with relevant vectors for regression parameters β and γ. Two-dimensional basis concept is fundamental here as a risk function *s* is decomposed on it. In case of two-dimensional parameterization the parameter-vector θ is coefficients for the function *s* decomposition as per this basis, or tensor product of two one-dimensional bases, in a space of temperature and a space of lags. It is necessary to introduce basic functions in order to reduce degrees of freedom in the regression mortality model so that an arbitrary dependence is decomposed as per a finite, and a rather small, set of basic functions. In this case the basis in the space of temperatures was a natural cubic spline with three internal nods that corresponded to specific percentiles in historical distribution of average daily temperatures in each city (Table 1), namely $T_{10\%}$, $T_{75\%}$ and $T_{90\%}$. Asymmetric choice on the nods ($T_{75\%}$ instead of $T_{50\%}$) reflects fundamental asymmetry in temperature dependence of mortality. Cubic spline nods in the space of lags were on days 1, 3 and 9, that is, we chose only three internal nods so that they would be approximately linearly located on the logarithmic time scale with its maximum lag $L = 21$ days. This suggestion means that the beginning of the period gives more data on a response in mortality than the end of it.

Attributable risks calculation. The model (2) takes into account all days in the examined period, not only cold or warm seasons; therefore, this model cal allow obtaining estimated values for mortality $\widehat{M}_i$ and attributable mortality $\widehat{AN}_i$ for all the days in the examined period. If we sum up $\widehat{AN}_i$, we get total attributable mortality $\widehat{AN}_{tot}$ which can be further divided into two summands that correspond to all the days with temperatures being higher than optimal and all the days with temperatures being lower than optimal. These two summands characterize impacts exerted by heat and cold and are given as $\widehat{AN}_{heat}$ and $\widehat{AN}_{cold}$. After it, according to the definition (1), we determine attributable fractions for heat and cold:

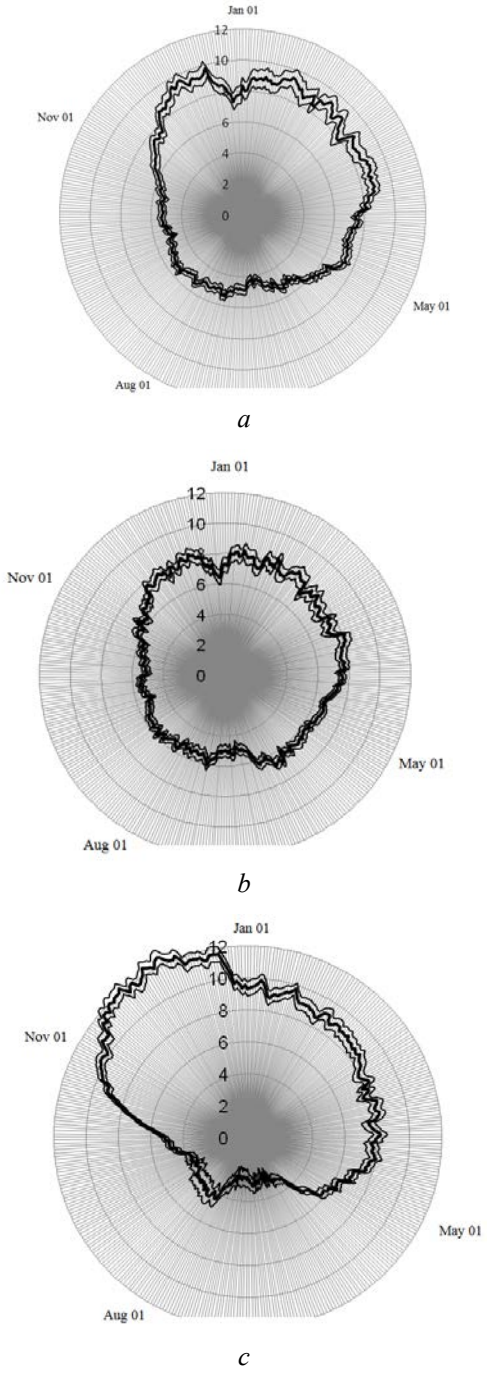
$$\widehat{AF}_{cold} = \frac{\widehat{AN}_{cold}}{M_{tot}};\ \widehat{AF}_{heat} = \frac{\widehat{AN}_{heat}}{M_{tot}}. \qquad (3)$$

A similar calculation can be accomplished for various predicted scenarios for future average daily temperatures $\vec{T}_f$, using the same mortality model which is given with the equation (2). The model allows determining "dose – response" function (a dose is a deviation in a temperature from the optimal one, and a response is a relative increase in mortality). As this function is supposed to be invariable during the whole 21st century, *model* in the equation (4) for future attributable fraction AF^f depends only on observed temperatures T_{obs}:

$$AF^f = \\ = attrdl\,(\vec{T}_f, crossbasis, \vec{M}_{obs}, model\,(\vec{T}_{obs}\ldots)). \qquad (4)$$

In the equation (4) $\vec{T}_f = \vec{T}_{obs} + \Delta\vec{T}$, $\Delta\vec{T}$ there is a vector for daily temperature anomalies, a periodical function with its period being equal to 1 year (Figure 1) during the prediction decade; "…" mean other parameters in the model (2); *crossbasis* is a two-dimensional basis as per which risk surface β ($T_{i\text{-}l}$, l), is decomposed; this basis is obtained via direct (Cartesian) multiplying of two one-dimensional bases in the spaces of temperatures and lags. User function *attrdl.R* applied to calculate attributable risks in R was developed for R-package *dlnm*2.2.0 and is available in online application to the work [10].

Building up confidence intervals for attributable risk. Since relative precision of climatic prediction remains several times (5–6) higher in all scenarios and prediction horizons than precision of *AF* and *AN* basic estimations, we can approximately calculate ultimate confidence intervals for predictive estimates in two steps. At the first step, three temperature scenarios are created on the basis of a preset emission scenario; they correspond to the central estimate and upper and bottom limits of confidence intervals for predicated average daily temperatures. Attributable numbers of death cases *AN* and fractions *AF* are calculated for each of these temperature scenarios. Let us give these fractions as $AF^f(T_{\text{l.b.}})$, $AF^f(T_{\text{mean}})$, $AF^f(T_{\text{u.b.}})$. Here l.b. and u.b. stay for an upper and bottom limit of 95% confidence interval (CI) for predicted temperatures, T_{mean} stays for the central estimate for each day. Each attributable function is calculated with its own confidence intervals. At the second step, the ultimate confidence intervals for *AN* and *AF* are constructed; these intervals take into account both errors (in a climatic model and an epidemiologic one). The bottom limit of the ultimate CI is chosen out of minimum three bottom limits of confidence intervals around $AF^f(T_{\text{l.b.}})$, $AF^f(T_{\text{mean}})$, $AF^f(T_{\text{u.b.}})$. Similarly, the ultimate upper limit of the confidence interval for AF^f is chosen as a maximum out of three upper limits of the same confidence intervals. This assumption is conservative as it combines confidence intervals of results obtained via two independent model calculations and it results in ultimate confidence intervals being insignificantly wider than they should be. Insignificance of this discrepancy with true confidence intervals around prediction estimates AF^f is provided exactly due to a considerable difference between uncertainties of climatic and epidemiologic models.



a

b

c

Figure 1. Daily temperature anomalies, a forecast for 2090–2099 against 1990–1999, RCP8.5 scenario. Thick line shows an average estimation, thin lines show 95% CI limits. Vertical axis shows temperature in °C; a) for Arkhangelsk, b) for Murmansk, c) for Yakutsk

Results. A temperature rise is predicted in all three examined cities all year round and it will be almost linear in time, that is, by the end of the 21st century temperatures will grow by approximately two time more than by the middle of it. Temperature anomalies are apparently seasonal. Figure 1 shows maximum warming under the most aggressive scenario of radiation exposure $RCP_{8.5}$ by the end of the century. To make comparisons between cities easier, all three diagrams in this Figure are given in the same scale. An order in which cities are located moving from sea climate to continental one corresponds to a growth in *winter* anomalies. Predicted winter warming in Murmansk is smaller than in Arkhangelsk as T anomaly is equal to about +8 °C in Murmansk and to more than +9 °C in Arkhangelsk. Summer temperature anomalies are almost the same in these two cities and are approximately +5 °C. In Yakutsk warming is even more season-dependent as a difference between summer and winter temperature anomalies is almost four times under the same emissions scenario; in summer it will get warmer by 3 °C, but in November and December temperatures will rise by 12 °C. Under "moderate" radiation exposure scenario $RCP_{4.5}$ warming amplitude will approximately be two times lower. Let us draw your attention to the extremely narrow confidence intervals around central estimates in temperature anomalies. For example, in Arkhangelsk a relative standard error in predicted temperature anomalies varies from 1.5% in April to 3.5% in mid-summer and mid-winter for the scenario shown in Figure 1.

Baseline of temperature-dependent mortality. We calculated population attributable fraction of mortality and attributable number of death cases separately for all days with average temperatures being lower than optimal (AF_{cold}) and higher than optimal (AF_{heat}) as per the formulas (3) for those mortality parameters for which we established a typical U-like dependence of mortality on temperature. As a time series for everyday mortality $\vec{M}_{obs}$ is a random function, we can determine this dependence only provided that an initial sampling for assessing mortality has sufficient statistical power. For example, we couldn't establish this dependence in any of three examined cities for mortality caused by cerebrovascular diseases (strokes) among people aged 30–64 due to a small number of such death cases. Naturally, authenticity of AF assessments is influenced not only by statistical power of a sampling but also by a sensitivity of mortality itself to changes in temperature as well as by local climate and local population's peculiarities. For example, there is a peculiarity in Yakutsk as its population has been growing fast; over the examined period it has increased from 195 thousand in 1999 to 304 thousand in 2016. Despite population number being quite comparable in Arkhangelsk, Murmansk, and Yakutsk (348, 316 and 250 thousand in 2007, the middle of the period considered in the basic model), a number of examined death cases was more than 2 times lower in Yakutsk (Table 1). It probably became a reason for a small number of authentic results obtained via risk assessment in this city. In Arkhangelsk ten examined mortality parameters allowed obtaining eight authentic (0.05) AF assessments (six for cold and two for heat); in Murmansk, four (three for cold and one for heat); in Yakutsk, only one (for cold). This result already allows us to stress that cold produces greater effects on mortality in all cities as well as that local peculiarities also have considerable influence.

Comparison between absolute values of basic AF_{cold} and AF_{heat} assessments which we obtained in our work is the most informative for those mortality parameters for which both assessments were statistically significant. It is possible only for two parameters, namely mortality caused by strokes and all circulatory system diseases in Arkhangelsk among people aged 65 and older. For the first of them, AF_{cold} =0.240; AF_{heat} =0.010; that is AF_{cold} value is 24 times higher than AF_{heat} value; for the second, AF_{cold}=0.236; AF_{heat} =0.007; that is, AF_{cold} value is 34 times higher than AF_{heat} value. Such a discrepancy between these values allows us to assume that future changes ΔAF_{cold} will also be higher than ΔAF_{heat} in their absolute value as warming increases. This discrepancy is probably due to both

Table 2

Minimum mortality temperature (MMT), °C and percentile of long-term average daily temperatures distribution

Age	City	Murmansk		Arkhangelsk		Yakutsk	
	Cause of death	°C	percentile	°C	percentile	°C	percentile
30–64	IHD	–	–	17.1	92	25.0*	99
	CVD	–	–	–	–	–	–
	CSD	–	–	18.0	93	–	–
	ROD	–	–	16.9	91	17.3	87
	Natural	12.4	89	17.1	92	–	–
65+	IHD	16.4	96	17.5	92	16.2	85
	CVD	–	–	16.1	90	–	–
	CSD	17.7	98	16.6	91	19.5	92
	ROD	12.8	90	11.3*	77	17.8	88
	Natural	14.8	94	16.6	91	18.8	90
Mean value		14,8	93	17.0	91	17.9	88

Note: * means outliers. Mean values are calculated without them.
IHD is ischemic heart disease;
CVD are cerebrovascular diseases;
CSD are all circulatory system diseases;
ROD are all respiratory organs diseases;
Natural means all natural reasons.
Dash means a value was not determined.

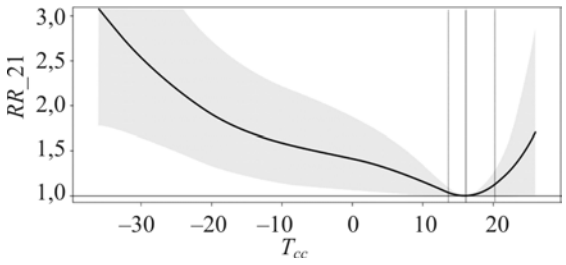


Figure 2. Cumulative relative mortality risk accumulated in a population during 21 days (RR_21) after exposure to average daily temperature T_{cc} (°C) obtained in Arkhangelsk for mortality caused by strokes among people aged 65+. A solid vertical line shows MMT (+16.1 °C), vertical broken lines show 95% confidence interval, grey area is confidence intervals of relative risk

different responses people tend to have to cold and heat and to fundamental asymmetry that a temperature curve of mortality has against average annual temperature: MMT corresponds to approximately 90-th percentile in average daily temperatures distribution. Table 2 contains obtained MMT values both in °C and percentiles of local long-term average daily temperatures distribution. If we compare a temperature curve of mortality to a hockey stick, then its "shaft" is going to be approximately 10 times longer than its "blade" (Figure 2).

As we can see from this table, risk assessment results are more reliable in Arkhangelsk than in two other cities due to MMT values being in a very narrow range there, from 16.1 °C to 18.0 °C, excluding an outlier marked with the star. In Murmansk MMT values are within a range from 12.4 °C to 17.7 °C; in Yakutsk, from 16.2 °C to 19.5 °C. Absolute MMT values grow as a climate on a territory changes from a sea one to continental; on the contrary, relative MMT values, that is, calculated in percentiles from local distributions of average daily temperatures, go down from the 93-th percentile in Murmansk to the 88-th percentile in Yakutsk. This decrease is considerable and is probably due to a type of a climate. For comparison, we can indicate that we applied the same technique to calculate estimate MMT values in Rostov-on-Don and they were detected within a range from 22.7 °C to 25.5 °C, that is, within a wider range than in Arkhangelsk, with their average value corresponding to the 89-th percentile [12].

In this case average values are not the most probable ones as there are no grounds for assuming that MMT values in a given city should be the same for various mortality parameters. Pathophysiological mechanisms of mortality caused by different reasons also differ; hence, estimate values that are given in Table 2 are taken from different distributions, not from just one. We should also note that some of the examined daily mortality distributions are not statistically independent as CSD comprises IHD and CVD, and CSD account for approximately two thirds of all natural causes.

Predicted dynamics of climate-dependent mortality separately for heat and cold. Attributable fractions AF_{heat} and AF_{cold} are given in Figure 3.

To give an example, we took "mortality from infarctions among people aged 65+" though similar patterns were obtained for the rest mortality parameters included into our research. But this very parameter was chosen because we managed to assess relevant fractions for it in all three cities, and the results we obtained in all three cities regarding hot season were quantitatively similar. The Figure 3 clearly illustrates that cold-dependent mortality is considerably higher than heat-dependent one in all three cities and in all warming scenarios. Value of the attributable fraction AF_{heat} grows as a climate changes from a sea one to continental as a basic AF^{b}_{heat} estimate has increased from 0.2% in Murmansk to 0.4% in Arkhangelsk and to 1.9% in Yakutsk. And there is a growth in not only absolute AF_{heat}, values but also in their changes in different decades. To provide a better insight into these changes, let us give some comments, for example, on the last three columns that correspond to $RCP_{8.5}$ scenario in Yakutsk. In the 21st century AF_{heat} will grow from 1.9% to 4.3%, that is, by 2.4%. Simultaneously, AF_{cold} will fall from c 33.6% to 26.3%, that is, by 7.3%. Obviously, a decrease in cold-dependent mortality more than compensates for any increase in heat-dependent one for all three cities and for both scenarios. So, a resulting effect is quite favorable as aggregated AF_{tot} steadily decreases over time. Let us stress that per cent AF_{cold} and AF_{heat} values are specially given in the definition (3) in such a way so that they could be directly summed up due to them having the same denominators.

Resulting influence exerted by warming on all the examined mortality parameters is given in Figure 4. Warming-associated changes over time $\Delta AF_{\text{heat}} = AF^{f}_{heat} - AF^{b}_{heat}$ and $\Delta AF_{\text{cold}} = AF^{f}_{cold} - AF^{b}_{cold}$ will always have a different sign as cold-dependent mortality will fall and heat-dependent one will grow. Their arithmetic sum gives an ultimate change in total temperature-dependent mortality ΔAF_{tot} between relevant decades that is given in per cent of the overall mortality in a given city according to the definition (3). It is more convenient to apply attributable fractions *AF*

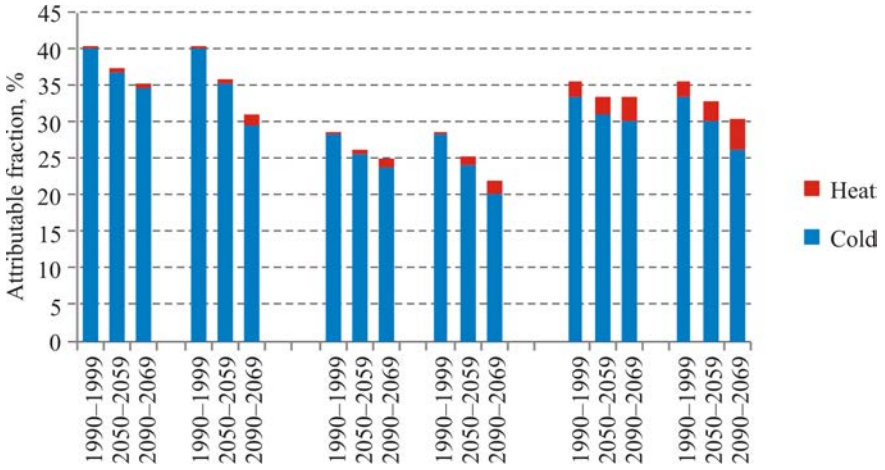


Figure 3. Attributable fractions (%) for "Mortality caused by infarctions among people aged 65 and older" due to exposure to temperatures being higher than optimal (AF_{heat}, given in red) and lower than optimal (AF_{heat}, given in blue). Horizontal axis shows decades applied for predicting

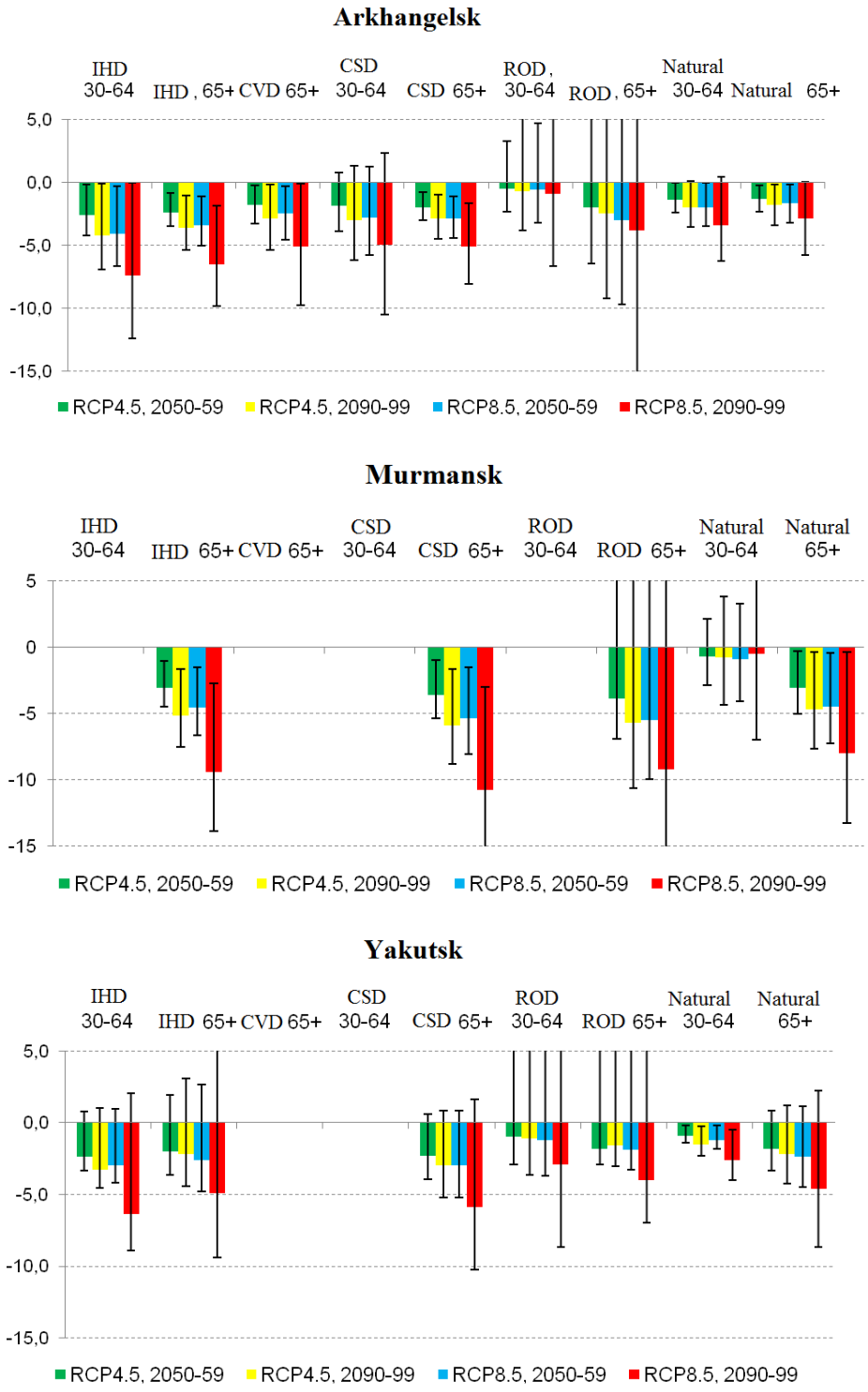


Figure 4. Changes in temperature-dependent mortality against the baseline (1990–1999) predicted by the middle of the 21st century (2050–2059 decade) and by the end of it (2090–2099 decade). $\Delta AF_{tot} = \Delta AF_{heat} + \Delta AF_{cold}$ values show resulting influence exerted by warming an overall decade in percents to the total mortality in the basic period according to the formulas (4). The vertical segments are 95% confidence intervals of predicted changes. X axis shows the following mortality parameters: IHD is mortality caused by ischemic heart disease or infarctions; CVD is mortality caused by cerebrovascular diseases; CSD is mortality caused by all circulatory system diseases; ROD is mortality caused by respiratory organs diseases; Natural is mortality caused by all natural reasons, external reasons excluded. The legend also contains data on both scenarios of greenhouse gases emissions, $RCP_{4.5}$ that results in moderate warming and $RCP_{8.5}$ that leads to the maximum one. The examined cities are put in such an order that it reflects a change in a climate from a sea one to continental

(as opposed to attributable numbers *AN*) to make comparisons between cities, regions, countries, etc. To make comparisons between the examined cities easier, we drew all the diagrams in Figure 4 in the same scale as per vertical axis.

Relative standard error (RSE) in AF_{cold} estimate is considerably greater than a standard error in AF_{heat}, estimate, that is, when we calculate a standard error in ΔAF_{tot} value, we can completely neglect an error in AF_{heat} estimate and apply the following approximated correlation:

$$RSE(\Delta AF_{\text{tot}}) \approx RSE(AF_{\text{cold}}) \qquad (5)$$

This correlation is based on the assumption that a change in ΔAF_T fraction is linear as per a log-risk β_T from the equation (1) at $\beta_T << 1$, that is true for any temperature and remains valid till relative precision of temperature anomalies calculations (shown in Figure 1) remains considerably higher than relative precision of basic AF_{cold} estimate calculation that should be assessed as per confidence intervals of relative risks in Figure 2. Approximated equality (5) allowed avoiding a necessity to empirically calculate confidence intervals of ΔAF_{tot} differences in the given situation. Numerical modeling of confidence intervals with Monte Carlo technique is usually applied in such tasks due to AF^b and AF^f fractions in equation (4) not being statistically independent random values. When calculating confidence intervals as per the formula (5), we took into account their asymmetry as relative error in a parameter AF_{cold} to the right (RSE_+) and to the left (RSE_-) can differ greatly; we applied the following correlations:

$$RSE_-\left(AF_{cold}\right) \approx \frac{\mu - l.b.}{2\mu}; \qquad RSE_+\left(AF_{cold}\right) \approx \frac{u.b. - \mu}{2\mu}. \qquad (6)$$

This conclusion indicates it is necessary to separately calculate a positive and a negative error in the parameter ΔAF_{tot} in Figure 4, and statistical authenticity of the obtained ΔAF_{tot} estimate is determined exactly by $RSE_-(AF_{cold})$ value: if in Figure 4 the overall CI is below X axis, then ΔAF_{tot} estimate should be considered authentic. Should CI cross X axis, we can't reject a zero hypothesis that there are no effects produced on mortality by warming.

Scenario differences. For both considered warming scenarios, a value of attributable fraction AF_{tot} continues to decline over time in comparison with the basic period during the whole 21st century with just one exception, namely total mortality caused by all natural reasons in Murmansk among people aged 30–64 within $RCP_{8.5}$ scenario. For this parameter, by the middle of the 21st century $\Delta AF_{\text{tot}} = -0.9$ % (–4.1 %; 3.3 %), and by the end of the century, $\Delta AF_{\text{tot}} = -0.5$ % (–7.0 %; 8.0 %). A growth rate for mortality anomalies is exactly equal to growth rate for temperature anomalies in both warming scenarios. Let us explain this statement. According to $RCP_{4.5}$ scenario, average annual temperature anomaly in Murmansk will reach $\Delta T = 2.4$ °C by 2050–2059 and $\Delta T = 3.7$ °C by 2090–2099 against the basic period. If we divide $\Delta T_{2090\text{-}95}$ by $\Delta T_{2050\text{-}55}$, we get 1.53. The same value is equal to 1.59 in Arkhangelsk, and to 1.36 in Yakutsk; the average value for all three cities is equal to 1.49. This value can be conditionally called an average growth rate for temperature anomalies over the period between the middle of the 21st century and the end of it. In the same way we can calculate a growth rate for anomaly AF_{tot}, via dividing $\Delta AF_{2090\text{-}95}$ by $\Delta AF_{2050\text{-}55}$. For example, the value is (-5.2 %)/(-3.1 %) = 1.68 for "mortality caused by IHD among people aged 65+ in Murmansk". ΔAF_{tot} values are negative, changes in mortality increase as per module over time. We made the same calculation for all mortality parameters in all three cities and then obtained an average estimate and dispersion. We excluded respiratory organs diseases in all three cities and overall mortality caused by natural reasons among people aged 30–64 in Murmansk from our calculations as confidence intervals of ΔAF estimates obtained for these parameters were too wide. Totally, 15 parameters were included into the calculations, three in Murmansk, seven in Arkhangelsk, and five in Yakutsk. As a result, growth rate for anomalies AF_{tot} in $RCP_{4.5}$ scenario over the period between the middle of the 21st century and the end of it amounted to 1.47 ± 0.17 and it practically coincides with growth rate for temperature

anomalies. Let us draw your attention to a very narrow standard deviation in this estimate. For $RCP_{8.5}$ scenario, corresponding growths are equal to 1.89 for temperature anomalies and 1.91 ± 0.15 for AF_{tot} anomaly, that is, growth rates are again the same. This result is significant as we can expect no "sudden change" in descending mortality trend by the end of the 21st century; annual mortality is expected to decline proportionate to temperature growth for all emissions scenarios.

Age-related differences can be seen among detected effects produced by warming in Figure 4. However, the research layout involved studying an equal number of mortality parameters in both age groups, a number of obtained results turned out to be greater in the older age group in all three cities (it is especially apparent in Murmansk). Effects produced by warming can be estimated as a change in fraction ΔAF_{tot} only for those mortality parameters that had an established dependence on temperature (Figure 2). Probably, it was impossible to establish such dependence (provided that a sampling has sufficient statistical power) due to this parameter not being sensitive to temperature changes. But if estimates of effects produced by warming are simultaneously obtained in a given city and for a given death cause in both age groups, then we can expect that an effect in the older group should be greater as per its absolute value than in the younger one. Such pair comparisons can be performed in Murmansk only for a single death cause, namely mortality caused by all natural reasons, excluding external ones; in Arkhangelsk, for all the death causes excluding strokes; in Yakutsk, for infarctions, respiratory organs diseases and all natural reasons excluding external ones. Overall, we can compare eight pairs; the effects were greater in the older age group for five of them; as for the remaining three (IHD in Arkhangelsk and Yakutsk, and all natural causes excluding external ones in Arkhangelsk), the effects were greater in the younger age group.

Geographical differences related to established effects produced by warming are the most interesting within the context of our research. Effects produced by warming were simultaneously detected in all three cities only for five out of ten examined mortality parameters. One out of these five parameters (mortality caused by all natural reasons excluding external ones among people aged 30–64) had outliers in ΔAF_{tot} in Murmansk (Figure 4) and was therefore excluded from the analysis; four remaining parameters are given in Table 3.

In Murmansk, effects produced by warming are approximately two times greater as per their absolute value than in two other cities. In Arkhangelsk and Yakutsk effects are comparable as per their value, but effects in Yakutsk as a rule tend to be stronger (for all mortality parameters excluding mortality caused by IHD among people aged 65+).

Table 3

Changes in attributable fractions of temperature-dependent mortality AF_{tot} in per cent to the baseline: parameters chosen for geographic differences analysis

Mortality parameters	Prediction scenarios and horizons	RCP4.5, 2050–59	RCP4.5, 2090–99	RCP8.5, 2050–59	RCP8.5, 2090–99
IHD, 65+	Murmansk	-3.1	-5.2	-4.6	-9.4
	Arkhangelsk	-2.4	-3.6	-3.4	-6.5
	Yakutsk	-2.0	-2.2	-2.6	-4.9
CSD, 65+	Murmansk	-3.6	-5.9	-5.4	-10.8
	Arkhangelsk	-2.0	-2.9	-2.9	-5.1
	Yakutsk	-2.3	-3.0	-3.0	-5.9
All reasons excluding external, 65+	Murmansk	-3.1	-4.7	-4.5	-8.0
	Arkhangelsk	-1.3	-1.8	-1.7	-2.9
	Yakutsk	-1.8	-2.2	-2.4	-4.6
ROD, 65+	Murmansk	-3.9	-5.7	-5.5	-9.2
	Arkhangelsk	-2.0	-2.5	-3.0	-3.8
	Yakutsk	-1.8	-1.6	-1.9	-4.0

Table 4

Values of attributable mortality caused by all natural reasons reduced to one year, totally for heat and cold (ANtot), number of death cases

City	Age	Basic	RCP4.5		RCP8.5	
		1990–1999	2050–2055	2090–2095	2050–2055	2090–2095
Murmansk	30–64	221 (–98; 424)	213 (–80; 408)	214 (–49; 408)	211 (–41; 403)	221 (–22; 392)
	65+	434* (53; 680)	378* (11; 642)	348* (21; 578)	352* (25; 590)	287* (4; 501)
Arkhangelsk	30–64	265* (71; 423)	245* (56; 387)	235* (64; 382)	236* (62; 370)	214* (73; 343)
	65+	373* (104; 582)	343* (93; 555)	330* (76; 528)	330* (77; 524)	302* (87; 481)
Yakutsk	30–64	323* (29; 494)	317* (19; 475)	313* (0; 476)	315* (0; 478)	304* (8; 460)
	65+	198 (–74; 348)	183 (–97; 346)	179 (–79; 335)	179 (–113; 331)	161 (–113; 305)

Note: * means an estimate is statistically significant at 95 % level.

Attributable numbers of deaths can be significant in certain cases, for example, when it is necessary to economically estimate consequences of warming or take specific managerial decisions. Table 4 contains estimates of AN_{tot} values in dynamics under various emissions scenarios, but only for all the death causes excluding external ones since this parameter is integral.

Most results given in Table 4 are statistically significant, however confidence intervals are rather wide. An error value is primarily determined by uncertainties related to a descending (that is, induced by cold) section in the temperature curve of mortality (see confidence intervals given in Figure 2). Mortality given in absolute values can decline by just several dozens of death cases per year against the basic level. For example, in Yakutsk according to RCP8.5 scenario that means strong radiation exposure mortality can fall by 56 death cases per year by the end of the 21st century, overall for both age groups.

Discussion. Previous predictive estimates of temperature by 2090–2099 against 2010–2019 [13] according to $RCP_{8.5}$ scenario give comparatively wide confidence intervals around average weighted estimates of average annual temperature anomalies; they are 4.9 °C (3.2–6.3) for the North America and 3.4 °C (2.8–5.4) for the Northern Europe [13] (Table 2). Climate in the North America is continental and, therefore, is closer to sub-arctic zones than that in the Northern Europe. A relative standard error in the prediction is rather great and amounts to 16 % and 19 % respectively. A confidence interval for temperature anomalies predictions that were applied in this work is considerably more narrow as average annual temperature anomalies amount to 5.4 °C (95 % CI 5.0 °C–5.7 °C) in Murmansk; 5.6 °C (5.2 °C– .0 °C), in Arkhangelsk; and 5.7 °C (5.3 °C–6.1 °C) in Yakutsk for the same emissions scenarios and the same time periods; that is, RSE is about 3 %. We should also note that our central estimates are well in line with temperature anomaly value for the North America which is 4.9 °C.

When predicting future changes in mortality, we assumed that changes occurred only in climatic conditions but temperature dependence of mortality remained the same during the whole 21st century as it was in the basic period of our climatic prediction. This assumption means there is no acclimatization, or individual or population adaptation to climatic changes. But in reality examinations performed on long time series of mortality (during the whole 20th century) show that people adapted to climatic changes that occurred in the 20th century. Thus, MMT value in Stockholm moved to the right as warming persisted, and it was apparent for both its absolute value (in °C), and its relative one (as a percentile of average daily temperatures distribution on a day of death). Percentile was calculated over 30-year periods from 1901 to 2009. Over the overall given period, absolute MMT values approximately increased from 11 °C to 20 °C, and relative ones, from 70-th to 93-th percentile [14], but at the same time average annual temperatures increased by 1.4 °C only. The same result (on a gradual MMT rise over time) was obtained in France when experts applied data on daily mortality starting from 1968 [15]. There were no

similar examinations in Russia, and digital data on daily mortality are available only for a period starting from 1999. Bearing this in mind, we can state that our assumption on absence of adaptation which we made in this work can result in an effect being exaggerated in future. To be more exact, we can calculate only an *upper limit* of a sought effect, or a maximum (as per its absolute value) change in temperature-dependent mortality caused by expected warming. Therefore, it is advisable to not interpret results obtained in the present research as a prediction for changes in climate-dependent component in mortality taking into account all the available scientific data; it is rather a scenario that describes probable consequences that climatic changes night have without taking into account people adapting to them.

Conclusion. Climatic warming will result in a decrease in temperature-dependent mortality in Murmansk, Arkhangelsk, and Yakutsk, and it confirms both results obtained in our previous research [16], and results obtained in global research [13]. Mortality caused by all natural reasons among people aged 30–64 within $RCP_{8.5}$ scenario that involves strong radiation exposure will fall by 4.5 % (95 % CI 1.1 %–7,9 %) in Murmansk, by 3.1 % (1.1 %–5.1 %)in Arkhangelsk, and by 3.6 % (0.3 %–7.0 %) in Yakutsk by 2090–2099 against 1990–1999. The same change in mortality within $RCP_{8.5}$ scenario is also expected by the end of the 21st century in the Northern Europe: –0.6 % (95 % CI –2.3 %–1.6 %) [14]. Nevertheless, mortality will increase during heat waves in sub-arctic cities, especially that among elderly people [8, 17, 18]. Mathematic techniques applied to assess influence exerted by such waves on population mortality are described in the work by D.A. Shapochnikov and B.A. Revich [19].

An expected relative decrease in mortality in sub-arctic regions can be several times more considerable than in the Northern Europe, but at the same time confidence intervals of obtained estimates are rather similar. These studies supplement each other thus proving that benefits and risks related to global warming are distributed rather unevenly. Undoubtedly, it is necessary to include scenario assessments of positive and negative consequences caused by climatic changes in various climatic zones in Russia into regional adaptation plans that are to be developed by executive authorities. And here it is important to apply economic parameters related to health losses, for example, in the same way as it was done when assessing consequences caused by abnormal heat in Moscow in 2010 [20].

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ANALYSIS OF TOOLS AIMED AT MANAGUNG AMBIENT AIR QYALITY IN PERM CITY

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The article dwells on analyzing tools aimed at managing ambient air quality on the example of Perm city and basing on the experience in using systems for dynamic standardizing. The authors discuss advantages and drawbacks of managing ambient air quality with unified programs for calculating atmospheric contamination (Russian abbreviation UPRZA), We analyzed drawbacks in methodology that could result in overstating when emissions from stationary sources were inventoried; those drawbacks didn't allow using results of dispersion calculation for managing ambient air quality. Basing on data taken from literature sources and experience in UPRZA systems application, we suggest to cease applying UPRZA for operative ambient air quality management; instead, we propose to calculate admixtures dispersion with software that has been tested and used worldwide and that is freely accessible. Such software enables modeling actual meteorological conditions using data on wind profile and air temperature at various heights.

To manage ambient air quality due to identifying sources that cause more substantial contamination, modeling of toxicants dispersion should necessarily be based not only on data obtained from ground meteorological stations but also on data on temperatures and wind speed in the lower troposphere. To correctly calculate ground concentrations, we suggest applying the following data: results of uninterrupted control over emission sources that will be obtained via emission measuring tools according to changes made in the legislation in 2018; data on speeds of motor transport and fixation of transport flows structure recalculated into emissions from motorways; data on ground concentrations of admixtures including hydrogen sulphide and alkyl hydrosulphides that should be measured at ecological monitoring stations and measuring periodicity should not exceed 60 minutes; profiles of temperature, wind direction, and wind speed at various heights.

Key words: *ambient air contamination, ambient air monitoring, monitoring posts, emissions standardizing, uninterrupted automated control, sulfur-containing compounds, ecological modeling, air probing.*

Background and the current situation. At present standardization of emissions is a basic mechanism for managing ambient air quality according to the RF legislation, first of all, the Federal law issued on May 04, 1999 No. 96-FZ «On ambient air protection»[1]. To standardize emissions, juridical persons with their activities resulting in contaminants being emitted into the atmosphere accomplish inventories of such emissions and their sources in conformity with the relevant procedures fixed by the RF Government.

According to the legislation, an inventory should reveal and take into account all probable sources that can emit or discharge contaminants into the atmosphere as well as adverse substances that can occur when technological processes are performed according to a technological regulation adopted by an enterprise. Besides, when standardizing emissions, it is necessary to take into account aggregated background contamination that occurs due to all the emission sources and is calculated basing on data collected via instrumental research at Rosgidromet monitoring posts.

According to the RF Government Regulation dated March 02, 2000 No. 183 «On standardizing emissions of adverse substances (contaminants) into the atmosphere and ad-

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[1] On ambient air protection: The Federal law No. 96-FZ issued on May 04, 1999 г. (last edited on July 26, 2019). *KonsultantPlus*. Available at: http://www.consultant.ru/document/cons_doc_LAW_22971/ (date of visit December 03, 2019).

verse physical impacts on it»[2], when standards for emissions are fixed, experts should apply relevant techniques to calculate dispersion of emitted contaminants in ambient air, including techniques applied to make aggregated calculations for cities and other settlements.

Dispersion is calculated as per data provided by inventories; to make these calculations, experts usually apply unified programs for calculating atmospheric contamination (Russian abbreviation is UPRZA). These programs allow calculating ground concentrations of contaminants. Apart from standardizing, UPRZA systems also provide a tool for selecting monitoring points and priority admixtures that are subject to obligatory control over atmospheric contamination [1–3]. And besides, results obtained via UPRZA calculations are applied in geoinformation technologies for social and hygienic monitoring of the environment and population health [4].

Practical experience gained in some Russian regions proves that it is quite efficient to apply aggregated calculations when emissions are standardized; Perm region is among them as this technique was first applied here in 1994 [5]. Experience accumulated in applying aggregated dispersion calculations in Perm region in 2000–2010 was disseminated into other regions according to the Order by the RF State Committee on the Environmental Protection No. 66 dated February 16, 1999[3]. «The system for dynamic analysis of the atmosphere and standardizations of contaminants emissions from industrial enterprises in Perm» («Lada» system) was created in the region. Long-term experience accumulated in applying a dynamic standardizing system that functioned in Perm region in 1994–2010 confirmed the methodology was quite efficient both for system participants (those who somehow used the environment and natural resources) and controlling authorities.

On one hand, «Lada» system gave its participants an opportunity to substantiate any changes in maximum permissible emissions (MPE) for emission sources in case there were any changes in technological processes. On the other hand, it allowed authorities responsible for environmental protection to respond to people's complaints and unfavorable meteorological conditions thus managing ambient air quality basing on the analysis of dispersion calculation results for specific meteorological conditions; it became possible due to access to actual data on emissions from enterprises.

But at the same time, experience accumulated over years when «Lada» system functioned in Perm, apart from efficiency, also allowed revealing certain drawbacks. First of all, there were rather few monitoring posts in the state network for monitoring over ground air and it didn't allow fully taking into account background contamination thus making standardization and management less efficient. We should note that monitoring networks are not dense enough in most RF regions [6]. Secondly, monitoring posts applied for performing control over ground air contaminations are located in such points that their location doesn't allow identifying emissions from stationary sources of industrial enterprises in case winds blow in certain directions.

Locations where some posts are placed haven't been changed over the last 30 years; but cities and economic activities have been actively developing and it has resulted in such a situation when a stationary post which was previously located on an open area is now «closed» by high buildings or is located too close to sources of near-ground emissions. For example, the monitoring post No. 17 located on Svyazeva str., 52, in Industrialniy district in Perm was placed there in 80ties last century at the boundary of a housing area on leeward side from the «Osentsy» industrial facilities. At present there is a busy motorway near this post, the traffic there is intense, and there are high local concentrations of toxicants emitted by motor transport. As a result, data obtained at this post

[2] On standardizing emissions of adverse substances (contaminants) into the atmosphere and adverse physical impacts on it: The RF Government Regulation No. 183 dated March 02, 2000 г. (edited on April 22, 2009 г.). Available at: https://prirodnadzor.admhmao.ru/dokumenty/rf/228670/ (date of visit December 03, 2019).

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can't be applied for monitoring over influences exerted by the «Osentsy» industrial facilities on air contamination in the city.

Thirdly, OND-86 procedure applied within «Lada» system which is a component in «Ecologist – city» UPRZA software package is aimed at standardizing emissions into the atmosphere. Calculation is performed either for a set of meteorological parameters or for a single wind speed and direction. Such a procedure for calculating doesn't allow using historical data on changes in wind directions, data on a wind direction and speed at a specific height (wind profile) and temperature profile of the atmosphere. Still, at present there is an opportunity to measure a wind profile and temperature profile of the atmosphere in a city [7].

As «Lada» system didn't provide an opportunity to use complete initial data, calculated contributions made by contamination sources into actual concentrations measured at monitoring posts were determined only roughly; calculated concentrations didn't correspond to those actually measured at monitoring posts. Data obtained via such calculations didn't allow unambiguous identifying sources of elevated air contamination and, consequently, didn't allow creating relevant management activities.

The system for dynamic standardization stopped its functioning in Perm in 2007 and providing even partial management over ambient air quality became impossible. At present air contamination is only measured by the Perm Center for Hydrometeorology and Environmental Monitoring (hereinafter called CHEM).

As per data provided by the Perm CHEM, there are seven posts for ground air monitoring now functioning in Perm [8]; their locations are shown in Figure 1. Table 1 contains a list of admixtures controlled at these posts; a post number corresponds to its number given in Figure 1.

According to accreditations granted to the Perm CHEM «ROSS RU.0001.512591»[4], contaminants are analyzed with conventional techniques within ranges given in Table 2. Techniques applied for measuring concentrations of all substances, excluding carbon

Figure 1. Location of monitoring posts aimed at controlling ambient air pollution in Perm

[4] Competency certification PKZ-100 issued on November 08, 2019. The Federal Accreditation Service official web-site. Available at: https://pub.fsa.gov.ru/ral/view/6754/current-aa (date of visit December 05, 2019).

Table 1

A list of admixtures controlled at monitoring posts in Perm

Admixtures that are subject to control	A post No., analysis performance						
	12	13	14	16	17	18	20
Sulfuric anhydride	X			X	X		X
Nitrogen dioxide	X	X	X	X	X	X	X
Carbon oxide	X	X	X	X	X		X
Ammonia	X	X	X	X	X	X	
Formaldehyde	X	X	X	X	X	X	
Xylol	X	X	X	X	X	X	
Toluene		X	X	X	X	X	
Benzene		X	X	X	X	X	
Ethyl benzene	X	X	X	X	X	X	
Phenol	X		X	X	X	X	X
Hydrogen sulphide					X	X	
Metals (Manganese, Copper, Nickel, Lead, Chromium, Zink, Cadmium, Iron)			X		X		
Hydrogen chloride	X		X	X		X	X
Chlorine						X	
Hydrogen fluoride	X		X			X	
Particulate matter	X	X		X		X	
Nitrogen oxide			X	X			

Table 2

List of contaminants, techniques and detection ranges
(according to accreditation granted to the Perm CHEM)

Detected contaminants	Documents that fix rules and techniques for research and measuring	Detection range, mg/m^3
Sulfuric anhydride	RD 52.04.822-2015	0.0025–8.0
Nitrogen dioxide	RD 52.04.792-2014	0.021–4.3
Carbon oxide	«Elan» gas analyzer User manual EKIT 5.940.000RE	0.6–50.0
Ammonia	RD 52.04.791-2014	0.02–5.0
Formaldehyde	RD 52.04.824-2015	0.01–0.3
Xylol	RD 52.04.838-2015	0.02–5.0
Toluene		0.02–5.0
Benzene		0.02–5.0
Ethyl benzene		0.01–5.0
Phenol	RD 52.04.799-2014	0.003–0.1
Hydrogen chloride	RD 52.04.795-2014	0.006–0.1
Hydrogen chloride	RD 52.04.793-2014	0.04–2.0
Chlorine	«Elan» gas analyzer User manual EKIT 5.940.000RE	1.0–10.0
Hydrogen fluoride	RD 52.04.797-2014	0.002–0.2
Particulate matter	RD 52.04.186-89 part 1 sec. 5.2.6	0.26–50.0
Nitrogen oxide	RD 52.04.792-2014	0.028–2.8
Chromium	RD 52.04.186-89 part 1 sec. 5.2.5.2	0.01–1.5
Lead		0.06–1.5
Manganese		0.01–1.5
Nickel		0.01–1.5
Zink		0.01–1.5
Copper		0.01–1.5
Iron		0.01–1.5
Cadmium		0.002–0.24

monoxide and chlorine monoxide, involve laboratory analysis of samples taken on absorbers. Therefore, the existing monitoring system doesn't allow uninterrupted obtaining of data on ground air contamination.

As dynamic standardization of emissions into the atmosphere is no longer performed, actual data on emissions from enterprises are also not collected in real time mode; data that are submitted every 5 years to substantiate standards for MPE can't be applied for modeling actual ambient air contamination. It partly explains substantial differences between calculated and actual data. Let us illustrate this situation with an example of an oil-processing plant located in Perm.

Data obtained via inventories performed at the said oil-processing plant revealed that emissions from contamination sources that were determined mostly with instrumental techniques changed considerably even when there were no changes in technological processes and the plant operated in its normal regime. This changeability is due to oil-processing being flexible as it allows satisfying changing market demands for a wide range of oil products with minimal costs taking into account changes in raw materials structure. For example, SO_2, and NO_x emissions from smoke pipes of technological furnaces can vary considerably as there are wide ranges for regulated changes in the structure of fuel that is manufactured by the plant, consumption of flows that are heated in these furnaces, and their structure. There are several factors that explain it, for example, a change in a share of liquid fuel that is used when gas fuel doesn't have sufficient heat-producing capacity; a change in production processes loading resulting in intermediate flows changing their direction and this, in its turn, leads to a change in the structure of gas fuel used in technological furnaces; a change in consumption of flows that are heated in furnaces and in their structure.

Emissions can be changeable not only in oil-processing but also at any other large industrial production. However, the existing standardization system doesn't allow taking into account possible changes in emissions and it makes its participants (economic entities or industries) fix higher standards for emissions than it is required in order to minimize risks of violating MPE.

Trying to take into account emissions changeability that can occur in future, economic entities develop their standards with MPE fixed at their maximum possible level for the maximum number of emission sources. Therefore, any report on an inventory basically contains only data on maximum emissions out of large data arrays obtained via measuring. As a result, even when maximum permissible level is reached at not more than 10 per cent of all the emission sources, dispersion calculation is based on modeling a situation when maximum number of emissions sources (ideally, all of them) emit maximum possible quantities of contaminants. Obviously, such a situation is impossible in real life.

The situation with fixing higher standards for emissions which is described above, apart from emission changeability, is due to the following drawbacks related to standardizing:

– firstly, as standards are fixed for a future period of time but on the basis of emissions measuring performed in the past, than, obviously, when instrumental control techniques are applied, it is necessary to predict that previously fixed operating conditions will be repeated; the task seems labor-consuming and sometimes even impossible;

– secondly, even if emissions are relevantly predicted, it is next to impossible to take into account all permissible emissions when calculating their dispersion as a number of emissions combinations that are to be modeled given a great number of emissions sources goes to infinity. Let us illustrate the last postulate with the following example.

Let us assume that there are two technological furnaces at an enterprise; they can emit nitrogen oxide (NO_X) in a quantity up to 5 g/sec. Changes in emissions are caused by changes in fuel consumption that occurs due to changes in heated hydrocarbons flows. Probable combinations of emissions from the furnaces correspond to points located within the square area limited with the coordinate grid given in Figure 2 with its sizes being 5×5 g/sec. Let us assume that an enterprise is located in an area where high background NO_X concentrations don't allow providing air quality that conforms to sanitary stan-

dards at the boundaries of a sanitary protection zone and beyond it when both furnaces emit their maximum quantity of 5 g/sec.

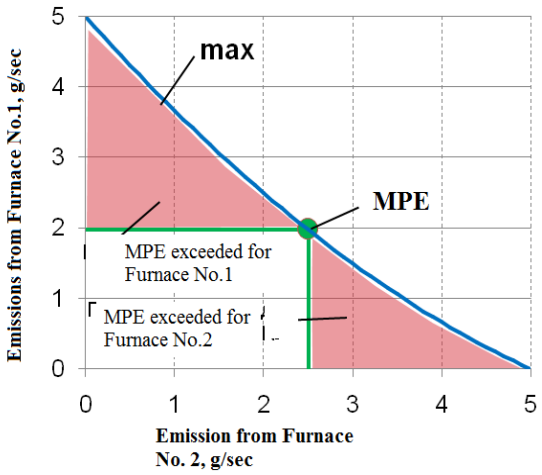

Figure 2. Illustration for combined emissions from two sources

In this case, to fix MPE standards for this enterprise, we should limit a possible emissions area with a certain line and coordinates axes. Hereinafter in this paper we call it «a permissible area». Boundaries of «a permissible area» for two emissions sources can be limited with a line given in Figure 2 as «max». Boundaries of this «permissible area» are determined with some UPRZA dispersion calculations performed with a conventional technique[5].

The existing standardization system fixes that there is the only possible choice of emissions combination given in Figure 2 and it is «MPE» point with its coordinated being 2.5 g/sec, 2 g/sec. And here a set of points that are located in areas limited in Figure 2 with coordinates 2.5 g/sec, 2 g/sec and «max» line corresponds to actually permissible emissions that are considered to be violations if the existing standardization system is applied.

If we apply the same logic to three emission sources, we will obtain a permissible area and a point that corresponds to MPE within a three-dimension coordinates system. In real life, an oil-processing plant can have more than a dozen smoke pipes only, and similar assumptions will lead to n-dimension image of permissible emissions combinations and MPE standards.

As a result, despite there is a theoretical possibility to develop MPE with a great number of emission combinations, experts usually prefer to fix greatest possible MPE but confine themselves to only one dispersion calculation variant. Therefore, authentic data obtained via inventories of certain air contamination sources that are applied for substantiating standards don't allow estimating actual emissions from an enterprise and perform relevant calculations of ground concentrations thus detecting sources that cause elevated ambient air contamination. Ultimately, it doesn't allow environmental authorities to take well-grounded decisions related to managing ambient air quality.

Sanitary standards for ambient air quality are to be met; provision of that remains one of the most significant tasks all over the world, including Russia [9]. As per WHO data, more than 92 % people in the world live on territories where ambient air contamination exceeds official safety standards [10]; therefore, tools for monitoring and managing ambient air quality are to be constantly developed and the task will become even more vital in the future [11–13].

Suggested tools for monitoring and management. Given all the above mentioned drawbacks that the existing standardization and monitoring system has, it seems advisable to perform the following tasks in order to provide proper functioning of a system for managing ambient air quality in any industrial center:

1. To provide a monitoring system with the most detailed and operative data on emissions from industrial enterprises and motor transport;

2. To provide a monitoring system with data that are uninterruptedly obtained from stationary monitoring posts; these are data on ground concentrations of contaminants emitted from enterprises located in a region including substances with a foul smell such as hydrogen sulphide, thiols, etc.;

3. To provide a monitoring system with actual data on temperatures as well as wind speeds and directions at a height up to 1,000 meters;

[5] On approving techniques for calculating dispersion of adverse substances (contaminants) emitted into the atmosphere: The Order by the RF Ministry for Natural Resources and Ecology No. 273 issued on June 06, 2017. *Garant: information and legal portal*. Available at: https://www.garant.ru/products/ipo/prime/doc/71642906/ (date of visit December 03, 2019).

4. To apply mathematical tools and procedures that have already been tested in the world practice and applied for modeling dispersion of contaminants. And here we should remember that calculation techniques applied for standardizing including aggregated dispersion calculations can't be used in operative monitoring as they are aimed at calculating maximum concentrations under the worst possible combinations of meteorological parameters and they don't allow taking into account winds with changing speeds and directions occurring in various layers of the atmosphere.

The first task can be solved due to emission sources being equipped devices for with uninterrupted control; these devices are to be applied at objects that belong to the first hazard category (in other words, they can cause the most adverse effects) in conformity with amendments made into the RF legislation in 2018[6].

We should note that there should be data on emissions of SO_2, NO_X, and CO from smoke pipes in a monitoring system as these contaminants make the greatest contribution into aggregated emissions; probably, it will allow applying emissions of these contaminants as indicators for adjusting models for contaminants dispersion. Any conclusion on whether data coming from uninterruptedly controlled sources are sufficient can be made only after tasks 2–4 are also fulfilled.

An oil-processing plant was assessed regarding how well it was equipped with meters described in the RF Government Orders dated March 13, 2019 No. 262 and 428-r[7]; the assessment revealed that uninterrupted control devices should be placed on smoking pipes of technological furnaces as they account for 80 % of such contaminants as SO_2, NO_X, and CO emitted into the atmosphere. However, according to a preliminary assessment, such meters will uninterruptedly control not more than 46 % of the aggregated emissions from a given enterprise. Therefore, even when the above-mentioned RF Government Orders are met, data on emissions that account for 53 % of the overall atmospheric contamination will not be included into uninterrupted monitoring. Monitoring won't either cover sources that emit substances with foul smell (hydrogen sulphide, thiols, etc.) and it is these substances people mostly complain about.

A lot of authors note that recently motor transport has been making the greatest contribution into ambient air contamination in cities [14] so it can't be neglected within a monitoring system. To take emissions from motor transport into account, experts can apply a procedure for uninterrupted monitoring of emissions based on uninterrupted measuring of transport flows in a city; the procedure was tested in Saint Petersburg[8]. To measure transport flows, experts applied data on speed of movement shown in internet resources such as «Yandex. Traffic Jams»[9]. An these data on how fast transport flows move can be bound to data on quantity and types of transport obtained as per data collected with video-registration devices with image recognition[10] [15].

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[6] On making alterations into the Federal law "On environmental protection" into Clauses 1 and 5 of the Federal law "On making alterations into the Federal law "On environmental protection" and certain legislative acts of the Russian Federation" as regards creating systems for automated control over emissions and discharges of contaminants: the federal law issued on July 29, 2018 No. 252-FZ (the last edition). *KonsultantPlus*. Available at: http://www.consultant.ru/document/cons_doc_LAW_303483/ (Date of visit December 04, 2019).

[7] Technical devices, equipment or their combinations that should be places at objects belonging to the 1st hazard category, stationary sources of contaminants emissions and discharges that are to be equipped with automated devices for measuring contaminants emissions or discharges as well as with technical means for fixing and transferring data on contaminants emissions and discharges into the state register of objects that exert negative influence on the environment: The RF Government Order No. 428-r dated March 13, 2019. Available at: https://rulaws.ru/goverment/Rasporyazhenie-Pravitelstva-RF-ot-13.03.2019-N-428-r/ (date of visit December 04, 2019).

[8] The procedure for detecting emissions of adverse substances (contaminants) from transport flows on motor ways in Saint Petersburg into ambient air / confirmed by the Order by the Committee on use of natural resources, environmental protection and ecological safety provision in Saint Petersburg No. 23-r dated February 17, 2012. SPb, 2012, 46 p.

[9] Yandex.Traffic jams. *Wikipedia. Free encyclopedia*. Available at: https://ru.wikipedia.org/wiki/Yandex.Trafficjams (date of visit December 05, 2019).

[10] Kuz'min D.M. Technologies and procedures for intellectual monitoring over transport flows and motorways conditions: abstract of the thesis. … Candidate of Technical Sciences. Moscow, 2008, 191 p.

To solve the task II, we need data on ground concentrations of contaminants emitted from enterprises and motor transport that are measured on monitoring posts either uninterruptedly or with a periodicity nor exceeding 60 minutes. As at the moment there are no technical devices for uninterrupted control over ground air, we suggest starting with data obtained from additional posts for uninterrupted automated control placed by large industrial enterprises in zones influenced by their activities. All the monitoring posts within Rosgidromet system where sampling is performed only periodically should be obligatorily equipped with devices for uninterrupted control and data transfer; it is also necessary to place additional posts with uninterrupted measuring and data transferring into a unified information and analytical center.

To control ground concentrations of substances with a foul smell, in our opinion, it is necessary to equip all the posts with devices for uninterrupted measuring of total concentrations of sulfur-containing substances, hydrogen sulphide, thiols, and sulfur dioxide.

Bearing in mind, that locations where some monitoring posts are placed no longer conform to requirements fixed in RD 52.04.186-89[11] due to changes in a city environment, it is necessary to move CHEM monitoring posts to places determined as per calculations of contaminants dispersion taking into account location of motor ways and houses.

Experts in Perm accumulated certain experience in placing additional posts for control over ambient air quality within a zone influenced by an oil-processing plant. This experience revealed that there was an obstacle in selecting the most optimal location for placing a monitoring post; namely, it was impossible to get an agreement from Rosreestr authorities to make amendments into a list of activities that could be performed on a land spot in order to locate a monitoring post (a pavilion, fence, or a device for remote protection and data transfer) on it. To avoid the problem in future, there should be amendments made into the legislation; these amendments are to allow making priority changes into permitted activities on land spots thus granting permission to acquire or rent land spots for placing monitoring posts on them.

To complete Task III, we should start with data on temperature profiles applied for monitoring over contaminants spread. Taking into account analysis of temperature profiles it is possible to obtain a relevant model for contaminants transfer; it seems to be incorrect to neglect data on temperature profile of the lower troposphere.

In our opinion, we should also use data of wind aerostatic sounding obtained twice a day together with data on temperature profiles. However, according to modeling results [16] confirmed with results of temperature-wind atmosphere sounding [17], zones with elevated changeability in wind direction can occur over urban and industrial territories; therefore, existing periodicity applied for obtaining data on wind profiles is insufficient for operating management of ambient air quality. Nevertheless, data obtained via aerostatic sounding can be applied at a primary stage in adjusting dispersion models.

There are tools for uninterrupted remote wind sounding of the atmosphere applied in the world; they are so called wind profilers. The most widely used technology here is application of acoustic or radar phase-locked antenna arrays in ultrasound sodars or radars operating within a range from 1 mm to 30 cm. There are also lidars or profilers that measure Doppler shift in laser radiation frequency to obtain data on a wind and temperature profile as per atmospheric height [18].

A cost-saving choice on equipment can be «XFAS» sodar with phase-locked antenna array produced by Scintec AG (Germany) (according to the manufacturer's data, it costs approximately 100 thousand EUR).

To fulfill Task IV, we suggest using freely available software packages that are described in detail on the web-site of the Support Center for Regulatory Atmospheric Modeling (SCRAM) that belongs to the US Environmental Protection Agency [19].

These packages apply a combination of the following calculation techniques:

– Receptor Modeling including PMF or Positive matrix factorization that are based on

[11] RD 52.04.186-89. Guide on control over ambient air contamination (Part I. Sections 1–5). Available at: http://docs.cntd.ru/document/1200036406 (date of visit December 03, 2019).

chemical and physical properties of contaminants measured directly on their sources to determine a contribution made by a source into concentrations at monitoring posts for control over ground air (receptors);

– together with PFM, «HYSPLIT» (Hybrid Single Particle Lagrange Integrated Trajectory) software package is applied; this package allows modeling dispersion of contaminants taking into account meteorological data such as profiles of wind speeds and directions as well as temperatures at various heights;

– Modeling dispersion and turbulent diffusion of contaminants using Euler, lagrange, and Gauss models.

B.Kh. Sandjapov [20] describes experience related to applying software packages for dispersion modeling WRF and CALPUFF that can be found on SCRAM web-site in Volgograd.

Difference solutions to turbulent diffusion equation reduced to a sequence of analytic expressions obtained via approximation and linearization of solutions to equations within Gauss model for dispersion are also applied in the methodology called «Techniques for calculating dispersion of adverse substances (contaminants) emitted into the atmosphere»[6] fixed by the RF Ministry for Natural Resources and Environmental Protection No. 237 issued on June 06, 2017.

We think that when the above-mentioned tasks are fulfilled, it will allow obtaining data that are sufficient for identifying sources of elevated ambient air contamination in order to work out relevant management activities aimed at ambient air quality in cities meeting all the sanitary standards.

These management activities can be both operative measures, for example, a decrease in emission capacities of specific air contamination sources or imposing limits on motor transport traffic, and strategic ones, for example, instructions issued for economic entities to develop environmental protection measures or construction of new motorways to redirect traffic flows.

To perform operative and strategic management of ambient air quality based on data obtained via monitoring and modeling, probably certain changes into ecological legislations are required; however, only time can tell whether they are necessary and what exactly should be changed in ecological laws and legislative acts.

Conclusion. To achieve relevant functioning of a system for managing ambient air quality in large industrial cities, it is necessary to perform the following steps: to equip emission sources located at objects belonging to the 1st hazard category with devices for uninterrupted on-line automated control over contaminants emissions; to develop a system of stationary monitoring posts as regards a wide range of contaminants including substances with a foul smell supplemented with a system for temperature-wind atmospheric sounding in the lower troposphere; the given systems should use conventional techniques for modeling contaminants dispersion tested in world practice and receptor data analysis taking into account air movement trajectories in a monitoring zone. Should all the steps be fulfilled, it will allow making ambient air quality conform to sanitary standards for the sake of people who live in large industrial cities.

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SOCIAL-HYGIENIC MONITORING SYSTEM UPDATING BASED ON HEALTH RISK ANALYSIS (at the municipal level)

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In order to increase efficiency of activities aimed at reducing impacts exerted by leading health risk factors it is necessary to optimize observation over the existing social and hygienic situation within social and hygienic monitoring (SGM). It is also necessary to substantiate reference points where monitoring posts for controlling ambient air quality should be located within zones influenced by industrial enterprises, primarily those ranked as economic entities that could cause extremely high or high potential health risks.

Methodical approaches to optimizing monitoring programs and location of monitoring posts within SGN system at the municipal level were implemented with complex analysis of health risk factors occurring due to economic activities by an enterprise that dealt with alumina production (Achinsk city in Krasnoyarsk region). The analysis included assessing and ranking potential threats to population health, first of all, to the respiratory organs; substances emitted into the atmosphere by the examined enterprise; consolidated calculations of ground concentrations diffusion; instrumental monitoring and field observations; hazard indexes under acute and chronic combined exposure to substances with one-way damaging impacts on the respiratory organs.

The obtained results allowed creating a specific list of admixtures that should be observed systematically (particulate matter, $PM_{2.5}$ and PM_{10}, formaldehyde, manganese, copper, aluminum, nitrogen dioxide, sulfur dioxide, hydrofluoride, xylene, and toluene) and periodically (vanadium (V), nickel, and chromium (IV)). We substantiated two reference points where monitoring posts for controlling ambient air quality should be located within SGM system (instead of 5 existing mobile points) with specific fix-up on a territory; these points characterized a zone influenced by an alumina-producing enterprise. Control over ambient air quality at the chosen reference points within SGM does not require any interaction with an economic entity when surveillance and control activities are being performed; it is advisable to apply an extended program for monitoring over ambient air quality at these points and assess residual risks caused by exposure to substances that could be potentially hazardous for the respiratory organs as such risks can occur when an enterprise develops and implements activities aimed at achieving acceptable levels of risks.

Key words: *ambient air quality, social and hygienic monitoring, chemical factors, risks for the respiratory organs, monitoring posts, monitoring program, stationary monitoring posts.*

Social and hygienic monitoring pursues the following major goals when performing all its activities: assessing public health and the environment, revealing any changes in their state and making predictions on a future situation, detecting and eliminating hazardous impacts exerted on human health by environmental factors. All these goals are fixed in the RF Federal Law No. 52-FZ "On sanitary-epidemiologic welfare of the population" (Clause 45). Achieving these goals requires solving such basic tasks as revealing cause-and-effect relations between public health and impacts exerted by environmental factors basing on systemic analysis and health risk assessment. These tasks can be solved only provided that systemic instrumental measuring of environmental objects quality yields adequate results, that is, allows obtaining current, relevant, and authentic data [1]. Collected data

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should fully provide necessary foundation for full-fledged hygienic assessment of environmental factors; that is, they are to provide not only insight into concentrations of this or that component (substance or admixture) in an environmental object but also into health parameters associated with a given factor and exposure to it [2].

Given that, it is necessary to constantly improve approaches to selecting control points and to optimize monitoring programs performed within SGM activities [3–6]. A lot of research has proven that when substantiating reference points for control over ambient air quality, a special attention should be paid to housing areas where exposure factors create the greatest health risks and the density of population exposed to such factor is also the highest. When giving grounds for lists and scales of monitoring, it is necessary to spot out chemicals with additivity and/or potentiating of adverse effects under simultaneous long-term introduction into a body and, consequently, imposing the greatest threats for human health [7–9].

Ambient air contamination with chemicals is a persistent health risk factor which has long been considered a significant one among other environmental factors [10–12]. Over the last decade Rospotrebnadzor's bodies and organizations have taken a substantial amount of efforts to develop a unified list of parameters for monitoring over ambient air quality in order to make social and hygienic monitoring more efficient [13–15]. Scientifically grounded methodical approaches to selecting control points and programs for monitoring over ambient air have been developed and tested as a result of activities performed within "Pure air" Federal project; they took into account specific features of already existing social and hygienic monitoring networks; tests have been carried out in several RF regions (at the municipal level) [1]. Such activities become especially significant in industrially developed regions where a lot of admixtures are emitted into the atmosphere with dust and gas emissions; concentrations of these admixtures create unacceptably high health risks, primarily for the respiratory organs. Such regions are cities where metallurgic enterprises are located including those producing alumina. Major economic activities performed in such regions belong to processing industries and economic entities operating there are assigned into a category of objects with extremely high and high potential health risks borne by exposed population [16]. Most chemical factors that contaminate ambient air are components of dust and gas emissions; specific features of technological processes applied at alumina production result in emissions containing particulate matter, di-aluminum-trioxide, gaseous fluorides, nitrogen oxide and dioxide, sulfur dioxide, dimethylbenzene, manganese, etc. Inhalation exposure to such chemical factors is primarily characterized with summation and synergy of adverse impacts exerted by them on the respiratory organs and it causes elevated risks of diseases among exposed population [11, 17–20]. Children who live in housing areas influenced by emissions from industrial enterprises are the most sensitive to such exposures and run the highest health risks caused by chemical factors[1]. A child's body, including the respiratory system, has certain age-related structural and anatomic peculiarities and its adaptation and detoxification mechanisms are not completely developed [21] thus making it more sensitive to ambient air quality and shortening a period of time during which a response occurs in the respiratory organs to adverse effects produced by exposure to chemical factors.

Given all the above stated, we believe it is necessary to make social and hygienic monitoring aimed at control over ambient air quality more efficient on territories where large industrial facilities are located; these improvements should also cover activities performed within existing programs for regular monitoring.

[1] G 2.1.10.1920-04. Guide on assessing population health risks caused by exposure to chemicals that pollute the environment. Moscow, The RF Public healthcare Ministry's Federal Center for State Sanitary and Epidemiologic Surveillance, 2004, 143 p.

Our research goal was to update an existing SHM system based on health risk analysis at the municipal level.

Data and methods. Methodical approaches to optimizing SHM activities at the municipal level were implemented in a region where a large alumina-producing enterprise was located (a city called Achinsk in Krasnoyarsk region). Achinsk has a population equal to 105.25 thousand people and its territory is 103.2 square kilometers. Major industries in the city are fuel and energy production, metallurgy, oil-processing and wood-processing. The largest enterprise is an alumina-producing plant which is assigned into a category of economic entities with the extremely high potential health risks. We accomplished complex analysis of health risk factors related to economic activities performed by the given enterprise; our analysis included identifying potential threats, primarily for the respiratory organs. We also identified components of emissions from stationary sources in Achinsk and from the alumina-producing enterprise basing on assessing data on actual gross emissions into the atmosphere (Statistical reports 2-tp (air) submitted in 2012–2017). To assess exposure and analyze spatial distribution of all obtained parameters, we took initial cartographic information, namely, an electronic map of the city territory (scaled 1:10000). Then we used GIS ArcView 3.2 and ArcGIS 9.3, ESRI to put different objects on it, plotting them in separate layers; these objects were houses, industrial objects, industrial facilities and areas, motorways and streets, monitoring points etc. To select priority admixtures for control, we performed aggregated calculations of ground concentrations dispersions for 26 substances as per data taken from the latest reference book on maximum permissible emissions from the alumina-producing enterprise (2016). The reference book included inventories that listed stationary sources of contaminants emissions. We performed our calculations according to "Procedures for calculating dispersions of adverse substances (contaminants) emissions in ambient air" (MRR-2017)[2] applying "Ecolog 4.50" unified UPRZA software package. We applied "Ekolog – Gorod" UPRZA software package to calculate average annual contaminants concentrations as it had a section for calculating "average values". A meteofile with data on typical meteorological conditions in Achinsk was obtained from Voeykov's Major Geophysical Observatory. Dispersions were calculated at 6,630 calculation points (nodes) in the regular grid; having done that, we applied the results to calculate risk parameters under acute and chronic introduction for each substance according to GP 2.1.10.1920-04. It allowed us to obtain exposure fields that created health risks; we put them on the vector map of the examined territory.

The next step was to select a number of monitoring points and places where to locate them; to do that, we standardized spatially-distributed parameters and performed cluster analysis on them with STATISTICA software for statistic analysis. This analysis involved applying "nearest centroid classifier" procedure. A number of clusters (a number of stationary posts for monitoring over ambient air quality) required for each territory was determined as per population living there[3]: one post was required per a territory with its population being lower than 50 thousand people; 2 posts, up to 100 thousand people; 2–3 posts, 100–200 thousand people; 3–5 posts, 200–500 thousand people; 5–10 posts, more than 500 thousand people; 10–20 posts (stationary and mobile), more than 1 million people. An optimal (reference) point for locating a monitoring post was a point located in a housing area where there was the greatest aggregated risk for the respi-

[2] On approval of procedures for calculating dispersions of adverse admixtures (contaminants) emissions in ambient air: The Order by the RF Ministry for Natural Resources and the Environment No. 273 dated June 06, 2017. *Garant. Information and legal portal*. Available at: https://www.garant.ru/products/ipo/prime/doc/71642906/ (date of visit October 15, 2019).

[3] On organizing laboratory control when performing social and hygienic monitoring activities: The Letter by the Federal Service for Surveillance over Consumer Rights and Human Well-being dated October 2, 2006 No. 0100/10460-06-32. Moscow, Moscow Regional Office of the Federal Service for Surveillance over Consumer Rights and Human Well-being. Available at: http://50.rospotrebnadzor.ru/293/-/asset_publisher/U8Fg/content (date of visit September 20, 2019).

ratory organs which occurred due to all the substances with the same effects and where density of exposed population was the highest in the cluster (more than 75 %).

To optimize the existing monitoring program, we assessed the current ambient air quality over 2012–2017 and compared calculated and instrumental data. We analyzed information provided by the Federal Information Center of Social and Hygienic Monitoring on a list of points where ambient air quality was controlled by the "Krasnoyarsk Regional Center for Hygiene and Epidemiology" in Achinsk; the given organization controlled ambient air quality within the current social-hygienic monitoring network as per 8 substances. We also took data obtained via instrumental research by the Federal Scientific Center for Medical and Preventive Health Risk Management Technologies accomplished in 2017; the research covered concentrations of 15 substances. We statistically processed and analyzed all the data with STATISTICA software package.

Results and discussion. As a whole, our analysis of gross emissions from industrial enterprises in Achinsk revealed that actual emissions into the atmosphere form stationary sources amounted to approximately 45 thousand tons annually (the third place in Krasnoyarsk region); emissions from alumina production made the greatest contribution into it accounting for 85–86 %. There were approximately 85–88 types of chemicals in the list; 45 chemicals out of them were emitted from the major economic entity on the territory. 23 substances were priority ones as per potential hazards of the respiratory organs diseases among population including silicon-containing dusts, nitrogen oxide, sulfur oxide, copper oxide, aluminum oxide, nickel oxide, sodium hydroxide, sulfuric acid, soot, manganese compounds, gaseous fluorides, hydrogen chloride, formaldehyde, etc. (Table 1).

Table 1

List of chemicals that were contained in emissions from the alumina-producing enterprise ranked as per potential hazards of respiratory organs diseases (as per data collected in 2017)

Chemicals	Hazard index for a chemical	
	Non-carcinogenic	Carcinogenic
Non-organic dust: SiO_2 lower than 20 % (dolomite)	11,611,372.5	–
Nitrogen dioxide	9,571,171.4	–
Black oil ash from a thermal power station (recalculated per vanadium)	7,131,550.0	–
Nitrogen oxide	6,441,603.3	–
Sulfur dioxide	4,870,348.9	–
Non-organic dust: SiO_2 20–70 % (fire clay)	4,682,106.0	–
Aluminum oxide (recalculated per aluminum)	379,543.1	–
Sodium hydroxide	232,457.5	–
Non-organic dust: SiO_2 higher than 70 %	76,139.0	–
Sulfuric acid	28,755.8	–
Back carbon (soot)	21,279.3	–
Manganese and its compounds (recalculated as per manganese oxide)	7,918.0	–
Copper oxide	1,065.0	–
Easily soluble gaseous fluorides (hydrofluoride)	368.1	–
Hydrogen chloride	225.8	–
Formaldehyde	191.7	19.2
Никель оксид	106.5	10.7
Particulate matter	85.2	–
Hydrogen sulfide	63.1	–
Nitric acid	28.8	–
Chromium (VI) (recalculated per chromium oxide)	10.7	10,666.7
Methyl benzene (toluene)	0.55	–
Dimethyl benzene (xylol)	0.11	–

We compared a list of priority contaminants emitted into ambient air by aluminum-producing enterprises and a list of substances which were subject to control within SHM system for monitoring air contaminants; it allowed us to reveal certain items in the existing program for control over ambient air quality which were not relevant to the current situation.

We determined that regular control covered only 4 admixtures (17.4 %) out of 23 substances that were potentially hazardous for the respiratory organs and were emitted into ambient air by the alumina-producing enterprise in 2012–2018; these 4 admixtures were nitrogen dioxide, sulfur dioxide, particulate matter, and formaldehyde.

In 2017 the monitoring program included aluminum and easily soluble gaseous fluorides. We detected significant discrepancies between calculated and instrumental data on admixtures concentrations in ambient air. Calculated data didn't reveal any concentrations which exceeded hygienic standards for most examined substances excluding nitrogen dioxide and non-organic dusts that contained less 20 % silicon. Dispersion calculations predicted violations of hygienic standards (in zones where monitoring posts were located) only as per contents of silicon-containing dusts (up to 1 single maximum MPC) and nitrogen dioxide (up to 3.2 average daily MPC). But still there were substances detected at SHM posts for control over ambient air in actual concentrations being higher than single maximum and/or average daily MPC; these elevated concentrations were detected in housing areas in the city in the examined period and a list of substances with such concentrations included nitrogen oxide, particulate matter, formaldehyde, and gaseous fluorides (on average from 4.16 to 10.4 single maximum MPC and from 1.38 to 43.6 average daily MPC); aluminum and sulfur dioxide (from 1.16 to 3.6 average daily MPC). Experts from the Federal scientific Center for Medical and Preventive Health Risk Management Technologies accomplished field observations in 2017 and detected violations of hygienic standards as per concentrations of toluene and xylol (from 3.04 to 4.32 single maximum MPC); solid and gaseous fluorides, particulate matter and its fractions PM2.5 and PM10 (from 1.78 to 4.97 single maximum MPC and from 3.11 to 8.92 average daily MPC); aluminum and manganese (from 1.12 to 3.06 average daily MPC). These violations were detected at 2 out of 4 mobile SHM posts and they were not predicted by any dispersion calculations. The experts also registered persistent occurrence of vanadium (V), chromium (VI) (up to 0.03–0.06 average daily MPC), and copper (up to 0.44 average daily MPC) in ambient air.

Aggregated calculations of dispersion didn't predict hygienic standards being violated practically as per all the components in emissions from the alumina-producing enterprise. But in spite of that, taking risk criteria into account, we assumed there was an unacceptable risk of respiratory organs diseases for children under combined acute inhalation exposure (HI is up to 11.2) and chronic inhalation exposure (HI is up to 5.02) to priority potentially hazardous chemicals (Figure 1).

Results of monitoring and field observations allowed revealing substantially elevated chronic risks of respiratory organs diseases (HI is up to 31.2–49.9) due to simultaneous occurrence of a wide range of substances with similar adverse effects on the respiratory organs.

The greatest contribution into hazard index are made by particulate matter and their fractions PM2.5 and PM10, formaldehyde, manganese, copper (9.05–17.91 %), aluminum, nitrogen dioxide, sulfur dioxide, easily soluble gaseous fluorides (1.82–5.57 %). Contributions made by vanadium (V), chromium (VI), xylol, toluene, and sodium hydroxide amount to 0.44–0.92 %.

Given all the above mentioned, the monitoring program aimed at control over ambient air quality and accomplished within SHM activities in a zone influenced by the alumina-producing enterprise needs to be expanded as it should necessarily include regular control over concentrations of manganese, copper, toluene, and xylol. These substances, according to data collected via field observations, are registered at monitoring posts in concentrations which are higher than hygienic standards

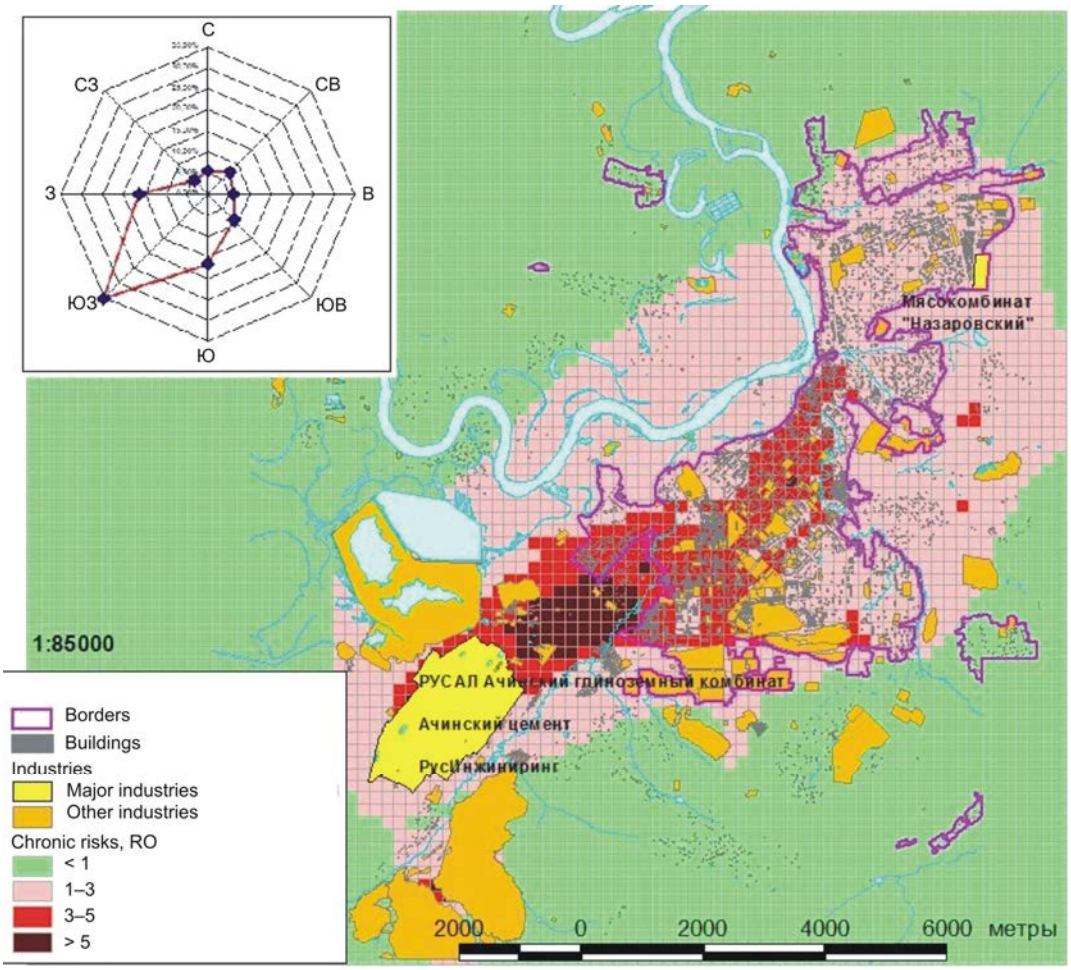

Figure 1. Map showing spatial distribution of hazard index for children's respiratory organs created by emissions from alumina-producing enterprise

(manganese, xylol, and toluene) and/or allow predicting a substantial contribution into aggregated non-carcinogenic risks for the respiratory organs (copper). Such admixtures as vanadium (V), nickel, and chromium (VI) belong to the 1st hazard category and are carcinogenic (nickel and chromium); therefore, it is advisable to include them into systematic monitoring programs to perform control over sanitary-hygienic situation and to determine residual risks in exposure zones.

We determined reference points which were the most suitable for locating monitoring posts included into SHM system for control over ambient air quality in a zone influenced by the alumina-producing enterprise; overall, there were 6 such points for SHM monitoring posts which characterized 2 clusters. Cluster No. 1 was characterized with only 1 point whereas cluster No. 5 was characterized with the remaining 5 points. Expert estimates and population density analysis allowed substantiating a choice on only 1 point which was the most representative one in cluster No. 2 (Figure 2; Table 2).

We compared places where proposed monitoring posts would be located and mobile monitoring posts where control over ambient air quality was performed within SHM activities as we tried to make recommendations on how to optimize the monitoring program for a territory influenced by the examined alumina-producing enterprise. We revealed they were convergent; consequently, it was quite possible to use data which were obtained at already existing monitoring posts.

Conclusions. We accomplished a piece of research at the municipal level in a region where a large alumina-producing enterprise was located; that enterprise could potentially

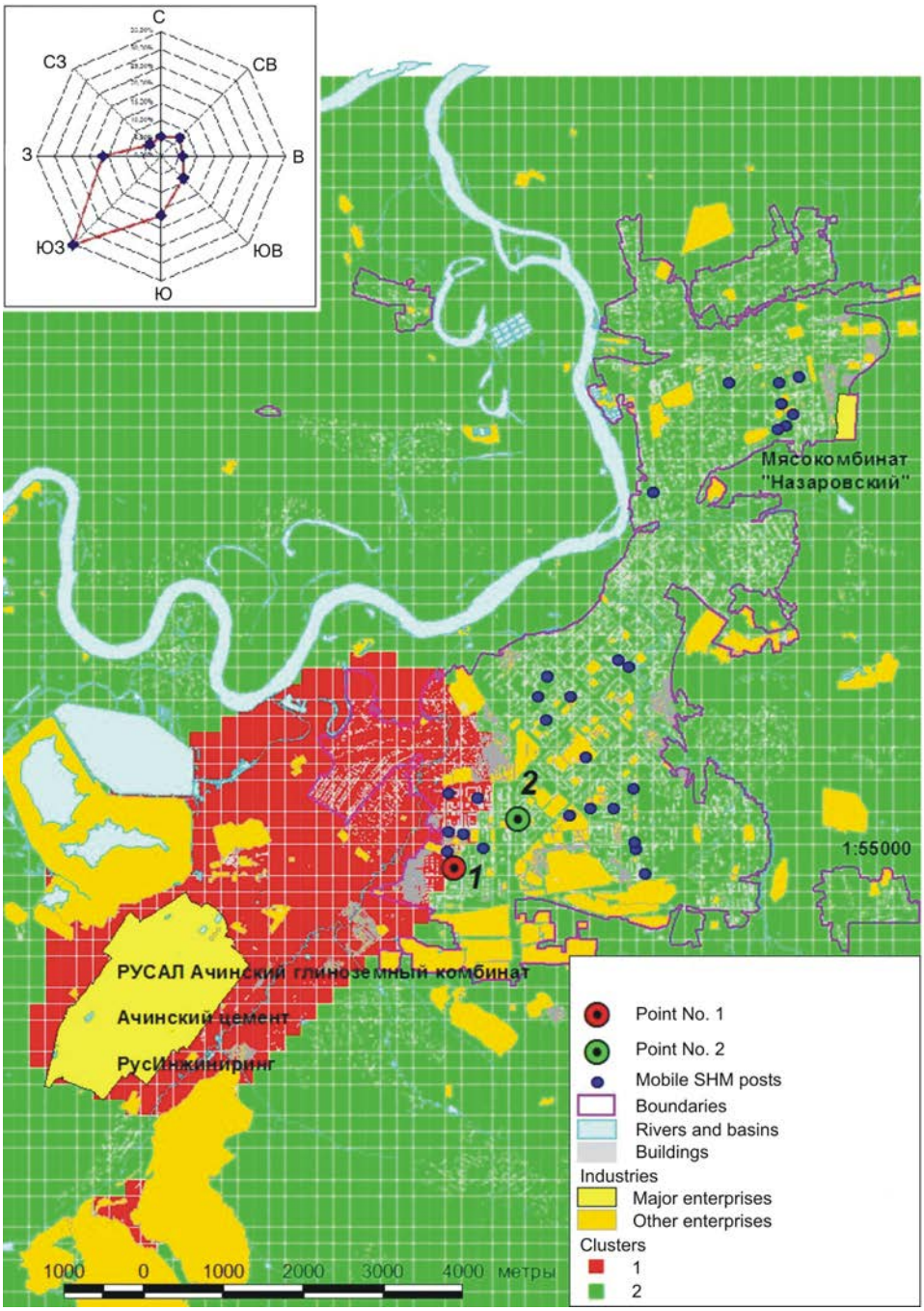

Figure 2. Representative points for locating ASHM monitoring posts aimed at control over ambient air quality in a zone influenced by alumina-producing enterprise

Table 2

Points proposed for locating SHM monitoring posts for control over ambient air quality in Achinsk

Point No.	Cluster	Coordinates, m		Rank sum	Population density quotient	Address of the closest apartment block
		X	Y			
4163	1	14,800	35,700	186	1.0	Stroitelei str. 25
4478	2	15,600	36,300	188	0.87	The 5th micro-district, 19

cause extremely high health risks. Our research allowed us to substantiate two reference points for control over ambient air quality (instead of existing 5 mobile control posts) with a concrete location; these two points characterized a zone influenced by the examined alumina-producing enterprise.

It is advisable to apply an expanded program for control over ambient air quality in recommended monitoring points within SHM system which is implemented without any interaction with the alumina-producing enterprise being subject to surveillance within control and surveillance activities. This expanded program should include systematic monitoring over particulate matter, PM2.5 and PM10 fractions, formaldehyde, manganese, copper, aluminum, nitrogen dioxide, sulfur dioxide, easily soluble gaseous fluorides (hydrofluoride), xylol, and toluene; and periodical monitoring (once a three years) over vanadium (V), nickel, and chromium (VI). It is also necessary to assess residual risks caused by exposure to substances which are potentially hazardous for the respiratory organs when experts at the examined enterprise develop and implement activities aimed at reducing risks up to their acceptable levels.

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ASSESSING RISK FACTORS THAT CAN CAUSE ALIMENTARY-DEPENDENT DISEASES AMONG STUDENTS DUE TO THEIR NUTRITION

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This research can be considered quite vital due to digestive organs diseases being widely spread among young students. We chose students attending I.M. Sechenov's First Moscow State Medical University as our research object. We questioned 840 students who attended the above-mentioned higher education establishment and assessed their medical check-ups data; having done that, we analyzed risks of alimentary-dependent diseases among students related to impacts exerted by their nutrition.

Our research goal was to assess students' nutrition, its structure, frequency, and conditions; to determine priority risk factors for students' health; and to develop recommendations on healthy nutrition provided for them as a factor related to pursuing healthy lifestyle.

We detected that about 20 % students didn't have breakfast; about 8 % didn't have lunch or dinner (and it meant they had less than 3 meals a day; however, half of the students had 3 meals a day. 65.7 % of the students had their last meal a day after 9 p.m., and about 20 %, after 23 (late meal). We ranked a correlation between nutrition-related risk factors and existing nosologies and revealed that 3 factors exerted the most significant influence on the digestive organs diseases; they were late meals, irregular hot meals, and a number of meals taken a day. Endocrine system diseases were mostly influenced by 2 factors, late meals and a number of meals a day. Number of meals a day was also correlated to respiratory organs diseases and urogenital system diseases; late meals, to diseases in the nervous and cardiovascular systems.

Key words: *risk assessment, students, number of meals a day, nutrition regime, late meals, meal, morbidity, health preservation, healthy lifestyle, prevention.*

Nowadays an issue related to rational and balanced nutrition consumed by various population groups as well as adherence to good nutrition is a priority in research accomplished in the sphere of nutrition including studies aimed at preventing the most widely spread non-infectious diseases [1].

Given that, it is necessary to accomplish task-oriented applied scientific research aimed at detecting and assessing influences exerted on population health by food products which are able to create intolerable (unacceptable) risks for people's life and health[1].

As a result, such research should allow achieving mass adherence to good nutrition as a factor that helps pursue healthy lifestyle[2].

Methodology for assessing risks caused by impacts exerted by environmental factors on population health is an efficient tool for assessing influence on a human body including adverse impacts exerted on health by non-rational and imbalanced nutrition.

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[1] The strategy aimed at increasing food products quality in the Russian Federation up to 2030. Approved by the RF Government Order dated June 29, 2016 No. 1364-p. Moscow, 2016, 17 p.

[2] On sanitary-epidemiologic welfare of the population in the Russian Federation in 2019: The State report. Moscow, 2019, 254 p.

Assessment of health risks caused by exposure to adverse environmental factors is given in details in multiple publications that focus both on assessing health risks themselves and assessing efficiency of accomplished control and surveillance activities aimed at preventing non-infectious diseases [2, 3].

Great attention has been paid to nutrition provided for children and teenagers in educational establishments. Annual State reports "On sanitary-epidemiologic welfare of the population in the Russian Federation"[2] contain data on nutrition provided for children and teenagers including senior schoolchildren as well as on nutrition provided for students who attend vocational schools. However, nutrition provided for students at higher educational establishments (HEE) is not given proper attention though they were school children only "yesterday" and are of the same age as students who attend vocational schools.

A growth in morbidity with gastrointestinal diseases among young students is a serious issue as 65 % of them already suffer from chronic diseases; it can be due to either improper nutrition regimes or imbalanced daily rations consumed by students and it exerts negative influence on macro- and micronutrient structure of consumed food [4, 5].

An issue related to providing students attending a medical HEE with regular and balanced nutrition is rather outstanding as their educational system is quite peculiar. A peculiarity is related to educational departments being located at a distance from each other and any student who attends a medical HEE has to spend a lot of time moving from one department to another; it leaves smaller amount of available time that could be spent on taking a meal. Due to it a lot of students have their meals at fast-food cafes or even "on foot". Besides, senior students spend a lot of time on duties and meals are not regular during them; hot meals are not always available [6–8].

Students' lifestyle has such peculiar features as untimely meals; systematic lack of sleep; too little time spent outdoors; necessity to study during night hours when a student should be in bed sleeping; absence of any physical exercise or activities aimed at health strengthening; smoking, etc. [9, 10].

All the above mentioned creates elevated risks of non-infectious diseases among students caused by both improper nutrition and other factors that are not in line with "healthy lifestyle" postulates [11, 12].

Besides, more and more foreign students have been attending Sechenov's Medical University over the recent years; they have their own tastes and nutrition habits due to a national nutrition culture. At the same time a range of food products and cooked meals provided for students at the University canteens, cafes, and cafeterias doesn't necessarily take into account their existing nutrition preferences and habits.

Despite there are multiple scientific research works on students' nutrition, assessment of risks related to bad nutrition and, consequently, non-infectious morbidity among students haven't been given proper attention or studied in greater detail.

Our research goal was to assess nutrition consumed by students who attended Sechenov's Medical University; to spot out priority risk factors that could cause health disorders in them; and to give recommendations on good nutrition as a healthy lifestyle factor.

Data and methods. Our research was based on reports that contained data obtained via periodical medical examinations of students performed at the Clinical and Diagnostic Center of the First Moscow State Medical University (Sechenov's Medical University) and on questioning results; overall, 840 students were questioned, 280 males and 560 females; they were 2–4 year students attending the Medical Faculty. Observation period was 2012–2017.

We determined an actual body mass of all the examined students and calculated their body mass index (BMI).

In our research we applied a correlation as per body mass index; determined a correlation between specific nutrition factors and existing

nosologies as well as between students' complaints and specific nutrition factors.

When assessing risks caused by influences exerted by food products on students' health, we applied procedures and techniques fixed in methodical guidelines approved by Rospotrebnadzor's Order dated January 18, 2016 No 16 and in several research works[3, 4] [14–17].

Results and discussion. We analyzed students' nutrition regimes and revealed several violations. First of all, 20 % students didn't have breakfast, about 8 % didn't have either lunch or dinner; consequently, these students had less than 3 meals a day (each 10th student), and only half of students had 3 meals a day (Figure 1).

Meals taken at home or dormitories were mostly breakfast or dinner (82–88 %). Most students (78 %) had their lunch at catering facilities. From 5.6 % to 11.3 % students had their lunch at the University canteens or cafes.

Besides, we detected that more than 30 % questioned students had only one or two meals a day; most students (79.9 %) had one or two hot (cooked) meals a day. Figure 2 shows students' answers regarding a number of hot meals they have a day.

The next vital issue is time when students have their last meal a day. It has been proven and substantiated from a physiological point of view that if a person is active during 10 hours and has his or her meals in this period of time than the next 14 hours, starting from the last meal a day to the first meal the next day, should be a break for rest. 14 hours is a period that is considered to be quite sufficient for all the food consumed a day to be digested by a body. This approach to distribution of meals over a day is based on human biorhythms theory [18, 19].

A late meal is a significant factor that can cause alimentary-dependent diseases. Thus, 65.7 % questioned students had their last meal rather late, at 9 p.m. and even later; about 20 % had it after 11 p.m. (Figure 3).

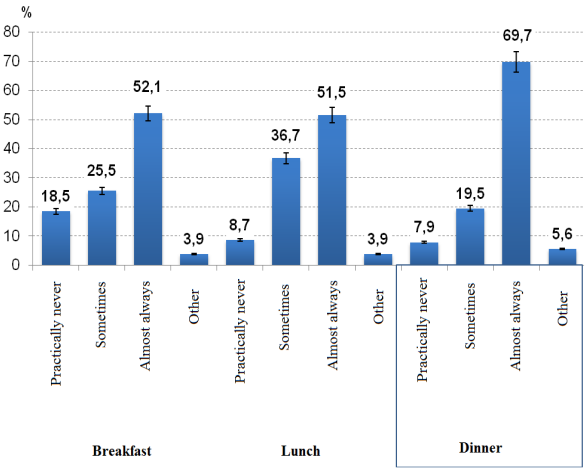

Figure 1. Answers given by students regarding their nutrition regime

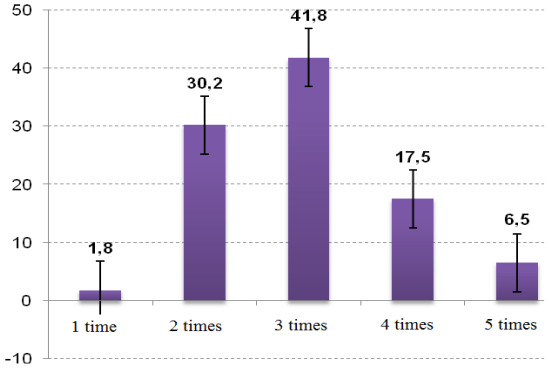

Figure 2. Number of hot meals students have a day

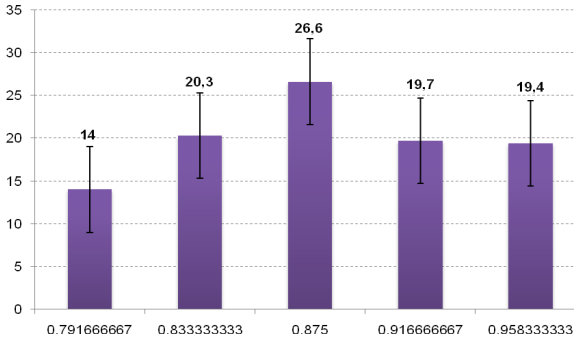

Figure 3. Distribution of the last meal taken by students a day (%)

[3] On implementation of the methodical guidelines "Classification of food products distributed on the market as per potential health risks and property losses borne by consumers for organizing scheduled control and surveillance activities": Rospotrebnadzor's Order dated January 18, 2016 No. 16. *KODEKS: The electronic fund for legal and reference documentation*. Available at: http: //docs.cntd.ru/document/420332234 (date of visit September 03, 2019).

[4] On sanitary-epidemiologic welfare of the population in the Russian federation in 2018: The State report. Moscow, The Federal Service for Surveillance over Consumer Rights Protection and Human Well-being, 2019, pp. 52–64.

This situation results in insulin being produced in greater amounts in a body; it makes for fat preservation in it and can lead to obesity. A late meal (after 9 p.m.) is a risk factor that can cause pancreatic diabetes and cardiovascular diseases.

As a body produces gastric juice and hormones more actively during the first half of a day, food consumed during it is digested rapidly and efficiently. A human body tends to function slower in the evening and at night, therefore, late dinners or suppers increase a load on the gastrointestinal tract. Too much food consumed in the evening can cause gastrointestinal diseases (gastritis, intestinal allergies, dysbacteriosis, etc.) [20, 21]. We should note that nutrition regimes exert direct impacts on students' body mass. Given that, we examined body mass of all questioned students and calculated their body mass index (Figures 4 and 5).

These data reveal that students' body mass is within average standards values for male and female students. At the same time students' body mass tends to grow which is more apparent among male students (regression quotient b1=1.5), than among female ones (b1 = 1.1).

We analyzed dynamics of body mass index (BMI) and concluded that the parameter was within its standards both for male and female students. However, average BMI values for men were detected close to the upper limit of its standard value. Should the detected trend be extrapolated to the future, we can obtain a prediction that after three next periods an average BMI among male students will exceed its standard value. These results can be expected if male students' nutrition continues to be improper.

Our next goal was to reveal specific risk factors related to students' nutrition that could cause relevant nosologies; to do that, we assessed correlations between them (Table 1).

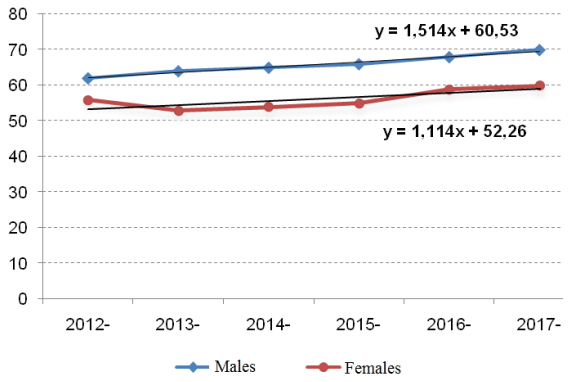

Figure 4. Body mass of students at the Medical faculty taken in dynamics (kg)

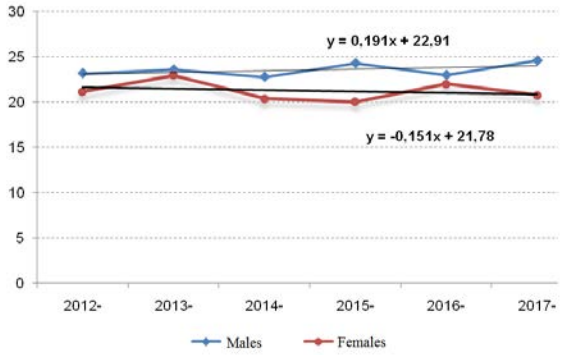

Figure 5. Body mass index taken in dynamics

Table 1

Assessment of correlations between specific nutrition-related factors and relevant nosologies

Nosologies	Regression quotients for correlations			
	Number of meals a day	Hot meals	Meals taken after 9 p.m.–11 p.m. (late meals)	Energy drinks consumption
Respiratory organs diseases	**0.52**	0.20	0.21	-0.15
Urogenital system diseases	0.30	0.26	0.23	0.16
Nervous system diseases	0.29	0.13	**0.63**	0.16
Cardiovascular diseases	0.30	0.25	**0.66**	0.02
Gastrointestinal diseases	**0.50**	**0.60**	**0.66**	-0.10
Endocrine system diseases	**0.32**	0.27	**0.64**	0.13

Table 2

Assessment of correlations between students' complaints and specific nutrition-related factors

Complaints (indicating there are health disorders)	Коэффициенты регрессии зависимостей b1			
	Number of meals a day	Hot meals	Meals taken after 9 p.m.–11 p.m. (late meals)	Energy drinks consumption
Fatigue	**0.59**	0.19	**0.49**	-0.06
Flabbiness	**0.35**	0.27	**0.57**	**0.37**
Headache	**0.31**	0.27	0.10	0.26
"Heart" ache	0.12	0.24	**0.41**	-0.16
Unpleasant feeling in the eyes	0.26	-0.20	-0.21	0.12
Dizziness	**0.52**	0.12	0.25	-0.21
Noises in the eras	0.15	-0.19	0.09	-0.08
Numbness in the extremities	0.12	0.22	0.09	-0.08
Dyspnea	0.12	0.23	**0.63**	-0.18
Heavy legs	0.03	0.09	**0.71**	-0.10

These data indicate that respiratory organs diseases are predominantly influenced by a number of meals (b1 = 0.52). Urogenital system diseases also have the greatest correlation with a number of meals a day (b1 = 0.30). Diseases of the central nervous system are predominantly influenced by late meals (b1 = 0.63). The most significant factor that causes cardiovascular diseases is also late meals (b1 = 0.66). Gastrointestinal diseases occur mostly due to late meals (b1 = 0.66), a number of hot meals taken a day (b1 = 0.60), and overall number of meals a day (b1 = 0.50). Endocrine system diseases are predominantly caused by late meals (b1 = 0.64) and a number of meals a day (b1 = 0.32).

We ranked correlations between nutrition-related factors and relevant nosologies and revealed that gastrointestinal diseases were influenced by three major factors, late meals, a number of hot meals a day, and overall number of meals a day; endocrine system diseases were influenced by two factors, late meals and a number of meals a day. Respiratory organs diseases were influenced by a number of meals a day; urogenital system diseases, a number of meals a day; central nervous system diseases, late meals; cardiovascular diseases, late meals.

We also assessed correlations between students' complaints and specific nutrition-related factors (Table 2).

Out of all the examined factors, increased fatigue is predominantly related to a number of meals a day (b1 = 0.59), and late meals (b1 = 0.49); flabbiness is influenced by late meals (0.57), a number of meals a day (0.35), and energy drinks consumption (0.37). Complaints about pains "in the heart" are related to late meals (0.41). Dizziness is most closely correlated to a number of meals a day (0.52). Dyspnea is most frequently met among those who take their last meal after 11 p.m. (0.63). Heavy legs are also most tightly correlated with late meals (b1 = 0.71).

We ranked correlations between students' complaints and specific nutrition-related factors and revealed that flabbiness was influenced by three factors, namely late meals, a number of meals a day, and energy drinks consumption; increased fatigue was related to two factors, a number of meals a day and late meals; complains about pains "in the heart" correlated with late meals; dizziness, with a number of meals a day; dyspnea, with late meals; heavy legs, with late meals.

In order to help students get acquainted with nutrition habits and tastes of their foreign counterparts, there is 'Unity Food Fest' annual festival organized at Sechenov's Medical University. During the festival students from Malaysia, China, Iran, Kuwait, Bahrain, Tajikistan, Uzbekistan, Kazakhstan, Abkhazia, Russia, and other countries present a great variety of dishes cooked by students themselves. Foreign students tell guests about

existing food preferences and nutrition habits in their national nutrition cultures. The festival is also visited by those who organize meals for students at the University buffets and canteens and they can learn some recipes. This event is a significant factor that can help pursuing healthy lifestyle by foreign students as it stimulates workers at the University canteens and buffets to cook national dishes.

Conclusions. Actual students' nutrition is improper due to its regime being violated as about 20 % students don't have breakfast, about 8 % don't have lunch or dinner, and only half of students actually have three meals a day.

Late meal is a risk factor that can cause alimentary-dependent diseases as 65.7 % questioned students have their last meal a day late in the evening, at 9 p.m. or even later; about 20 % have it after 11 p.m.

Students' body mass is within average standard values both for male and female students but it tends to grow, Rx/y = 1.5 and Rx/y = 1.1 accordingly.

Body mass index is within its standard values both among male and female students. However, its average values in male students are close to the upper limits of its standard value.

We ranked correlation between nutrition-related factors and relevant nosologies and revealed that gastrointestinal diseases were influenced by three major factors, late meals, a number of hot meals a day, and overall number of meals a day; endocrine system diseases were influenced by two factors, late meals and a number of meals a day. Respiratory organs diseases were significantly influenced by a number of meals a day; urogenital system diseases, a number of meals a day; central nervous system diseases, late meals; cardiovascular diseases, late meals.

We also ranked correlations between students' complaints and specific nutrition-related factors and revealed that flabbiness was influenced by three factors, namely late meals, a number of meals a day, and energy drinks consumption; increased fatigue was related to two factors, a number of meals a day and late meals; complains about pains "in the heart" correlated with late meals; dizziness, with a number of meals a day; dyspnea, with late meals; heavy legs, with late meals.

The greatest adverse effects were produced on health by nutrition conditions such as too few meals a day (mostly, two meals a day), late meals, too few hot meals a day, and energy drinks consumption.

Recommendations. To increase a number of hot meals a day, we recommend equipping the University canteens and buffets with microwave ovens so that students could warm up cooked dishes they buy there or bring in lunch boxes from home.

To make cooked dishes more consistent with foreign students' nutrition habits, we recommend making a range of cooked dishes more variable taking into account food preferences and nutrition habits as well as national cultures of foreign students who attend Sechenov's Medical University.

To make students pursue healthy lifestyle and to prevent alimentary-dependent diseases, it is necessary to organize and hold lectures, discussions, and consultations on rational and balanced nutrition for students who attend a medical HEE.

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Conflict of interests. The authors declare there is no any conflict of interests.

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A COMPARATIVE STUDY OF FOOD CONSUMPTION PATTERNS AMONG CHILDREN YOUNGER THAN THREE IN RUSSIA AND VIETNAM

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The publication presents the results of the exposure assessment within the framework of a joint Russian-Vietnamese study aimed at children's health risk assessment associated with the N-nitrosamines contamination in food. People who permanently cared for children aged from six months to three years were questioned in two urbanized areas of Vietnam and Russia – in the cities of Hanoi (n=481) and Perm (n=183). It is shown that the structure of food consumption among children up to three years differs significantly. Children's nutrition in Russia is includes a lot of dry soluble cereals and canned meat/vegetables. The most common product in children's nutrition in Vietnam has no analogues in Russia: it is purchased cereals prepared in specialized stores. Canned foods and dry soluble cereals are also included in the diet of children in Vietnam, but the share of consumers and consumption volumes for them are significantly lower than in Russia. Thus, in the age group of 6–12 months, the share of consumers in Russia is 53 %, in Vietnam – 21 %, the median distribution of average daily consumption in Russia is 152 grams, in Vietnam – 28 grams. Taking into account the share of consumers, as well as the volume and frequency of consumption, we determined the priority products for the children's health risk assessment associated with the N-nitrosamines contamination in food. They are canned meat and dry soluble cereals in Russia; grilled meat and sausages; in Vietnam.

Key words: *children, food, consumption, risk assessment, Russia, Vietnam, children's nutrition, risk assessment, exposure assessment, questioning.*

Introduction. Food-borne diseases have high medical, sanitary and social importance for all modern countries [1]. The WHO Regional Europe Office keeps stressing the importance of achieving higher food products quality and improving nutrition status, especially for vulnerable groups such as elderly people, pregnant women and children [2]. Quality of nutrition provided for children draws special attention of the Regional Bureau programs for East Asia countries, for which nutrition security of infants and young children is one of the top priorities together with immunization and better access to qualified healthcare [3]. Providing adequate nutrition support for children and food-borne diseases prevention are among the top priorities in national policies adopted in different countries,

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for example, of Food quality improvement strategy in Russian Federation till 2030[1] and National strategy of Vietnam in nutrition sector in 2011–2020[2].

One of the main problems related to nutrition for children is food contamination [4]. Consequently, there is a pressing issue whether it is possible to produce contamination-free organic food for children, taking into account the intensive pollution of the environment (soil, water, and air) [5]. Among foreign chemical substances, found in food, nitrates are especially hazardous [6], as they deoxidize to nitrites in human body, thus making a base for carcinogenic N-nitrosamines occurrence [7]. Russian researchers have fixed nitrate contamination of drinking water [8, 9] and others nutrition products (vegetables [10, 11], greenery [12], and fruit [13]). Within joint studies of Russian and Vietnamese researchers N-nitrosamines were detected in canned meat for babies [14] and in baby cereals with and without milk [15].

Assessment of health risks caused by food contamination with hazardous chemical substances, which include N-nitrosamines, allows not only to define the quantitative measurement of food contamination but also to characterize the different groups of products consumed by the population.

The purpose of the study was to comparatively examine actual food consumption by children younger than 3 in Russia and Vietnam in order to assess health risks associated with influence exerted by contaminated food on children's health.

Data and methods. The object of the study was child population living on urbanized territories in Russia and Vietnam. In Vietnam the study was organized in Hanoi (the capital city, huge financial and industrial centre with its population being equal to 7.7 million people), In Russia it was organized in Perm (huge industrial centre with its population being equal to 1 million people). Necessary data were collected via questioning conducted among people who took care of children aged from 6 months to 3 years. At the first stage (summer – autumn 2018) the questioning was organized in Perm and analysis procedures and tools were tested. At the second stage (winter – spring 2019). after the procedures and tools had been corrected and adapted, the questioning was organized in Hanoi.

In Perm the questioning was organized in six random polyclinics for children in six districts of the city (except the Lenin district, due to low population number living there and specific low-rise housing). In these polyclinics random pediatricians gave out questionnaires to adult visitors with children younger than 3. Total sampling included 183 people (children aged from 6 months to 3 years accounted for 35 %; children aged 13–24 months, 36 %; children aged 25–36 months, 29 %; 49 % children were boys, and 51 %, girls).

In Hanoi, the questioning was organized in child health and nutrition centers in two districts of the city (Dong Da and Bac Tu Liem) and two counties (Dan Phuong and Thanh Tri), which were parts of Hanoi in order to provide a representative population sampling according to social and economic characteristics. Total sampling included 481 people (children aged from 6 months to 3 years accounted for 30 %; children aged 13–24 months, 46 %; children aged 25–36 months, 24 %; 51 % children were boys, and 49 %, girls).

Research tools included two general sets of questions: a) one concerning eating meat, meat and vegetable, vegetable canned baby food and baby cereals with milk (food products with detected N-nitrosamines contamination [14, 15]), b) demographical questions (sex and age of a child, social and economic status and members of the family). Questionnaires in

[1] Food quality improvement strategy in Russian Federation till 2030 year. Approved by the Order of Russian Federation Government dated of 29 June 2016 No. 1364-r. Available at: http://www.garant.ru/products/ipo/prime/doc/71335844/ (01.12.2019).

[2] Food quality improvement strategy in Russian Federation till 2030 year. Approved by the Order of Russian Federation Government dated of 29 June 2016 No. 1364-r. Available at: http://www.garant.ru/products/ipo/prime/doc/71335844/ (01.12.2019).

Vietnam included questions aimed at estimating consumption of products that were typical for the country. Those products were cooked cereals (fresh cereals), which could be bought in specific retail outlets, grilled sausages and meat. The reason for these products being included into the questionnaire was a hypothesis that they might include N-nitrosamines.

Questioning results were processed electronically with SPSS Statistics 22 software package (descriptive statistics, central tendencies measures definition, and correlation analysis).

Results. The structure of food consumption, which is of interest as regards assessing risks associated with the impacts exerted by N-nitrosamines on children's health in Russia and Vietnam, has significant differences already in the youngest age group. Among Russian children aged from 6 to 12 months, 61 % have experience in consuming canned meat and vegetable products, while in Vietnam only 36 % consumers in this age group eat such products. At the same time, fresh cooked cereals (both cereals without admixtures or ones with the beef, pork, turkey, fish, crab meat and shrimp) are highly popular in Vietnam; from 90 % to 98 % of Vietnamese children in the examined age groups and 95 % in the overall sampling have eaten this type of product. Fresh cereals cooked in retail outlets have no analogues in Russia (the closest type of product is cereals that are cooked at home or at catering companies, but in Russia meat and poultry are usually added only to buckwheat cereal, and fish and seafood are not added at all).

The average daily consumption of fresh cooked cereals in Vietnam is quite large – the median of distribution among children aged 6–12 months was 92.8 grams; among those aged 13–24 months, 200 grams; among children aged 25–36 months, 171.4 grams. The consumption volume of this product among boys aged from 6 to 12 months was significantly higher than among girls of the same age (Cramer's V = 0.211 at p 00.05); the proportion of consumers with an average daily volume being equal to 300 grams or more among boys aged 6–12 months was by 10 % higher than among girls of the same age. The most popular cereals were beef (from 55 % to 78 % consumers in the examined age subgroups) and turkey (from 58 % to 80 % consumers).

Differences in food consumption patterns in Russia and Vietnam were also observed concerning dry instant cereals as consumers of this product among Russians in the age group from 6 to 12 months accounted for 53 %, and among Vietnamese only 21 % (Table 1).

As Table 1 shows, the proportion of children consuming canned industrially manufactured products is gradually growing in Vietnam (up to 67 % among children aged 25–36 months), while in Russia it remains almost permanent among children aged 6–24 months, and then increases to 75.5 % for the oldest children aged 25–36 months. At the same time, a significant part of canned food consumed in Russia is canned meat (in the age group of 6–12 months, 88 % of consumers preferred one-component canned meat), while in Vietnam

Table 1

A share of consumers eating various products in Russia and Vietnam
(as a percentage of all respondents in group)

Food product type	6–12 months		13–24 months		25–36 months	
	Russia	Vietnam	Russia	Vietnam	Russia	Vietnam
Grilled meat	No data	10.5	No data	52.9	No data	74.1
Sausages	No data	11.9	No data	61.5	No data	87.9
Canned food	60.7	35.7	54.1	57.5	75.5	67.2
Dry instant cereals	53.0	21.0	40.0	44.8	26.0	45.7
Fresh cereals cooked in retail outlets	No data	90.9	No data	95.0	No data	98.3

Table 2

The average daily consumption of various food products in Russia and Vietnam (distribution median)

Food product type	6–12 months		13–24 months		25–36 months	
	Russia	Vietnam	Russia	Vietnam	Russia	Vietnam
Grilled meat	No data	21.4	No data	23.6	No data	35.7
Sausages	No data	28.5	No data	17.1	No data	28.6
Canned food	50.1	14.2	104	21.4	58.0	15.7
Dry instant cereals	152.4	28.5	200.0	50.0	280.0	78.5
Freshly cooked cereals in store production	No data	92.8	No data	200.0	No data	171.4

this type of canned food is absolutely not popular as all consumers of canned food consumed meat and vegetable or multi- and one-component vegetable canned food.

Children in Russia eat less dry instant cereals with aging and the share of consumers is gradually reducing to 26 % in the 25–36 months subgroup, and in Vietnam, this share rises to 46 % for the elder group, while it remains permanent in the previous two subgroups.

The average daily consumption of canned food and instant cereals in the studied samples also varies significantly. Thus, in the 25–36 months subgroup, where the share of canned food consumers is the largest in both countries, the distribution median of the average daily consumption of canned food was 58 grams in Russia and only 15.7 grams in Vietnam. The median distribution of the average daily consumption of dry instant cereals in the middle age group of 13–24 months was 200 grams in Russia and only 50 grams in Vietnam (Table 2).

Significant differences are observed in the average daily consumption of dry instant cereals by 13–24 months old boys and girls in Vietnam (Cramer's $V = 0.258$ at $p < 0.05$).

Starting from 13 months sausages and grilled meat are actively included into nutrition provided for Vietnamese children. So, 61.5 % of 13–24 months old children and 88 % of 25–36 months old children have experience in eating sausages, the share of grilled meat consumers in these groups amounts to 53 % and 74 %, respectively. The average daily consumption of grilled meat increases with aging: the median value among children aged 6–12 months was 21.4 grams; 13–24 months, 23.6 grams; 25–36 months, 35.7 grams. The average daily consumption of sausages was the same in the youngest and oldest age groups (distribution medians were 28.5 and 28.6 grams, respectively), and it was significantly lower in the 13–24 months group (17.1 grams).

Discussion. The structure of nutrition provided for children younger than three years in Russia and Vietnam is different due to economic, historical and cultural reasons. The low popularity of canned baby products in Vietnam is due to a rather small number of local producers (two brands against four in Russia), the high cost of imported products in relation to the average per capita income in the country (it results in its low physical availability, poor assortment offered by retail outlets and supermarkets), as well as due to preference for more high-calorie meat products. As a 2013 study in the Dong Da area (central Hanoi, also included in the survey sampling) showed, parents in Vietnam often implement «intensive feeding practices» for their preschool children, wanting their children to eat more high-calorie foods. This behavior pattern may be associated with historical experience of surviving starvation during wars, when children were the most vulnerable group [16].

The intensive inclusion of the products that are not recommended for preschool children (sausages, grilled products, or sweets) into children's ration has been noted in several other studies in Vietnam. Thus, a survey conducted in five urban areas of Central and South Vietnam revealed a high level of consumption sweets by children aged from two to

five years [17]. However, misbalance in children's ration among children aged from one to three years is also typical for Russia. According to the data provided by the Russian Pediatricians Union, 56 % children began to receive confectionery products and "not-for children" products (snacks, mayonnaise, or semi-finished products) when they were about two years old [18]. The data of the RAMS Institute of Nutrition indicate that there are sausages in ration offered to 23.4 % of Russian children aged 1–2 years [19].

The tendency among Russian parents to use ready meals for children (canned food, dry instant cereal) detected during the study is associated with a desire to reduce an amount of time spent on cooking. A similar behavior is observed when analyzing the results obtained via examining the Vietnamese sampling as fresh cooked cereals produced by retail outlets, which are popular in Vietnam, are an alternative option of «fast food» and similarly help saving time spent on cooking.

Conclusions. The study allowed us to draw a number of conclusions regarding the characteristics of food consumption by children younger than three in Russia and Vietnam:

1. Children in Russia and in Vietnam eat canned baby food. Children in Russia start eating meat and vegetable canned food earlier. In two of the three age children subgroups, the proportion of canned baby food consumers in Russia is higher than in Vietnam. The difference is especially apparent in the age group of 6–12 months: in Russia 61 % children in this age group consume this type of products, and in Vietnam their share is almost two times lower (36 %);

2. The average daily consumption of canned baby food in Russia is higher than in Vietnam. While in all age groups in Vietnam children receive no more than 30 grams of canned food per day, in Russia the average daily consumption is 88 grams (arithmetic average for the sampling as a whole);

3. Dry instant cereals are a typical choice for the first supplemental feeding for 6 to 12 months old children in Russia. Over half (53 %) of children in the youngest age group received this food product. In Vietnam, the proportion of consumers who eat dry instant cereals amounted to months 21 % among children aged 6–12. With aging, the share of product consumers in Russia decreases (to 26 % in the group of children 25–36 months old). In Vietnam, in groups of 12–24 months and 25–36 months, the proportion of children who ate dry instant cereals is approximately 44–45 %;

4. Average daily consumption of instant cereals by children in Russia is higher than in Vietnam in all age groups. The differences are especially apparent in the youngest group (6–12 months), 191 grams in Russia against 42 grams in Vietnam (arithmetic mean distributions). In general, instant cereals are the main (daily) food product for children in Russia, while in Vietnam this type of product is not included in children's ration, the frequency of its consumption is low;

5. Grilled sausages and meat (products potentially contaminated with N-nitrosamines) are actively introduced into children's ration in Vietnam from the age of 12 months. In a 12–24 months subgroup, sausages are consumed by 61 % children, and grilled meat, by 53 %. In the age group of 25–36 months, the proportion of children who have eaten these types of products increases to 88 % and 74 %, respectively;

6. The priority products for research in the framework of evaluation the risk associated with the impact of chemical contamination of food products with N-nitrosamines on the health of children under three years are: meat and vegetable canned food and dry instant cereals in Russia, grilled meat and sausages in Vietnam;

7. When performing studies to evaluate health risks caused by chemical contamination of food products, including food for young children, estimation of their actual consumption is a key condition for reducing exposure estimation uncertainty.

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RISK FACTORS CAUSING HEALTH DISORDERS AMONG WORKERS INVOLVED IN OIL EXTRACTION AND PERFORMING THEIR WORKING TASKS OUTDOORS DURING A COLD SEASON

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The research focuses on a vital issue related to preserving health of workers who perform their working tasks outdoors in regions with cold climate.

Our research goal was to examine influence exerted by working conditions and working experience length on prevalence of chronic diseases and other health disorders among workers who performed their working tasks outdoors during a cold season.

We accomplished a cross (one-moment) epidemiologic study aimed at assessing adverse impacts exerted by weather and climatic factors on workers who performed their working tasks on open grounds in regions with cold climate. We conducted hygienic assessment of working conditions for 1.647 workers employed at oil-extracting enterprise in Nizhnevartovsk and analyzed results obtained during their regular medical check-ups.

We analyzed average number of diseases per 1 worker; it varied from (0.45 ± 0.06) among workers dealing with electrogas welding to (0.27 ± 0.022) among compressor unit operators. Each additional 5 years of working experience resulted in an ascending trend for a number of detected diseases per 1 worker (p = 0.0015).

We also revealed that workers who maintained oil-extracting machinery ran the greatest health risks as they had to spend the greatest amount of time outdoors (on average, 27 hours out of 40 hours per 1 working week) during a cold season. Besides, our research showed that exposure to cold potentiated adverse impacts exerted by other occupation factors on workers' health. Thus, given the same amount of time spent outdoors during a cold season for different occupational groups, welders ran the greatest risks of circulatory system diseases (AR = 2.0), ear and mastoid diseases (AR = 5.0), digestive organs diseases (AR = 2.2) due to the air at their working places being contaminated with welding aerosol.

When working tasks are performed outdoors in regions with cold climate, it leads to elevated risks of chronic health disorders that occur due to long-term occupational exposure to uncontrollable meteorological factors and simultaneous air contamination with welding aerosols.

Key words: *working conditions, oil-industry workers, adverse working conditions, work on open grounds, cold, workers' health, cold injuries, cold stress, cold and carbohydrate metabolism.*

Oil extraction plays the leading role in the economy of northern regions in West Siberia. A significant number of employable people work in the branch. Technologies that are applied at oil-extracting enterprises are developing rapidly; still, s lot of workers employed at such enterprises in West Siberia work in adverse working conditions. A specific weight of workers who were employed at fuel and energy resources extraction (including oil and gas) and performed their work tasks in adverse or hazardous conditions increased from 44.1 % in 2012 to 54.7 % in 2018 [1]. There are several risk factors that cause general and occupational diseases: they are overall and local vibration, noise, adverse chemicals and aerosols, physical strain, work in forced and uncomfortable postures, as well

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as some other factors related to working environment or work processes. And we should note that these adverse occupational factors exert their influence in specific natural and climatic conditions existing in the Polar Regions. Cold season is very long there and air temperatures are low [2–4]. An enterprise which we examined in the present work was located in an area where average long-term temperature was equal to –24,4 °C during three coldest months, and snow cover didn't melt for 200–210 days[1]. In 2018 workers employed at mining and extracting enterprises had the greatest specific weight of occupational diseases, 47.59 % of all the first registered morbidity cases. In 2018 occupational morbidity per 10 thousand workers registered at mining enterprises held the first rank place among all types of economic activities; it was equal to 25.01[2].

We examined impacts exerted by working conditions existing on open-air facilities in the Polar Regions on health of workers employed by an oil-extracting company; those workers had to spend a lot of time outdoors during their working week.

Our research goal was to examine influence exerted by cold factor on workers employed by an oil-extracting enterprise when they had to work outdoors in cold season and were exposed to adverse occupational factors related to specific working environment.

Data and methods. We examined influence exerted by working conditions in cold season on health of workers employed by an oil-extracting enterprise depending on a period of time they had to spend outdoors during a working shift. We analyzed structure and intensity of effects produced by adverse occupational factors and results obtained during periodical medical check-ups of 1,674 workers employed by "Samotlorneftegaz" public company (located in Nizhnevartovsk, the Khanty-Mansi Autonomous Area). Basing on a performed time study, we divided all workers into three groups with different amount of time spent outdoors in cold season and taking into account exposure to adverse occupational factors. The first group included 344 people (about 30 % of a working shift spent outdoors); the second one was made up of 647 people (about 50 % of a working shift spent outdoors); there were 689 people in the third group (60–75 % of a working shift spent outdoors).

We assessed impacts exerted by working experience on workers' health after all the examined workers had been divided into four groups: with working experience not exceeding 5 years (n = 796); 6–10 years (n = 238); 11–15 years (n = 201); and longer than 16–20 years (n = 441). When assessing working conditions, we took into account labor hardness and intensity, microclimate at workplaces, and exposure to physical and chemical factors [5–8]. We performed statistical analysis with Statistica 12.0 for Windows; we determined Student's t-test for independent samplings, goodness-of-fit test χ^2, attributable risk (AR), and Pearson's linear correlation quotient (r). Numeric data were given as a mean value and its standard error ($M \pm m$). Discrepancies were considered to be significant at $p < 0.05$. Data on working conditions were assessed as per reports of special assessment of working conditions accomplished in 2016 at workplaces where workers from the selected occupational groups performed their work tasks as well as basing on industrial control protocols issued in 2010–2018. Prevalence of diseases among workers employed by "Samotlorneftegaz" public company was assessed basing on results of periodical medical check-ups collected in 2017–2018 (Appendix No. 1).

Results and discussion. We assessed working conditions and revealed that noise and

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overall vibration at them exceeded acceptable levels, and certain adverse chemicals were detected in working area air in quantities higher than hygienic standards. Overall vibration exceeded hygienic standards (working conditions belonging to 3.1 hazard category) for operators who handled pumping units (PU) and compressor units (CU) (workers from the 1st group); oil-extracting devices handled by those workers included units for pumping working substance into a bed, vacuum compressors, units for pumping trapped oil, deposit water, outer drainage, storm drainage, and dehydrating and desalting units (DDU). Adverse chemical factors included substances belonging to 1–4 hazard categories (oil and its components, dihydrosulfate, sulfur dioxide, carbon oxide, nitrogen oxide, and ozone). Maximum manganese concentrations that existed at workplaces of repairmen were up to 1.17 times higher than MPC (working conditions belonging to 3.1 hazard category) with maximum single MPC being equal to 0.6 mg/m^3. Electro-gas welders were also exposed to increased manganese concentrations that exceeded MPC. When performing their work tasks, welders were exposed to ozone concentrations that were 1.13 times higher than MPC. Technological processes applied in oil extraction involved working in forced and uncomfortable postures and a worker had to move a lot during a working shift sometimes covering a distance equal to 8.4 km. Overall, working conditions for workers from the 1st group were the most hazardous (3.3 category) than for those from the 2nd and the 3rd ones (3.2 category) (Table 1).

We accomplished a time study of work processes in the examined occupational groups basing on observation checklists or working day profiles; it allowed us to determine that workers from the 3rd group had to spend the longest period of time outdoors or in cold rooms during a 40-hour working week among all the examined groups (27 ± 0.23 hours).

We analyzed results obtained via periodical medical examinations of workers from the selected occupational groups in 2017–2018. There were no authentic differences among workers as per their age; we revealed a distinct correlation between an average number of detected diseases per one worker and an amount of time workers had to spend outdoors in cold season during a 40-hour working week. Thus, there was a strong direct correlation between periods of time spent outdoors by workers from the 3rd group and a number of diseases per one worker (0.37 ± 0.02); it was the strongest among all the examined groups ($r = 0.74$). Also, a fraction of practically healthy people was authentically lower (70.5 %) than in the 2nd group ($\chi^2 = 11.422$; $p = <0001$) (Table 2).

We examined morbidity among workers from the examined occupational groups as per their age and sex depending on their working experience, a number of diseases per one worker, and average amount of time spent outdoors in cold season.

Circulatory system diseases were the most frequently detected in all three examined

Table 1

Assessment of working conditions for workers from the examined occupational groups employed at an oil-extracting enterprise

Parameter	Group 1 CU operators and PU operators	Group 2 DDU operators	Group 3 Repairmen / Elector-gas welders
Chemical factors	2.0	2.0	3.1
Noise	3.3	3.2	3.2
Overall vibration	3.1	2.0	2.0
Labor hardness	2.0	3.1	3.1
Working conditions category	3.3	3.2	3.2

Table 2

Sex and age characteristics of the examined occupational groups depending on work experience, a number of diseases per one worker, and average amount of time spent outdoor in cold season

Parameter	Group 1 CU operators and PU operators	Group 2 DDU operators	Group 3 Repairmen / Elector-gas welders	Total
Sex, men	299 (87 %)	352 (54.92 %)	688 (99.85 %)	1,339 (80 %)
Sex, women	45 (13 %)	289 (45.08 %)	1 (0.15 %)	335 (20 %)
Average age, years	42.89 ± 0.55	40.16 ± 0.4	40.42 ± 0.41	40.83 ± 0.26
Average work experience	10.32 ± 0.37	9.88 ± 0.27	7.65 ± 0.29	9.05 ± 0.16
AS number of practically healthy workers	252 (73.3 %)	504 (78.6 %)	486 (70.5 %)	1,242 (74.19 %)
An average number of diseases per one workers	0.33 ± 0.034	0.27 ± 0.022	0.37 ± 0.02	0.32 ± 0.014
Average amount of time spent outdoors in cold season during a 40-hour working week	14.1 ± 0.013	24.5 ± 0.07	27 ± 0.23	23.4 ± 0.15

groups and held the 1st rank place accounting for 24.8 %; the 2nd rank place belonged to endocrine system diseases (18 %). The 3rd rank place was taken by symptoms, signs, and deviations from physiological standards revealed via clinical and laboratory research, namely, deviations in tolerance to dextrose (17.4 %). There were no statistically significant discrepancies between three groups regarding these three rank places. Ear and mastoid diseases accounted for 15.6 % in morbidity structure in all three groups of workers employed by "Samotlorneftegaz" public company and it was the 4th rank place.

Overall, prevalence of diseases was the same in all three occupational groups, the 1st rank place taken by cardiovascular diseases; the 2nd rank place in the 1st and 2nd group taken by endocrine diseases, and by ear and mastoid diseases in the 3rd group; the 3rd rank place belonged to deviations in tolerance to dextrose in all three occupational groups.

Prevalence of ear and mastoid diseases per 100 workers was 1.875 and 2.8 times authentically higher in the 3rd group that in the 1st and 2nd one accordingly ($\chi^2 = 17.61$, $df = 2$, $p < 0.001$). Digestive organs diseases held the 5th rank place and their prevalence in the 3rd group (4.4 %) was authentically higher than in the 1st one (3.8 %) and in the 2nd one (1.2 %) accordingly ($\chi^2 = 11.633$, $df = 2$, $p = 0.003$).

We revealed substantial discrepancies in prevalence of blood and blood-making organs diseases between the examined groups; thus, morbidity in the 2nd group (8.2 %) was authentically higher than in the 1st (6.9 %) and the 3rd one (1.6 %) accordingly ($\chi^2 = 7.274$, $df = 2$, $p = 0{,}027$).

Some chronic diseases tended to prevail in workers from the 3rd occupational group and were the most frequent among them, in particular, circulatory organs diseases, ear and mastoid diseases, digestive organs diseases, skin and subcutaneous tissues diseases, as well as symptoms, signs, and deviations from physiological standards revealed via clinical and laboratory research. Those diseases accounted for the biggest part of all diseases detected among workers from the examined occupational groups (Table 3).

We calculated attributable risk and revealed that influence exerted by longer overall exposure to cold during a working week was accompanied with excessive morbidity[3] with

[3] Metody obrabotki informatsii [Information processing techniques]. In: A.G. Sysa, R.A. Dudinskaya. Minsk, IVTs Minfina Publ., 2018, 20 p.

Table 3

Prevalence of diseases among workers employed at oil-extracting enterprise that had to work in different working conditions (number of cases per 100 workers) as per results of periodical medical examinations

Disease category as per ICD-10	Group 1	Group 2	Group 3	Total
Diseases of the circulatory system	8.4 ± 1.49	6.7 ± 0.98	8.7 ± 1.07	7.9 ± 0.66
Endocrine, nutritional, and metabolic diseases	6.1 ± 0.52	6.4 ± 0.97	4.9 ± 0.82	5.7 ± 0.57
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	5.5 ± 1.2	4.2 ± 0.79	6.8 ± 0.96	5.5 ± 0.55
Diseases of the ear and mastoid process	4 ± 1.06	2.5 ± 0.55	7.5 ± 1	4.9 ± 0.53
Diseases of the digestive system	3.8 ± 1.03	1.2 ± 0.43	4.4 ± 0.78	3 ± 0.42
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	2.3 ± 0.8	2.2 ± 0.58	0.6 ± 0.29	1.6 ± 0.3
Diseases of the genitourinary system	2 ± 0.75	1.6 ± 0.49	0.9 ± 0.36	1.4 ± 0.29
Diseases of the musculoskeletal system	1.5 ± 0.65	0.8 ± 0.36	1 ± 0.38	1 ± 0.37
Diseases of the skin and subcutaneous tissue	0	0.3 ± 0.22	0.7 ± 0.32	0.4 ± 0.15
Other diseases	0	0.5 ± 0.28	0.3 ± 0.2	0.3 ± 0.13

ear and mastoid diseases (AR = 3) as well as more frequent deviations in tolerance to dextrose (AR = 1.3). Therefore, excess annual frequency of ear and mastoid diseases amounted to 2.4 cases per 100 workers in the occupational group who had to spend the longest period of time outdoors. Excess annual frequency of deviations in tolerance to dextrose amounted to 1 case per 100 workers in the occupational group who had to spend the longest period of time outdoors.

Long periods of time spent outdoors in cold season combined with exposure to adverse chemicals detected in working area air lead to a substantial increase in morbidity with circulatory system diseases (AR = 2.0), ear and mastoid diseases (AR = 5.0), digestive organs diseases (AR = 2.2) as well as to an increase in number of workers with deviations in tolerance to dextrose (AR = 2.6). Discrepancies in morbidity detected among exposed and non-exposed workers as per overall vibration were determined by combined exposure to cold and overall vibration which substantially increased prevalence of digestive organs diseases (AR = 2.6), circulatory system diseases (AR = 1.7), and ear and mastoid diseases (AR = 1.5).

We examined influence exerted by work experience on health of workers employed at oil extraction and revealed that a number of practically healthy people was the highest among those with their work experience not exceeding 5 years (76.7 %) against workers with longer work experience. Circulatory system diseases prevailed among detected health disorders including primary hypertension with predominant damage to the heart with (congestive) heart failure (Table 4). Still, we didn't detect any growth in morbidity with circulatory system diseases among workers with longer work experience and there were no statistically significant discrepancies as per this parameter between groups of workers with different work experience. It is probably due to a so called "healthy worker" effect when there is a trend for a decrease in number of workers who work in harmful working conditions and suffer from chronic diseases[4] [9, 10]. As a rule, nosologies that predominantly occur at an older age, including cardiovascular pathologies, characterize "healthy worker" effect during later periods of a person's work experience.

[4] Rossiiskaya entsiklopediya po meditsine truda [The Russian encyclopedia on occupational medicine]. *Rossiiskaya akademiya meditsinskikh nauk*. In: N.F. Izmerov. Moscow, Meditsina Publ., 2005, 656 p. (in Russian).

Table 4

Prevalence of diseases among workers from the examined occupational groups as per different work experience

Clinical parameters	Work experience /					
	<5 years (n = 866)	6–10 years (n = 212)	11–15 years (n = 164)	16–20 years (n = 432)	> 20 years (n = 0)	Total (n = 1,674)
Prevalence of diseases per 100 people	27.7	22.6	34.15	43.75	0	31.8
Number of diseases in 1 worker, cases	0.29 ± 0.019	0.24 ± 0.037	0.34 ± 0.049	0.44 ± 0.03	0	0.32 ± 0.014
Practically healthy people, %	76.7	80.7	73.2	66.4	0	1,244/74.3
Age, years	37.13 ± 0.35	37.63 ± 0.59	42.31 ± 0.66	49.26 ± 0.32	0	40.83 ± 0.26
Diseases category as per ICD-10 / % in morbidity structure						
Diseases of the circulatory system	25.0 ± 1.5	18.7 ± 2.7	25 ± 3.4	25.9 ± 2.1	0	24.8 ± 1.05
Endocrine, nutritional, and metabolic diseases	14.2 ± 1.2	25.0 ± 2.9	23.2 ± 3.2	19.6 ± 1.9	0	18 ± 0.9
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	15.4 ± 1.2	16.7 ± 2.6	19.6 ± 3	19.6 ± 1.9	0	17.4 ± 0.9
Diseases of the ear and mastoid process	14.6 ± 1.2	14.6 ± 2.4	23.2 ± 3.3	14.8 ± 1.7	0	15.6 ± 0.9
Diseases of the digestive system	15.8 ± 1.2	10.4 ± 2	0	4.2 ± 0.96	0	9.6 ± 0.7
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	4.2 ± 0.7	4.2 ± 1.4	3.6 ± 1.45	6.3 ± 1.2	0	4.9 ± 0.5
Diseases of the genitourinary system	4.6 ± 0.7	6.26 ± 1.7	0	4.8 ± 1.03	0	4.3 ± 0.5
Diseases of the musculoskeletal system	3.3 ± 0.6	1.2 ± 0.75	1.8 ± 1.04	3.7 ± 0.9	0	3.2 ± 0.4
Diseases of the skin and subcutaneous tissue	1.7 ± 0.4	0	3.6 ± 1.45	0.5 ± 0.3	0	1.3 ± 0.28
Other diseases	1,25 ± 0,38	1,2 ± 0,75	0	0,5 ± 0,3	0	0,9 ± 0,23

We detected statistically significant increase in prevalence of all the diseases per 100 workers among those with their work experience being equal to 16–20 years against workers with short work experience (χ^2 = 15.806, df = 1, p < 0.001). We also detected an authentic fall in number of people without any diagnosed diseases / practically healthy people among workers with 16–20 years of work experience against workers with short work experience (χ^2 = 15.806, df = 1, p < 0.001).

As work experience grew, there appeared a growing trend in average number of detected diseases per 1 worker (p = 0.0015). Endocrine diseases took the 1st rank place in workers with 6–10 years of work experience, and their share increased considerably from 14.2 % to 25 %; however, as work experience grew by each 5 years, there was a substantial decrease in morbidity with such diseases (p = 0.007). Prevalence of symptoms, signs and abnormal clinical and laboratory findings (deviations in tolerance to dextrose) persistently took the 3rd rank place in morbidity among workers and as their work experience reached 11–15 years it leveled off (19.6 %). According to scientific research results there is a statistically significant increase in dextrose concentration in blood under exposure to extreme cold [11, 12]. It can be caused by substantial activation of

thermogenesis and peculiarities of nutrition in cold season that result in elevated concentrations of glycation end products in tissues and increase risks of II type pancreatic diabetes.

As work experience reached 11–15 years, there was a significant growth in prevalence of ear and mastoid diseases, from 14.6 % to 23.2 % ($p = 0.028$) (Table 4).

We detected a weak direct correlation between work experience and an average number of diseases ($r = +0.091$). There was also a correlation between work experience and prevalence of the most frequent diseases that took the 1st, 2nd, and 3rd rank places such as cardiovascular diseases ($r = +0.0564$), and endocrine system diseases ($r = +0.0691$), as well as deviations in tolerance to dextrose ($r = +0.08$) (a correlation is direct and weak).

Diseases in the digestive organs tended to become less prevalent as work experience grew longer. Circulatory diseases were at the same level regardless of work experience becoming longer. As for other diseases, such as endocrine system diseases, ear and mastoid diseases, blood and blood-making organs diseases, and musculoskeletal system diseases, there was a stable growth in their prevalence, although not the same for all the nosologies. Prevalence of arterial hypertension with predominant damage to heart and (congestive) heart failure grew by 1.4 times against its initial level when work experience reached 16–20 years [13, 14]; insulin-independent pancreatic diabetes, by 2.75 times; hypercholesterolemia, by 1.8 times; deviations in tolerance to dextrose, by 2.2 times; iron-deficiency anemia, 3.5 times; two-sided conductive deafness, by 2 times. When work experience exceeded 20 years, prevalence of insulin-independent pancreatic diabetes grew by 3 times; iron-deficiency anemia, by 4 times; prevalence of two-sided conductive deafness amounted to 7 people per 100 workers.

Conclusions

1. Our research on influence exerted by working conditions on workers' health revealed that a period of time spent outdoors in cold season was a significant risk factor that could cause health disorders among workers from the 3rd occupational group employed by "Samotlorneftegaz" public company.

2. Such health disorders as ear and mastoid diseases as well as deviations in tolerance to dextrose were the most frequent among workers who had to spend the longest period of time outdoors or in cold rooms in cold season; prevalence of those disorders was the greatest among them.

3. There was a growth in prevalence of ear and mastoid diseases among workers who repaired and maintained drilling and oil-extracting equipment such as repairmen and electro-gas welders; this growth was due to long-term exposure to adverse uncontrollable occupational factors such as cold and simultaneous contamination with welding-produced aerosols.

4. Non-occupational two-sided conductive hearing loss was the most prevailing pathology among ear and mastoid diseases; it was widely spread among workers who had to spend the longest period of time outdoors. This pathology was usually caused by complications after acute otitis media or by chronic otitis media [15, 16].

5. High frequency of tolerance to dextrose deviating from physiological standards among workers who had to perform their work tasks outdoors in cold season was associated with a growth in insulin-independent pancreatic diabetes occurring in workers with longer work experience; it grew by 3 times when work experience exceeded 16–20 years. Disorders in tolerance to dextrose are compensated when adverse cold factor is removed and are corrected by healthy nutrition in case test results deviate from physiological standards.

6. When workers are simultaneously exposed to cold weather and contamination of working area air with adverse chemicals and welding-produced aerosols, it leads to a significant increase in prevalence of circulatory diseases (AR = 2), ear and mastoid diseases (AR = 5), and digestive organs diseases (AR = 2.2), and it is consistent with results of several previous works [17–20].

Therefore, our research results indicate it is necessary to develop a specific recovery and

health-improving program for workers from senior age groups who have to spend a lot of time outdoors in cold season in areas with cold climate. This program should be oriented at primary and secondary prevention of health disorders that are very likely to occur among workers from such occupational groups; first of all, it should cover II type pancreatic diabetes, ear and mastoid diseases, and circulatory diseases. Also it is necessary to organize groups of workers who run high occupational risks of cold-induced diseases and therefore should undergo regular medical check-ups.

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MORBIDITY WITH ARTERIAL HYPERTENSION AMONG WORKERS INVOLVED IN NUCLEAR WEAPONRY UTILIZATION

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Cardiovascular diseases remain a basic socially significant issue in most countries all over the world. Our research goal was to comparatively assess morbidity with arterial hypertension (ICD-9 codes 401–404 or ICD-10 codes I.10 –I.14) among workers involved in nuclear weaponry utilization. We examined an occupational cohort that included workers employed at chemical-metallurgical production of "Mayak" Production Association (PA). They were all employed in 1949–2014 and observed by medical personnel up to December 31, 2017; overall, the cohort included 10,908 people. We analyzed morbidity parameters taking into account both radiation factors (external gamma-irradiation and internal alpha-irradiation caused by incorporated plutonium) and basic non-radiation ones. Standardization was accomplished indirectly with an internal standard. Morbidity was calculated with medical statistics tools per 1,000 workers. We also assessed excess relative risk per one dose (ERR/Gy). As a result, we revealed that on December 31, 2017 2,270 arterial hypertension cases were registered in the examined cohort that included workers employed at "Mayak" PA who were involved in utilizing nuclear weaponry. We showed that standardized morbidity with arterial hypertension among workers employed at "Mayak" PA and involved in utilizing nuclear weaponry statistically significantly depended on non-radiation factors (sex, age, smoking status, attitude towards alcohol intake, body mass index, and pancreatic diabetes) and didn't depend on total dose of external gamma-irradiation and internal alpha-irradiation absorbed in the liver.

Key words: *arterial hypertension, morbidity, external gamma-irradiation, internal alpha-irradiation, occupational irradiation, cohort study, "Mayak" PA, nuclear weaponry utilization.*

Cardiovascular diseases (CVD) remain a most socially significant problem in many countries all over the world. In particular, in Europe 4 million people annually die due to CVD; 1 million out of them are deaths in Russia [1]. In 2011 in Russia CVD-related mortality accounted for 55.9 % out of overall mortality while in Europe the figure was 47 % [2].

Circulatory system diseases (CSD) cause more than 1/3 deaths among employable population, and mortality among men is higher than among women. It is 4.7 times higher for CSD as a whole; 7.2 times, for ischemic heart disease (IHD); 9.1, for cardiac infarction; and 3.4 times, for cerebrovascular diseases [3]. Despite a decrease in CVD-caused mortality that has occurred in developed countries and over the last few years in Russia also, the situation in the country remains serious as it is highlighted in multiple domestic and foreign research works [1, 4, 5].

Arterial hypertension (AH) is a leading risk factor causing cardiovascular diseases (cardiac infarction, stroke, IHD, and chronic heart failure), cerebrovascular diseases (ischemic or hemorrhagic stroke, transient ischemic attack), and renal diseases (chronic renal disease).

AH prevalence in the world is different in different countries and varies from 27 % in

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Iran to 67 % in Poland; in developed countries it is approximately 41 % [6, 7]. In the Russian Federation AH prevalence also amounts to approximately 42 % [8].

Our research goal was to assess impacts exerted by radiation and non-radiation factors on morbidity with AH among workers employed at Mayak PA who took part in nuclear weaponry (NW) utilization.

Data and methods. Mayak Production Association or Mayak PA was the first atomic enterprise in the former USSR. Long-term chronic irradiation has always been the major occupational hazardous factor for workers employed at it. We selected a cohort that included workers employed at a chemical and metallurgic plant of the whole PA who started their work in 1949–2004 and took part in NW utilization. To do that, we used the Mayak PA medical and dosimetric register that contained data on each worker and was created and kept by the Radiation Epidemiology Laboratory of the Southern Urals Institute for Biophysics [9].

We observed workers included into the cohort for a period that started from their employment date and finished on either of the following days: a day when a circulatory system disease was diagnosed; a day of a worker's death; December 31, 2017 for those who were alive on that day; a date for which "the last medical data" were available for those workers who had moved from Ozersk to other places, or in case we couldn't find out whether a person was dead or alive on December 31, 2017.

There were 10,908 people in the examined cohort, 27.6 % of them were females. We determined whether a person was dead or alive in 96.6 % cases; 49.1 % of them were dead, and 50.9 %, alive. A share of women accounted for 54.6 % on the date when the observation finished. All the workers in the examined cohort had been exposed to occupational long-term irradiation (external gamma-irradiation and/or internal alpha-irradiation). As of state on December 31, 2017, data on diseases which workers in the examined cohort had suffered from during the overall observation period were available for 5,877 (94.65 %) men and 1,764 (94.385) women.

Within our research, we analyzed morbidity with AH among workers employed at Mayak PA who had taken part in NW utilization as per 401–404 codes in ICD-9 or I 10–I 14 codes in ICD-10:

– Essential hypertension (401 in ICD-9 or I-10 in ICD-10);

– Hypertensive heart disease with congestive heart failure (402 in ICD-9 or I-11 in ICD-10);

– Hypertensive renal disease with congestive renal failure (403 in ICD-9 or I-12 in ICD-10);

– Hypertensive heart and renal disease with both congestive heart failure and renal failure (404 in ICD-9 or I-13 in ICD-10).

Initial data were statistically processed with Statistica 10 standard software. We calculated both non-standardized ("rough") morbidity parameters and standardized (as per sex and age) ones. We applied indirect standardization techniques to standardize the examined parameters. To do that, we applied an internal standard distributing the overall examined cohort of workers employed at Mayak PA as per their age. Morbidity parameters were calculated per 1,000 workers according to medical statistics techniques [10].

Parameters of morbidity with AH were analyzed taking into account both radiation-related factors (external gamma-irradiation and internal alpha-irradiation caused by incorporated plutonium) and basic non-radiation ones (sex, age, smoking status, attitude towards alcohol intake, body mass index or BMI, as well as diagnosed pancreatic diabetes).

Data on attitudes workers had towards smoking were taken for the whole observation period and assessed with a qualitative parameter (smoked / didn't smoke).

Data on attitudes workers had towards alcohol intake were taken for the whole observation period and assessed with a quantitative parameter (chronic alcoholism; drank reasonably; didn't drink).

BMI was assessed over 5 years prior to a date when AH was first diagnosed. Body

mass index was measured as a ratio of body mass in kilos (KG) and height (m^2). BMI = = 18.5–24.99 kg/m^2 was considered to be normal, BMI = 25.00–29.99 kg/m^2 meant a person had overweight, and BMI ≥ 30 kg/m^2 meant a person suffered from obesity.

The tables below contain non-standardized ("rough" or "intensive") and standardized (as per age) mortality and morbidity parameters ± standard error (SE). We applied Student's t-test to assess whether discrepancies between mean values were statistically significant. Significance level was taken at $p < 0.05$ [11].

Results and discussion. As of state on December 31, 2017, 2,270 AH cases were registered among workers from the examined cohort who had been employed at Mayak PA and taken part in NW utilization. Table 1 shows AH cases distribution depending on a person's sex and age at the moment AH was diagnosed. The obtained data indicate that the greatest number of AH cases was registered among men aged 31–60 (70.56 %); and among women aged 41–70 (79.55 %).

Table 2 contains standardized parameters of morbidity with AH among the examined workers employed at Mayak PA who had taken part in NW utilization; parameters are standardized depending on a sex and age. Morbidity with AH statistically significantly increased both among men and women in the

Table 1

Workers suffering from AH distributed as per age and sex on a date the disease was first diagnosed

Age on a day AH was first diagnosed	Men		Women		Both sexes	
	Number	%	Number	%	Number	%
< 20	5	0.31	0	0	5	0.23
21–30	151	9.44	13	1.94	164	7.22
31–40	303	18.93	52	7.76	355	15.64
41–50	416	26	160	23.88	576	25.37
51–60	410	25.63	195	29.1	605	26.65
61–70	232	14.5	178	26.57	410	18.06
> 70	83	5.19	72	10.75	155	6.83
Total	1,600	100	670	100	2,270	100

Table 2

Morbidity with AH among workers employed at Mayak PA who had taken part in NW utilization depending on sex and age at which the disease was first diagnosed

Morbidity parameters	Age	Men		Women	
		Number of cases	Morbidity	Number of cases	Morbidity
Intensive	< 20	5	1.4 ± 0.62a	0	0 ± 0
	20–29	151	4.69 ± 0.38^{ab}	13	2.13 ± 0.59^{b}
	30–39	303	9.48 ± 0.54^{ab}	52	5.09 ± 0.71^{b}
	40–49	416	16.39 ± 0.8^{b}	160	14.54 ± 1.15^{b}
	50–59	410	28.43 ± 1.4^{b}	195	26.31 ± 1.88^{b}
	60–69	232	40.68 ± 2.67^{ab}	178	53.53 ± 4.01^{b}
	> 70	83	58.24 ± 6.39^{b}	72	67.98 ± 8.01
	Total	1,600	15.11 ± 0.36	670	13.93 ± 0.59
Standardized	Internal standard		13.96 ± 0.35^{a}		17.02 ± 0.66

Note:
a means discrepancies are statistically significant when compared as per sex;
b means discrepancies are statistically significant against the previous age group.

examined cohort as they grew older. Morbidity with AH was statistically significantly higher among men aged 20–39 than among women in the same age group. However, among people aged 60 and older the situation changed completely and morbidity with AH became statistically significantly higher among women than it was among men in this age group.

As life expectancy has been persistently growing, a share of elderly people in population structure has also been increasing. An increase in AH numbers among older people is considered to be well-proven and confirmed by results obtained via multiple research works, both in Russia and abroad; it was first highlighted in Framingham Heart Study. Arterial hypertension (AH) prevalence among people who are older than 60 is more than 2 times higher than this parameter for the overall population [12]; ⅔ people older than 65 have AH [13].

Gender-related peculiarities in arterial hypertension (AH) are determined not only with biological but also with social and cultural factors, namely different lifestyles, nutrition, and behavior patterns; different ways to fight stress; social and economic inequality; sleep disorders; mood disorders; different attitudes towards treatment and prevention of diseases etc. [14]. Besides, pregnancy or use of oral contraception and hormonal substitute therapy during menopause can influence mechanisms that regulate blood pressure (BP) in female bodies. All this contributes into cardiovascular pathology occurrence [15, 16].

There are also sex- and age-related differences in AH prevalence. According to some authors, women aged younger than 40 tend to suffer from AH not as frequently as men [15–19]. Besides, young women usually have lower systolic BP than men. Diastolic BP, as a rule, is lower in women than in men regardless of an age. But the situation changes to an opposite one when it comes to 50 years of age. Morbidity among women starts to grow more intensively than among men and the parameter becomes comparable in both groups as they reach 60 years of age. After this age, AH prevalence is higher among women than among men. Therefore, favorable sex-related differences level off as menopause occurs [13, 15]. Higher blood pressure and arterial hypertension prevalence among women grows considerably after menopause starts [20, 21]. Sex hormones deficiency leads to disorders in vascular endothelium functioning, balance between various vasoactive substances, and functioning of cells in smooth muscles of vessels; it results in higher peripheral vessels resistance and, consequently, higher blood pressure [22].

In this research we focused on a dynamics of morbidity with AH among workers employed at Mayak PA over the whole observation period, starting from January 01, 1948 and till December 31, 2017 (Figure 1). “Rough” morbidity with AH increased by the end of the observation period due to an increase in workers’ age in the examined cohort (that is, workers became “old enough” to have an age-associated pathology).

An increase in standardized morbidity with AH in 1986–2000 was probably due to a complicated social and economic situation in the country that was caused by perestroika in 1985–1991 and all the events that followed the collapse of the USSR in 1990-ties [23].

We analyzed dependence between morbidity with AH and smoking status; the results are given in Table 3. We detected that there were no statistically significant discrepancies in standardized morbidity with AH among smoking and non-smoking men in the examined cohort. However, we detected statistically

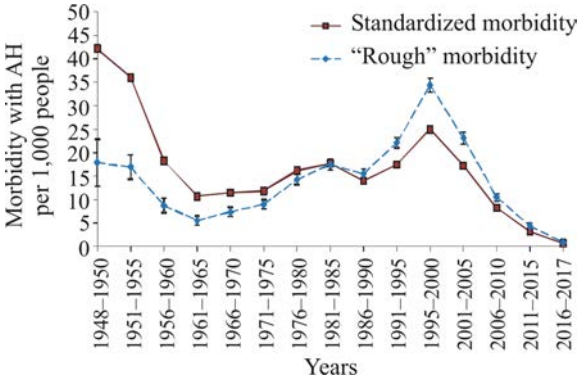

Figure 1. Dynamics of morbidity with AH over the whole observation period (01.01.1949–31.12.2017)

Table 3

Morbidity with AH among workers employed at Mayak PA who had participated in NW utilization depending on a worker's sex and smoking status at the moment the disease was first diagnosed (per 1,000 workers)

Sex	Smoking status			
	Non-smokers		Smokers	
	Number of cases	Morbidity	Number of cases	Morbidity
Men	350	15.72 ± 0.81 (14.45 ± 0.77)	1246	15.28 ± 0.42 (14.31 ± 0.41)
Women	626	14.58 ± 0.65 (18.07 ± 0.72)	41	9.28 ± 1.54[a] (10.48 ± 1.64[a])

Note:
a means statistically significant discrepancies against non-smokers.
Rough morbidity is given in brackets.

significantly lower morbidity with AH among smoking women in the examined cohort against their non-smoking counterparts.

Morbidity with AH among men and women in the examined cohort who suffered from chronic alcoholism was statistically significantly lower than among those who drank reasonably or rarely (Table 4).

The data we obtained on impacts exerted by smoking status and alcohol intake on morbidity with AH are not consistent with results obtained by many domestic and foreign researchers [24–34]. These facts require further profound investigations and we plan to accomplish them at the next stage in our analysis of AH risk among workers employed at Mayak PA who had participated in NW utilization.

Our analysis revealed that morbidity with AH was statistically significantly higher among men in the examined cohort who suffered from pancreatic diabetes (PD) than among those who didn't have this disease. The same trend among women was detected only when rough morbidity with AH was analyzed (Table 5).

Our results are well in line with existing literature data. Arterial hypertension is the most widely spread cardiovascular disease and at the same time it is a significant risk factor that causes cardiovascular complications; when it is combined with PD, the risk grows considerably [35, 36]. Besides, AH is considered to be a most widely spread complication of PD [37]. AH prevalence among patients with PD is three times higher than among those who don't suffer from it [38]. A 10-mmHg increase in systolic blood pressure in patients suffering from PD leads to a 20 % rise in a risk that cardiovascular complications occur. When AH occurs in a patient with PD, it leads to an elevated risk of not only macrovascular (ischemic heart diseases or IHD, heart failure, and stroke) but also microvascular complications (diabetic nephropathy, retinopathy). Damage to coronary, cerebral, and peripheral vessels results in macrovascular complications in case a person suffers from PD II; it to a great extent determines a clinical course of the disease. AH considerably increases risks of morbidity and mortality among patients with PD which are high as it is. Overall mortality among patients suffering from both AH and PD II is 4–7 times higher than among patients who have normal blood pressure and don't suffer from PD [39, 40].

Table 6 contains data on morbidity with AH among workers employed at Mayak PA who had participated in NW utilization depending on their BMI. Morbidity with AH was statistically significantly higher both among men and women who had BMI ≥ 25 than among those who had normal body mass.

Each fourth person in the world suffers either from overweight or obesity. There has been an increase in number of people suffering from obesity all over the world, both among adults and children. Prevalence of obesity and diseases associated with it has been steadily growing in the Russian Federation. As per data

Table 4

Morbidity with AH among workers employed at Mayak PA who had participated in NW utilization depending on a worker's sex and attitudes towards alcohol intake at the moment the disease was first diagnosed (per 1,000 workers)

Sex	Attitudes towards alcohol intake					
	Never / rarely drinks		Reasonably		Chronic alcoholism	
	Number of cases	Morbidity	Number of cases	Morbidity	Number of cases	Morbidity
Men	147	14.41 ± 1.07 (11.6 ± 0.96)	1,046	17.66 ± 0.54* (17.12 ± 0.53*)	365	12.35 ± 0.65§ (12.33 ± 0.65§)
Women	407	13.84 ± 0.77 (17.29 ± 0.86)	241	15.62 ± 1.11 (19.09 ± 1.23)	10	8.03 ± 2.76*§ (9.47 ± 2.99*§)

Note:
a means statistically significant discrepancies against those who didn't drink;
b means statistically significant discrepancies against those who drank reasonably.
Rough morbidity is given in brackets.

Table 5

Morbidity with AH among workers employed at Mayak PA who had participated in NW utilization depending on a worker's sex and diagnosed pancreatic diabetes at the moment AH was first diagnosed (per 1,000 workers)

Sex	Pancreatic diabetes			
	PD diagnosed		PD not diagnosed	
	Number of cases	Morbidity	Number of cases	Morbidity
Men	1,562	14.93 ± 0.36 (13.69 ± 0.35)	38	30.35 ± 7.46[a] (69.68 ± 11.3[a])
Women	646	13.69 ± 0.59 (16.57 ± 0.65)	24	26.11 ± 8.38 (64.49 ± 13.16[a])

Note:
a means statistically significant discrepancies against those who didn't suffer from PD.
Rough morbidity is given in brackets.

Table 6

Morbidity with AH among workers employed at Mayak PA who had participated in NW utilization depending on a worker's sex and BMI at the moment the disease was first diagnosed (per 1,000 workers)

Sex	Body mass index					
	18.50–24.99		25.00–29.99		≥ 30.00	
	Number of cases	Morbidity	Number of cases	Morbidity	Number of cases	Morbidity
Men	353	15.49 ± 0.77 (13.6 ± 0.72)	653	19.9 ± 0.72[a] (17.03 ± 0.67[a])	275	18.18 ± 1[a] (15.11 ± 0.91)
Women	52	8.15 ± 1.19 (9.07 ± 1.26)	208	15.81 ± 1.16[a] (17.65 ± 1.22[a])	218	17.75 ± 1.29[a] (20.45 ± 1.39[a])

Note:
a means statistically significant discrepancies against workers with BMI equal to 18.50–24.99.
Rough morbidity is given in brackets.

Table 7

Morbidity with AH among workers employed at Mayak PA who had participated in NW utilization depending on a worker's sex and total dose of external gamma-irradiation absorbed in the liver (per 1,000 workers)

Sex	Total dose of external gamma-irradiation absorbed in the liver, Gy					
	< 0.2		0.2–0.5		≥ 0.5	
	Number of cases	Morbidity	Number of cases	Morbidity	Number of cases	Morbidity
Men	1,108	17.69 ± 0.53	238	18.52 ± 1.33	176	19.12 ± 1.6
Women	486	17.26 ± 0.92	76	17.87 ± 2.25	76	17.74 ± 2.18

Таблица 8

Morbidity with AH among workers employed at Mayak PA who had participated in NW utilization depending on a worker's sex and total dose of internal alpha-irradiation absorbed in the liver (per 1,000 workers)

Sex	Total dose of internal alpha-irradiation absorbed in the liver, Gy					
	< 0.025		0.025–0.05		≥ 0.05	
	Number of cases	Morbidity	Number of cases	Morbidity	Number of cases	Morbidity
Men	731	18.96 ± 0.69	119	19.08 ± 2.13	253	17.12 ± 1.38
Women	364	18.21 ± 1.08	42	15.71 ± 3.19	146	19.97 ± 2.08

obtained via ESSE-RF epidemiologic research (2013), prevalence of obesity tends to grow with age, both as per BMI and waist circumference (WC) [28]. Thus, in Russia 26.6 % men and 24.5 % women aged 35–44 suffer from obesity; 31.7 % and 40.9 % among those aged 45–54; and 35.7 % and 52.1 % among those aged 55–64 accordingly.

Obesity is a significant risk factor that can cause AH. It was proven that AH in 85 % developed in people with their BMI >25 kg/m^2 and it was 5 times more frequent among such people than among those with normal body mass [41]. Literature data confirm that AH develops together with abdominal obesity in 48.7 % cases [42].

There is a tight pathogenetic relation between obesity and AH [43]. AH combined with obesity is drawing attention of public healthcare experts due to it causing early disability, elevated risks of cardiovascular complications and untimely deaths among people who suffer from it as compared with population in general. Obesity is both an independent factor that causes cardiovascular complications and a probable trigger mechanism that stimulates AH occurrence [44].

As workers in the examined cohort had been exposed to occupational long-term external gamma-irradiation or internal alpha-irradiation caused by incorporated plutonium, we analyzed morbidity with AH depending on radiation factors (Tables 7 and 8). We didn't reveal any statistically significant influence exerted by either external gamma-irradiation or internal alpha-irradiation on morbidity with AH among workers who had participated in NW utilization.

Experts are still arguing whether irradiation exerts any influence on blood pressure in spite of all their efforts to clarify it [45–47]. A possible increase in morbidity with cardiovascular diseases caused by irradiation in small doses first attracted scientists' attention when they were analyzing several categories of non-carcinogenic diseases in people who had survived atomic bombing in Japan and had had their whole bodies irradiated within a range of doses less than 5–6 Gy [48]. Excess mortality caused by AH with damage to the heart associated with irradiation was detected in a cohort in a life span study (LSS cohort); an excess relative risk per a unit of a dose (ERR / Gy) amounted to 0.21 (90 % CI: 0.00;

0.45; $p = 0.003$) [45]. Later, when an observation period was extended up to 2008, a statistically significant dose – effect dependence was detected in the same cohort for AH-caused mortality as ERR / Gy amounted to 0.36 (95 % CI: 0.10; 0.68; $p = 0.004$) [49, 50]. In the last Adult Health Study (AHS) Yamada et al. [46] detected excess risk of morbidity with hypertension that was related to irradiation. That risk was in general statistically insignificant; however, quadratic dose dependence for morbidity with hypertension turned out to be statistically significant. There was also an examination conducted on a cohort that included 61,017 liquidators of Chernobyl Disaster; the results indicated there was a statistically significant elevated risk of essential hypertension (ERR / Gy = 0.36 (95 % CI: 0.05; 0.71; $p = 0.04$)) [47]. When an observation period for the same cohort was extended up to 2012, experts revealed a statistically significant trend in morbidity with AH, namely its dependence on an irradiation dose as ERR / Gy amounted to 0.26 (95 % CI: 0.12; 0.41; $p < 0.001$) [49]. Sasaki et al. were the first to describe statistically significant relationships between systolic and diastolic blood pressure and an irradiation dose [50].

Therefore, we plan to assess risks of morbidity with AH under chronic irradiation exposure at the next stage in our research and to determine a dose – effect relationship taking into account non-radiation factors.

Conclusion. We calculated standardized morbidity with AH for workers employed at Mayak PA who had participated in NW utilization. The results revealed that it was statistically significantly depended on non-radiation factors (sex, age, smoking status, attitudes towards alcohol intake, body mass index, and pancreatic diabetes) and didn't depend on a total dose of external gamma-irradiation and internal alpha-irradiation absorbed in the liver.

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RELATION BETWEEN ATROPHIC GASTRITIS AND RISK FACTORS PREVALENCE AMONG WORKERS EMPLOYED AT ATOMIC ENTERPRISE

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Atrophy of the stomach mucosa in the stomach is a significant predisposing factor that causes elevated risks of stomach adenocarcinoma. It was shown that mortality caused by malignant neoplasms in the digestive organs accounted for 36 % of all the death cases due to solid carcinoma among workers employed at basic enterprises included into "Mayak" Production Association (Mayak PA).

***Our research goal** was to study a relation between atrophic gastritis (AG) prevalence and potentially hazardous endogenous and exogenous factors among personnel employed at an atomic enterprise of Mayak PA.*

***We analyzed** data obtained via clinical and laboratory examinations performed on a sampling that was made of 1,116 people, 70% of them being workers employed at Mayak PA.*

***Our research allowed us to** reveal and analyze 26 hazardous factors that contributed to AG development. Data array was processed with a modified "case – control" procedure based on well-known principal components analysis. Observation clusters and strata that formed certain groups in various areas of the factor space differed both as per "overloading" with risk factors and as per intensity of an effect. Accomplished analysis allowed us to conclude that there was a correlation between AG development and risk factors prevalence as we revealed certain factors exerting statistically significant impacts on AG development in the examined sampling even within the zero hypotheses H0. In order to determine how intense that relation was, in further analysis it was advisable to apply an alternative hypothesis H1 on a possible relation between an effect and examined factors. Application of a modified statistical procedure allowed us to make any conclusions only on certain trends occurring in AG risks when there were some changes in aggregated overloading with risk factors; adequate and complete statistical analysis can only be multi-factor one. As "factor – effects" relations lack evidence, it creates a possibility for artificial neural networks approximations; we are going to demonstrate it in our future works.*

***Key words:** atomic enterprise, personnel, atrophic gastritis, clinical and laboratory examination, risk factors, principal component analysis, one-factor analysis, multi-factor analysis.*

According to official statistic data stomach cancer (SC) holds the third rank place in the structure of mortality caused by malignant neoplasms [1, 2]. Gastric mucosa (GM) atrophy is a significant predisposing factor that causes elevated risks of stomach adenocarcinoma. Given that, atrophic gastritis (AG) is the first section in "precancerous cascade" chain that results in stomach cancer [3–5]. Despite risk factors that cause stomach cancer and AG being rather close [6], some of them that are proven to be related to SC don't cause GM atrophy. Thus, for example, an established negative influence exerted by sex and smoking on SC occurrence is quite disputable in case of AG [7–9].

In this relation it seems truly vital to examine a correlation between AG and potentially hazardous endogenous and exogenous factors, especially concerning people who

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were exposed to occupational external and internal irradiation and hazardous chemicals, in particular, workers employed at nuclear enterprises included into Mayak Production Association (Mayak PA). It was shown that solid tumors in the gastrointestinal tract held the 3–4th rank places in the structure of mortality and morbidity caused by malignant neoplasms (MN) among workers employed at Mayak PA; mortality caused by MN in the digestive organs accounted for 36 % among workers employed at major enterprises included into Mayak PA [10, 11]. Previously we detected that AG prevalence among workers employed at Mayak PA was statistically significantly 3–4 times higher than among people who weren't exposed to occupational risk factors [12]. Our present work is an attempt to perform detailed analysis of correlations between a great number of risk factors and AG for a more representative sampling. When atrophic state of GM is revealed, it can allow spotting out people who run elevated risks of SC occurrence; it can also make managing individual risks more efficient and allow performing prevention activities in order to prolong a working period for a specific worker. It will also make for a decrease in overall specific parameters of mortality with SC in the population [13].

Data and methods. Our sampling was made up of 1,116 people and consisted of 614 workers employed at major enterprises included into Mayak PA, 181 workers employed at auxiliary enterprises in Mayak PA, and 320 people who worked in non-industrial establishments. The structure of our sampling proved it was a heterogeneous one in terms of epidemiologic research. Demographic data and data on occupational and non-occupational risk factors (F) that caused gastric diseases were obtained via questioning and case histories examination. All people included into the sampling underwent laboratory examinations to check functional state of the stomach with "serologic biopsy" ("Gastro Panel", Finland). We identified various phenotypes of GM state as per a combination of pepsinogen-1, gastrin-17, and IgG antibodies to *H. pylori* in blood serum [14]. Normal stomach functioning was detected in 165 cases; non-atrophic *Helicobacter pylori* (*H.pylori)*-associated gastritis, in 814 cases; atrophic gastritis, in 137 cases.

To reveal any relation between AG and risk factors prevalence, we applied a hybrid procedure which we modified ourselves; the procedure combined certain traits of "case – control" study and group factor analysis based on principal components technique [15]. Our modification was primarily about "cases" and "controls" not being divided into pairs of traditional groups that either had or didn't have an examined risk factor; we divided them into several fixed strata that had different "burden" with all the factors with a relevant difference in a significance of an observed effect. This procedure can be considered as a certain substitute to multi-factor analysis applied to examine a relation between an effect and factors; this analysis, just as "case – control" analysis, is applied for groups with different effects; it allows analyzing a nature of distribution for each factor separately (a one-factor analysis). Within a zero hypothesis (*H0*) which assumes there is no correlation between an effect and factors there should be no statistical difference in prevalence of factors or an effect between strata. On the contrary, statistical significance of discrepancies between factors, provided that there are differences in an effect, will allow not only revealing potentially hazardous factors but also ranking them and comparing a risk trend with a factor prevalence trend. In addition to that, group prevalence and intergroup relative AG risks were estimated within Bayesian approach as per relevant beta-distributions [16, 17].

Results and discussion. Table 1 contains factors (F) that can exert their influence on AG occurrence according to our own data and those taken from literature [7–9, 12, 18]. We can assume there is a statistical correlation between AG and influencing factors as per results obtained via comparing distributions of all observations and specific events in the factors space.

Table 1

Examined factors that influence AG occurrence and their distribution in the sampling

No.	Factor	Factor value	Number of people with factor value "1"	Per cent of people with factor value "1"
1	Age at the moment of screening (years)	36–82	–	–
2	Sex (female)	[0; 1]	491	44 %
3	Alcohol intake	[0; 1]	835	74.8 %
4	Smoking	[0; 1]	350	31.4 %
5	Exposure to radiation caused by living on territories contaminated due to accidents at Mayak PA	[0; 1]	260	23.3 %
6	A dose of occupational γ-irradiation on the gastrointestinal tract (mGy)	0–475	–	–
7	Pu contents (kBq)	0–0,78	–	–
8	Organic chemicals with carcinogenic effects	[0; 1]	306	27.5 %
9	Organic chemicals with gastrotoxic effects	[0; 1]	171	15.4 %
10	Generally toxic organic chemicals	[0; 1]	371	33.3 %
11	Non-organic chemicals with carcinogenic effects	[0; 1]	212	19.0 %
12	Non-organic chemicals with gastrotoxic effects	[0; 1]	408	36.6 %
13	Generally toxic non-organic chemicals	[0; 1]	295	26.5 %
14	Extragastric precancerous diseases	[0; 1]	24	2.2 %
15	Extragastric MN	[0; 1]	33	2.9 %
16	Extragastric hormone-dependent benign tumors (BT)	[0; 1]	73	6.5 %
17	Extragastric hormone-independent BT	[0; 1]	56	5.0 %
18	Autoimmune diseases (AID)	[0; 1]	69	6.2 %
19	Type-II diabetes mellitus (DM)	[0; 1]	89	8.0 %
20	Gastric acid-dependent diseases	[0; 1]	261	23.4 %
21	Non-ulcer gastric diseases	[0; 1]	223	20.0 %
22	Maternal SC predisposition	[0; 1]	41	3.7 %
23	Paternal SC predisposition	[0; 1]	80	7.2 %
24	Maternal gastric / duodenum ulcer predisposition	[0; 1]	26	2.4 %
25	Paternal gastric / duodenum ulcer predisposition	[0; 1]	87	7.8 %
26	Concentration of IgG antibodies to *H.pylori* (EIU)	0.5 – 135.5	–	–

Note:

1. Factors No. 1,6,7,26 are quantitative; all the others are categorical;

2. Hormone-dependent BT (benign prostatic hyperplasia, uterine myoma), hormone-independent BT (all the rest, predominantly polyps);

3. Autoimmune diseases excluding diabetes mellitus.

It is geometrically impossible to show distribution of all 26 factors in a fully-dimensional space (R^{26}); so, to give a relevant illustration, we compared one-dimension empiric distributions in a projection of the main trend in factors changeability. This analysis technique can be seen as an analogue to the simplest variant of principal component analysis [15]. To do that, we performed centering and standardizing for each factor F as per standard deviation value thus making each factor acquire a standardized weight that was not higher than 1 as per its module. Therefore, each specific individual had certain conditional vector "burden" with factors (aggregated factor burden) within 26-dimension space. A shift along the first major direction turned out to be predominantly determined by a positive influence exerted on AG occurrence by an increase in age (F1) and hor-

mone-dependent benign tumors (F16) as well as negative contribution made by ulcer in mother's case history (F24). The major trend in factors changeability was determined along a straight line that connected two extreme individuals with a maximum distance between state vectors with standardized coordinates; their initial characteristics are given below.

The first extreme individual had the following risk factors that could cause AG: age equal to 43 (F1); proneness to regular alcohol intake (F3); duodenum ulcer (F20); hereditary predisposition to ulcer (mother had it (F24); substantially increased concentration of antibodies to *H. pylori*, namely 91.4 EIU.

The second extreme individual had the following potential AG risk factors: age equal to 73 (F1); proneness to regular alcohol intake (F3); benign prostatic hyperplasia (F16); non-ulcer gastric diseases (F21); concentration of antibodies to *H. pylori* amounted to 31.1 EIU which was insignificantly higher than its threshold value (30 EIU). We should note that there was no AG in both cases.

Figure 1 shows graduated graphs for two empiric distributions of all cases and AG cases in the sampling that are characterized with the constant sign of a shift in one distribution relative to another. Within a zero hypothesis as per signs criterion such an event seems to be almost impossible and it indicates there is a non-random correlation between AG occurrence and at least several examined factors. Nevertheless, when two dispersions don't coincide, it shows there is a statistic correlation between an effect and factors.

Along with a graphic way applied to show that dispersions don't coincide, we also applied table stratification of events in one-dimension space of the major trend (Table 2). We selected stratification conditions as per the single uninterrupted scale showing the aggregated factor burden so that discrepancies in AG prevalence between strata were as statistically significant as it was only possible. In this case discrepancies in an effect can be correlated to discrepancies in distribution of both specific factors and the aggregated one as per strata. To make interpretation more convenient, we assigned the aggregated coordinate 0 to the first extreme individual, and 9.77 (a length of difference between vectors), to the second extreme individual; therefore, all the cases along the major trend were distributed in the interval [0–9.77]. The section was conditionally divided into 4 strata according to the following intervals: S1 (0–4.8); S2 (4.8–6.2); S3 (6.2–8.1), and S4 (8.1–9.77).

Strata S1, S2, S3, and S4 can be described verbally notwithstanding the fact that they don't have well-defined boundaries in the space of the first principal component. Thus, S1, unlike S2, S3, and S4, contains cases with the least average age, the least average γ-irradiation doses and radionuclides contents; there were no people with pancreatic diabetes, pre-cancer diseases and MN not located in the stomach in this stratum. But still, prevalence of gastric acid-dependent diseases was rather high among participants in this stratum; smoking was the most widely spread in this stratum; it had the highest average concentration of antibodies to *H. pylori*; and all 26 registered cases of ulcer in mother's case history were also in this stratum. As regards the effect (AG), there were only 2 AG cases in S1 stratum (the fraction amounted to 0.053; Table 3). All the rest 47 individuals had normally functioning stomach in 11% cases; in 89% cases they suffered from non-atrophic helicobacter gastritis.

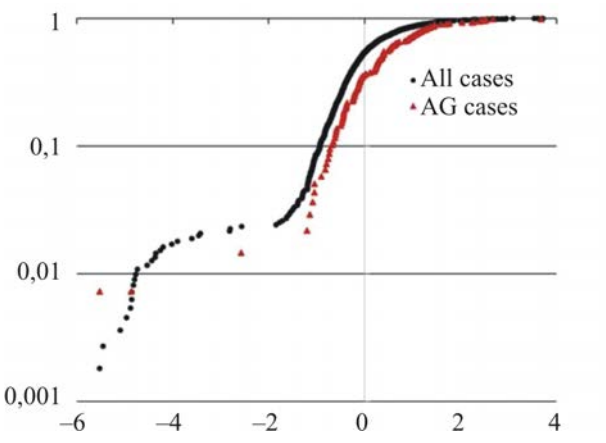

Figure 1. Empiric cumulative distributions of all cases and AG cases in the sampling as per projection value of aggregated factor burden along the major trend

Table 2

Distribution of cases as per strata along the major trend in factors changeability (as regards categorical factors)

Strata	S1 (0–4.8)		S2 (4.8–6.2)		S3 (6.2–8.1)		S4 (8.1–9.77)		*n*/*N*	*P*-value
Factors	Yes	No	Yes	No	Yes	No	Yes	No		
2 (f = 1)	19	30	208	422	236	162	28	11	4/6	≈ 0
3†	38	11	499	131	276	122	22	17	2/6	0.00017
4†	26	23	277	353	46	352	1	38	4/6	≈ 0
5†	5	44	66	564	174	224	15	24	4/6	≈ 0
8†	16	33	204	426	82	316	5	34	2/6	< 0.0001
9	7	42	112	518	49	349	4	35	0/6	**0.085**
10†	20	29	244	386	100	298	8	31	1/6	< 0.0001
11	10	39	144	486	55	343	4	35	1/6	0.0018
12	19	30	277	353	105	293	8	31	2/6	< 0.0001
13	12	37	201	429	77	321	6	33	1/6	< 0.0001
14*	0	49	4	626	7	391	13	26	3/6	≈ 0
15*	0	49	11	619	15	383	7	32	3/6	< 0.0001
16	1	48	0	630	35	363	37	2	4/6	≈ 0
17†	3	46	39	591	13	385	1	38	0/6	**0.17**
18	3	46	19	611	41	357	6	33	2/6	< 0.0001
19	0	49	35	595	52	346	2	37	2/6	< 0.0001
20	24	25	187	443	48	350	2	37	5/6	≈ 0
21	9	40	25	605	164	234	25	14	6/6	≈ 0
22*	0	49	21	609	15	383	5	34	1/6	0.01
23*	1	48	35	595	35	363	9	30	2/6	0.00012
24†	26	23	0	630	0	398	0	39	3/6	≈ 0
25	2	47	60	570	25	373	0	39	1/6	0.043
Effect (AG)	2	47	50	580	76	322	9	30	4/6	≈ 0

Note:

1 – *P*-value according to Pearson within zero hypothesis *H0* on prevalence of each factor or effect (table 4×2 for each line);

2 – *n*/*N* is a number of statistically significantly different pairs of strata n out of *N* possible (Bonferroni corrections taken into account);

3 *P*-value of statistically insignificant factors are given in semibold type;

* means a trend in factor prevalence as per strata is similar to an effect trend

† means a trend in factor prevalence as per strata contradicts to an effect trend

Table 3

AG prevalence (in fractions) in different strata/clusters

Groups		Number of people	AG cases	AG prevalence, median [90 % confidence interval (CI) of uncertainty]	P-value (Pearson)
Strata	S1	49	2	0.053 (0.017–0.121)	$P < 10^{-6}$
	S2	630	50	0.080 (0.064–0.099)	
	S3	398	76	0.192 (0.161–0.226)	
	S4	39	9	0.240 (0.142–0.360)	
Clusters	S5	26	2	0.098 (0.031–0.215)	P = 0.46
	S6	1,001	121	0.121 (0.105–0.139)	
	S7	89	14	0.162 (0.106–0.232)	

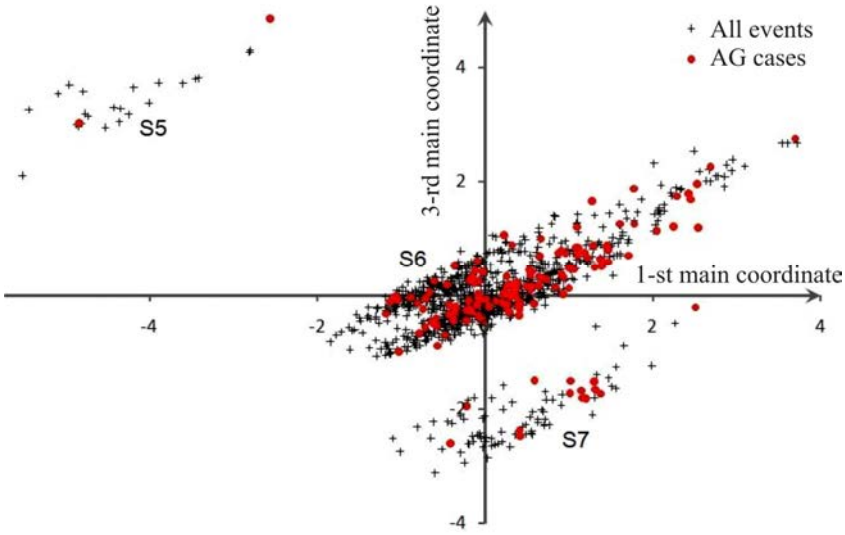

Figure 2. Distribution of events without AG (crosses) and AG cases (rounds) within the plane of two centered principal components in the factor space

S4 stratum was completely opposite to S1 stratum as per a number of predisposing factors and their prevalence. It contained the highest share of women and elderly people; it had high fractions of people who contacted adverse chemicals, people with SC in case histories of family members, people with AID (predominantly autoimmune thyroiditis), with hormone-dependent benign tumors and precancer diseases, with MN not located in the stomach, and with non-ulcer gastric diseases. But still the fraction of smoking people was the lowest in this stratum; there was no stomach ulcer in case histories of parents, and the stratum also had the lowest prevalence of gastric acid-dependent diseases. It should be noted that the highest AG share was detected exactly in S4 stratum (0.24). Strata S2 and S3 had various transient states; AG prevalence in stratum S2 (0.08) was close to that in S1, and in stratum S3 (0.19), to that in S4 (Table 3).

Obviously, it is interesting to perform analysis not only as per one principal component, but also as per other ones. Thus, when we added other centered orthogonal components into distributions of all cases, it allowed us to reveal three well-defined clusters that could indicate there was possibly a cause-and-effect relation between factors (Figure 2). Cluster S5 turned out to be very close to stratum S1 as per a set of factors and obviously it was completely included into this stratum.

All statistical tests that give an opportunity to "work" with zero values in cells of relevant tables identify a combination of these facts as being a non-random one. We can state that all the listed extreme values of signs are linked both to each other and to a comparatively low averaged value of AG prevalence in cluster S5 against clusters S6 and S7 (Table 3). Cluster S7 also has a common sign, namely, all the cases with pancreatic diabetes are located in it. Independent grouping performed for S7 cluster indicates that there is a link to other signs but it is not as obvious as it is the case with cluster S5. We should note that links between certain factors/signs don't necessarily mean a link between them and the effect (AG) is obvious; it is proven by estimates of how statistically significant AG prevalence is in strata S5, S6, and S7 (Table 3). Despite there is a monotonous growth in median AG prevalence from S5 to S7, strata sizes and distribution of specific events in them were not sufficient for Pearson's P-value to surmount conventional decision-making level 0.05 for each of the pairs S5–S6, S6–S7 and S5–S7.

So, basing on the applied procedure that was a substitute to multi-factor analysis, we can only conclude that there are certain trends in risks of AG occurrence when aggregated factor burden changes. Risk values could be 4–5 times higher or lower between certain subgroups in the examined sampling. For exam-

ple, relative risk (RR) of AG in strata S4:S1 reached 4.49 (90 % CI: 1.70–15.37). As S1 and S2 strata were heterogeneous, ratios of individual risks could be substantially higher. Nevertheless, we can't neglect a possible multi-factor influence exerted on AG prevalence as such influence is confirmed by statistical criteria calculated for two pairs of non-crossing strata S9-S8 and S11-S10 which were artificially selected as per a combination of several factors.

Factors that could have either positive or negative influence on AG risks were selected according to our own data and those available in literature. It was shown that smoking didn't exert any influence on occurrence of atrophic changes in GM; there was even lower AG prevalence among smoking people [9, 12]. In our opinion, this peculiar "protection" of gastric mucosa from atrophic changes that occurs due to smoking results from competing interrelations at the regulatory level or genetic dominating for binding places between effects produced by nicotine and humoral factors causing GM atrophy. There are data that autoimmune diseases (especially autoimmune thyroiditis and diabetes mellitus) and gastric pathology are correlated and mutually determined. Over the last decade experts have even applied "thyrogastric syndrome" definition [19]. Indeed, AG fraction was the lowest in stratum S1 where there were no DM cases while it was the highest in cluster S7 where all the DM cases were located (Table 3).

Taking into account all the given data and results of estimating correlations between factors and the effect (Table 2), some strata were made up of people who had factors with their prevailing trend being opposite to AG trend; alternative strata included people with "pro-atrophic" factors. Thus, if stratum S8 was made up of only smoking men who didn't suffer from AID, then S9 stratum included only women who didn't smoke and suffered from an AID. S10 stratum included predominantly men who worked in various non-industrial establishments and didn't have any contacts with adverse chemicals without any AID in their anamnesis. On the contrary, S11 stratum included predominantly women employed at Mayak PA who were exposed to chemical carcinogens, suffered from gastric acid-dependent diseases and had hereditary predisposition to ulcer (Table 4). AG prevalence in pairs of strata S8-S9 and S10-S11 had significant intergroup discrepancies ($P < 0.001$ according to any existing statistical criteria) (Table 4). Bayesian median estimate of relative risk amounted to 4.38 for S8-S9 pair (90% CI: 2.75–6.89); and to 11.0 for S11-S10 pair (90 % CI: 5.22–26.9), and we certainly can't neglect that.

Table 4

AG prevalence (in fractions) in S8–S11 strata

Strata	Number of people	AG cases	AG prevalence, median (90% CI of uncertainty)	RR (90% CI)
S8	282	22	0.080 (0.056–0.109)	4.38 (2.75–6.89)
S9	49	17	0.351 (0.247– 0.465)	
S10	106	4	0.043 (0.019–0.083)	11.0 (5.22–26.9)
S11	27	13	0.482 (0.333–0.634)	

We examined AG prevalence in case people in the sampling were grouped only as per their place of work; this examination revealed that it amounted to 4.8 % among people who were not exposed to technogenic irradiation and harmful chemicals (people working in non-industrial establishments) [12]. It is consistent with a fraction prevalence of the effect observed in strata S1 and S10 within uncertainty limits (0.053 and 0.043 accordingly) (Tables 3 and 4). At the same tine AG prevalence among workers employed at Mayak PA (14.8 %–20 %) [12] corresponded to the results of fraction estimates of the effect in stratum S4 and cluster S7 (0.24–0.16) (Table 3). In our opinion, this coincidence in an increase in AG prevalence in industrial workers sub-group and in created stratum S4 and cluster S7 confirms that workers employed at nuclear production are more quantitatively "burdened" with factors that predispose AG occurrence as well as that there are qualitatively other factors that cause higher AG prevalence among them.

We should note that our exploratory analysis didn't allow us to reduce a list of factors that could potentially influence risks of AG occurrence. Basing on factors distribution as per different strata, we can conclude that only two factors, namely F9 and F17, didn't exert any statistically significant influence on AG occurrence within the limits of our examined sampling (Table 2). "Pro-atrophic" effects are most likely to be produced by such factors as age (F1), external irradiation dose (F6), pre-cancer diseases (F14), MN not located in the stomach (F15), hormone-dependent benign tumors (F16), non-ulcer gastric diseases (F21), and hereditary predisposition to stomach cancer (F22-23). The first major trend has a single vector with projections having such value and sign that it allows us to assume changes in these factors occurring in consistency with an increase in risks of AG. At the same time such factors as alcohol intake (F3), smoking (F4), acid-dependent gastric diseases in case history (F20), ulcer in mother's case history (F24), and concentration of antibodies to *H. pylori* (F26) had a direction that was opposite to risks of AG occurrence. For these factors, AG risks trend was also opposite even as per a sign of a factor prevalence trend. Such an opposite direction detected for impacts exerted by certain organic chemicals (F8, F10) is not consistent with conventional opinion on adverse effects produced by them; the issue requires further investigation. Probably a distribution of factors which we obtained doesn't give us a correct picture due to cases being grouped arbitrarily or mutual correlations between factors when impacts exerted by one factors were somehow disguised by those exerted by another.

It came out that both procedures which we applied (graphs and tables) didn't allow giving a complete picture due to probable correlations between factors and even their mutual dependence. Another circumstance that makes any analysis even more difficult is an a priori assumption that factors make equal contributions into the overall "burden"; it means an issue related to mathematic standardizing of R^{26} space is not properly regulated. However, individual data on factors occurrence in each stratum allowed making direct comparisons between AG prevalence in strata with heterogeneous distribution of factors. Besides, basing on our pilot research, we can assume that observed prevalence of atrophic gastritis in the examined sampling can't correspond to a typical zero hypothesis *H0* that there is no correlation between the effect and factors. Given that, we should take another basic hypothesis for making any probabilistic estimates; this alternative hypothesis *H1* states there is a correlation between the effect and almost all the examined factors. It is advisable to perform relevant estimates with maximum-likelihood techniques applying a distribution that is typical for en empirical sampling itself, and considering alternatives to *H1* comparing them with it. It necessarily leads us to Wilkes or Kullback tests [20]. Obviously, full-fledged statistical analysis should be only multi-factor one. Nature of "factor – effects" relations is usually intricate and not obvious, and it gives opportunities for artificial neural networks approximations. We are planning to dwell on it in our future works.

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PECULIARITIES OF MORBIDITY AND ASSESSMENT OF OCCUPATIONAL HEALTH RISKS FOR WORKERS WHO CONTACT AEROSOLS OF MAN-MADE MINERAL FIBERS

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Our research focused on health of workers who had contacts with aerosols of man-made mineral fibers.

Our research goal was to determine peculiarities related to dynamics and structure of morbidity with temporary disability and to assess occupational health risks for workers who had contacts with aerosols of man-made mineral fibers.

The paper dwells on the results obtained via in-depth interpretation analysis of morbidity with temporary disability among workers who were permanently involved in manufacturing heat insulating boards from mineral wool (the test group); morbidity was analyzed over a 5-year period taking into account workers' sex, age, and working experience. Occupational conditionality of morbidity was assessed via comparative analysis as the test group was compared with the conditional reference group (workers employed at a workshop where cell concrete blocks were manufactured), overall morbidity parameters taken for the whole country, and morbidity parameters taken for construction materials manufacturing. Risk was assessed via applying occupational risk index, calculated on the basis of relative risk and total coefficient of working conditions.

We detected that morbidity with temporary disability among workers from the test group was authentically higher than morbidity among workers from the conditional reference group, regarding both all disease categories, and respiratory organs diseases in particular. Relative risk and etiological fraction of morbidity caused by working conditions indicates that such conditions have direct influence on morbidity with respiratory organs diseases among workers from the test group. Occupational risk index characterizes occupational risk for workers from the test group as being moderate but still requiring specific activities aimed at reducing it, although there is no urgent necessity to perform them. Workers from the test group also tended to have lower "health index" than those form the conditional reference group.

Morbidity with temporary disability among workers from the test group was authentically lower than in the Republic of Belarus on average as well as than standard parameters fixed for construction materials manufacturing; but it was statistically significantly higher than both in the country on average and in the branch for respiratory organs diseases, musculoskeletal and connective tissue diseases; it was also statistically significantly higher than on average in the country for digestive organs diseases and diseases of skin and subcutaneous tissue.

Key words: *mineral wool manufacturing, man-made mineral fibers, industrial aerosols, working conditions, morbidity, occupational risk, occupational diseases, morbidity dynamics.*

The World Health Organization estimates 2.1 % of all the death cases all over the world to be caused by occupational risks; a share of global disease burden associated with exposure to occupational factors reaches 2.7 % [1]. Industrial aerosols traditionally take the 1st rank place among adverse industrial factors for workers from various occupational groups.

There has been a drastic increase in application of various synthetic fibers over the recent years especially after asbestos was completely banned in many countries or its application was significantly limited [2]. These data are confirmed by official statistics in Belarus; according to it, volumes of mineral cotton production increased by 266.5 % from 2005 to 2017[1, 2].

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[1] Industries in the Republic of Belarus: statistic report. Belarus National Statistics Committee. Minsk, 2013, 159 p.
[2] Industries in the Republic of Belarus: statistic report. Belarus National Statistics Committee. Minsk, 2018, 118 p.

Production processes applied in manufacturing products out of synthetic mineral fibers involve formation of fine-disperse dust with its particles diameter being less than 10 μm. This dust deposits in calm air due to gravity force at a speed being less than 1 cm/sec; consequently, mineral cotton particles persist in working area air and penetrate workers' bronchopulmonary system and gastrointestinal tract [3]. Impacts exerted on a body by such aerosols depend not only on fibers size but also a degree of their biological persistence [4]. And even though several research works indicate that mineral cotton fibers have low biological persistence [5], we should note that production processes for manufacturing ready products based on these fibers involve applying binding components with different structure (phenol-formaldehyde resins are often used). It can substantially change their solubility thus increasing their biological persistence [2, 6].

There was a monograph issued by the International Agency for Research on Cancer (IARC) that focused on assessing carcinogenic risks caused by synthetic mineral fibers; according to its authors, glass cotton, mineral cotton, and slag cotton were moved from the group 2B ("probably carcinogenic for people" into the group 3 ("not classified as having carcinogenic effects on a human body"). It was substantiated by research results that indicated there was no increase in frequency of tumors in the lungs and mesothelioma under inhalation exposure to them and their intratracheal penetration into a body [7]. However, there are several works mentioning a correlation between exposure to synthetic mineral fibers and pleura mesothelioma and lung cancer [8–14], as well as cytotoxic and genotoxic effects produced by mineral cotton [15, 16]. Exposure to synthetic mineral fibers is also considered to be correlated to high risks of pneumoconiosis [17], cardiovascular pathology [3], and hyperkeratosis with highly probable malignant change [18].

Official statistical data collected in Belarus give evidence that occupational morbidity annually decreases; in 2017 there were 84 occupational diseases cases registered in the republic (there were 97 such cases in 2016), and it is not consistent with working conditions existing in the country as 65.4 % work places are estimated as having harmful working conditions [19]. Given that, it becomes truly vital to examine morbidity with temporary disability (morbidity with TD) and to determine an extent to which diseases are caused by occupational factors and occupational health risks existing at work places.

Our research goal was to determine peculiarities related to dynamics and structure of morbidity with TD and to assess occupational health risks for workers who had contacts with synthetic mineral fibers aerosols.

Data and methods. We accomplished our research at the largest industrial enterprise dealing with construction materials production in Belarus, "Gomel'stroimaterialy" public company located in Gomel; among other products, it manufactured heat insulating boards made of mineral cotton.

To examine morbidity with TD among workers who contacted synthetic mineral fibers aerosols, we created our basic test groups that included workers employed at a workshop where heat-insulating materials were produced (Workshop No. 1) in a quantity equal to 1,096 year-round person-years. Our reference group (conventional control) was made up of workers employed at a workshop where cell-concrete blocks were produced (Workshop No. 2) in a quantity equal to 848 year-round person-years.

Groups were created taking into account differences between them as per leading adverse industrial factors existing at work places and similarities as per non-industrial factors (the same locations, communal conditions, and medical support). To create the reference group, we chose a workshop with working conditions which were comparable as per their hazard category at most work places (1st and 2nd hazard categories). What mattered a lot here was a fact that both groups being exposed to industrial aerosols with fibrogenic effects; however, that factor was predominantly caused by synthetic mineral fibers aerosols while workers from the reference group were primarily exposed to fibrous silicon-containing aerosols occurring in working area air.

We statistically analyzed both samplings and revealed that they were comparable as per

sex as men accounted for 85.3 % in the test group ($n = 278$) and for 81.5 % in the reference group ($n = 221$, $p = 0.275$, Fisher's two-tailed exact test); age (age distribution median amounted to 38 in the test group (31; 46), and to 41 in the reference group (33; 49), $p = 0.229$, Mann-Whitney); work experience (work experience median amounted to 8 years in the test group (4; 12), and to 11 years in the reference group (5; 16), $p = 0.498$, Mann-Whitney); and as per workers' occupations.

To obtain data on morbidity with TD, we examined 2,120 sick leaves issued over a period from 2012 to 2016. We didn't include temporary disability (TD) cases caused by home injuries, sick leaves given to take care of a sick family member, as well as TD cases for workers with their working experience not exceeding 1 year at the moment a disease occurred.

We analyzed morbidity with TD and assessed statistical significance of discrepancies between examined TD parameters according to MG No. 112-9911-99 "In-depth analysis of morbidity with temporary disability"[3].

Relative risk (RR), 95 % confidence interval of RR, and etiological fraction (EF) were calculated according to the Application Instruction No. 062-1109 "Assessment criteria and occupational morbidity parameters for complex analysis of impacts exerted by working conditions on workers' health and occupational risks assessment"[4].

To assess long-term morbidity dynamics, we calculated growth rates as per geometric mean.

Obtained data were statistically treated and analyzed with STATISTICA 10 applied software. Initial data were given as absolute and relative values with confidence intervals [$CI_{0.95}$]. Central trends and spreads of quantitative parameters that had approximately normal distribution were given with mean value (M) and error of the mean (m) as M±m. Central trends and dispersions of quantitative signs with their distribution not being normal were given with median and inter-quartile spread (the 25th and 75th percentiles) as Me (25; 75).

We applied Kolmogorov-Smirnov test, Lilleiefors test, and Shapiro-Wilk test as criteria showing that signs were normally distributed in the examined groups. Confidence intervals for frequencies and fractions were calculated as per Wald procedure. We applied Mann-Whitney criterion to compare two independent groups as per quantitative signs with their distribution not being normal. Significance of discrepancies between two independent groups was estimated with Chi-square and Fisher's exact two-tailed test). Critical significance (p) applied to test statistical hypotheses was taken as 0.05.

Results and discussion. Having analyzed morbidity with TD among workers from the test group taken in dynamics over the examined 5-year period, we detected there was a descending trend in number of TD cases by 22.3 % from 102.3 (95 % CI 88.78–115.89) cases per 100 workers to 72.4 (95 % CI 60.87–83.89) cases; on average, a number of cases decreased by 8.3 % a year (Table 1). A number of TD days also tended to go down by 10.0 % from 843.5 (95 % CI 617.44–1,069.48) days per 100 workers to 639.5 (95 % CI 466.53–812.52); however in2013 there was a 3.2 % growth in number of TD cases against 2012, and average duration of a TD case was the longest in 2013 over the examined period and amounted to 10.0 (95 % CI 8.57–11.44) days. Overall, a number of ND cases registered in 2012–2016 was considered to be "above average" in 2012 according to E.L. Notkin's scale for assessing morbidity with temporary disability; 2013–2014, "average"; 2015–2016, "below average"; and a number of TD days was estimated as "average" (2012–2014) and "below average" (2015–2016).

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Table 1

Morbidity with temporary disability among workers employed by "Gomel'stroimaterialy" public company taken in dynamics over 2012–2016

Year	Workshop No. 1 $M \pm m$				Workshop No. 2 $M \pm m$			
	Cases	Day	Average duration of a TD case	IP	Cases	Day	Average duration of a TD case	IP
2012	102.3±6.92	843.5±11.32	8.2±0.4	293.8±16.31	90.2±7.42	742.1±115.89	8.2±0.53	258.8±15.83
2013	91.1±6.36	870.2±116.03	9.6±0.51	281.6±15.07	92.4±7.07	785.4±115.49	8.5±0.6	269.4±15.71
2014	85.9±6.25*	859.6±115.9	10.0±0.73	271.7±14.56*	66.9±6.13	619.7±92.89	9.3±0.64	203.5±10.88
2015	70.5±5.57*	693.4±92.04*	9.8±0.74*	221.1±10.86*	54.4±5.68	442.0±68.00	8.1±0.43	155.1±7.11
2016	72.4±5.87	639.5±88.26	8.8±0.55	215.2±10.86*	60.5±6.31	534.9±86.77	8.8±0.71	179.9±9.73
2012–2016	84.4±2.77*	782.0±47.24*	9.3±0.26	256.9±6.06*	73.4±2.94	628.9±43.19	8.6±0.27	214.8±5.39

Note:

* means discrepancies between the test and the reference group (Workshop No. 2) are statistically significant at $p < 0.05$.

We compared TD parameters detected in the test group with average long-term parameters taken for the whole country and revealed authentically lower morbidity with TD among workers from the Workshop No. 1 against morbidity with TD in the country in general as per TD days ($t = 2.28$, $p < 0.05$) and as per an integral parameter (IP) that took into account both cases and days ($t = 2.47$, $p < 0.05$). We obtained the same results after comparing morbidity with TD in the test group with standards accepted in construction materials production both as per TD days ($t = 3.1$, $p < 0.05$) and IP ($t = 4.18$, $p < 0.05$).

Lower morbidity with TD among workers employed at the workshop where heat-insulating materials are produced both against country levels and branch ones is probably due to qualitative occupational selection that allows hiring workers with initially greater adaptation abilities. It is well-known that workers who are employed ad harmful productions are in general healthier than their counterparts who work in rather comfortable conditions and a share of people with functional limitations and weak health is usually lower among them [20]. We should also remember that labor turnover grows proportionate to working conditions becoming more harmful as workers with weaker health leave; working conditions existing in the workshop where heat-insulating materials were manufactured were assessed as having 1–4 harmful categories for 87 % of total work places.

Dynamics of morbidity with TD detected in the reference group revealed a trend quite similar to that in the test group. Thus, a number of TD cases detected in the Workshop No. 2 decreased by 25.6 % over the examined 5-year period, from 90.2 (95 % CI 75.78–104.78) cases per 100 workers to 60.5 (95 % CI 48.16–72.89); a fall in number of cases was more intensive than in the test group and on average amounted to 9.5 % a year. Duration of TD (number of days) also decreased by 21.5 % in 2012–2016, from 742.1 (95 % CI 514.92–969.22) days per 100 workers to 534.9 (95 % CI 364.80–704.93). In general, in 2012–2016 number of TD cases in the Workshop No. 2 were estimated as "average" as per E.L. Notkin's scale (2012–2013); "below average" (2014, 2016): and "low" (2015); duration of TD (days) was estimated as "below average" (2012–2014); "low" (2016); and "extremely low" (2015).

Morbidity with TD was statistically significantly higher in the test group than in the reference one. Comparative analysis of morbidity with TD as per TD cases revealed authentically higher levels in the test group against the reference one; by 28.4 % in 2014

($t = 2.18$, $p < 0.05$) and by 29.6 % in 2015 ($t = 2.02$, $p < 0.05$). Average long-term number of TD cases over the whole 5-year period was also higher by 15.0 % ($t = 2.73$, $p < 0.05$). Number of TD cases per 100 workers was by 56.9 % authentically higher in the Workshop No. 1 than in the Workshop No. 2 in 2015 ($t = 2.20$, $p < 0.05$) and on average by 24.3 % over the whole examined period ($t = 2.39$, $p < 0.05$).

IP also was higher for morbidity with TD in the test group from 2014 to 2016 varying from 19.6 % ($t = 2.42$, $p < 0.05$) to 42.6 % ($t = 5.08$, $p < 0.05$), and on average by 19.6 % over 2012–2016 ($t = 5.20$, $p < 0.05$). We also calculated RR and EF as per days of TD (RR 1.24 [1.12; 1.38], EF 19.6 %) and as per a number of sick people (RR 1.17 [1.09; 1.26], EF 14.8 %) and revealed that morbidity with TD was statistically authentically higher in the test group than in the reference one. Occupational risk index calculated on the basis of relative risk and a total quotient describing working conditions (3.9) was equal to 3 and it indicated that occupational risk was moderate for workers from the test group; consequently, specific activities were required to reduce it but there was no necessity to implement them immediately.

Shares of workers who fell sick over the 5-year period from 2012 to 2016 were similar in both groups and tended to decrease just as other parameters of morbidity with TD. In general, a number of sick workers in the Workshop No. 1 in 2012–2016 was estimated as "average" and "below average' as per E.L. Notkin's scale; in the Workshop No. 2, "below average" and "low". We compared average long-term "shares of workers who fell sick" (49.3 % in the Workshop No. 1 and 41.4 % in the Workshop No. 2) and "health index" (50.7 % in the Workshop No. 1 and 58.6 % in the Workshop No. 2) and it allowed us to detect a higher share of workers who fell sick in the test group and, consequently, lower "health index" ($\chi^2 = 11.95$, $p = 0.0005$, Chi-square).

When examining morbidity with TD, we also aimed to assess gravity of diseases; to do that, we applied such a parameter as a number of workers who frequently fell sick and remained on a sick leaf for a long period of time as well as a share of workers who were taken to in-hospital departments. Our analysis of number of workers who often fell sick and remained on a sick leaf for a long period of time revealed that there were no statistically significant discrepancies in overall number of workers who could be ranked as "frequently sick" and "frequently sick for a long time" in the test and reference groups. A share of workers who could be ranked as "sick for a long time" on average amounted to 3.1 % in the Workshop No. 1 over the examined period and it was authentically higher than in the reference group where it was equal to 1.5 % ($\chi^2 = 4.99$, $p = 0.026$, Chi-square). A share of workers who were taken to in-hospital departments amounted to 13.3 % in the Workshop No. 1 over the whole examined period and there were no statistically significant discrepancies between both groups as per this parameter as it was equal to 11.9 % among workers form the Workshop No. 2.

We also examined morbidity structure as per specific nosologies using average long-term number of TD cases and duration of TD cases in days in the Workshop No. 1; the results are shown in Figure 1. Respiratory organs diseases took the 1st rank place in morbidity with TD, both as per a number of cases and days of TD, with their specific weight being equal to 52.5 % and 40.8 % accordingly. Acute respiratory infections accounted for the highest specific weight among such nosologies, 95.9 % as per TD cases and 93.1 % as per TD days.

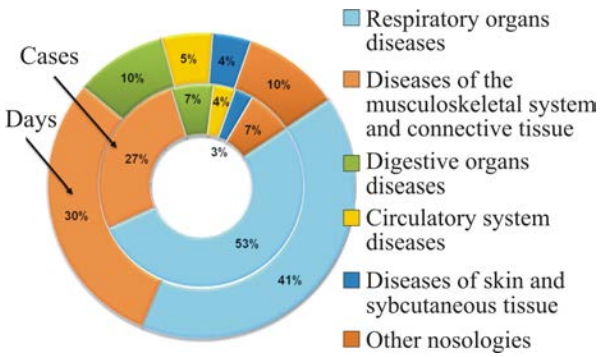

Figure 1. Structure of Td cases and TD days
In the test group over 2012–2016 (%)

The 2nd rank place belonged to diseases of the musculoskeletal system and connective tissue, their specific weight being equal to 27.1 % as per cases and 29.8 % as per TD days. Digestive organs diseases took the 3rd place both as per cases (6.7 %) and days (9.7 %).

We performed comparative assessment of morbidity with TD as per specific nosologies and it allowed us to reveal that morbidity with respiratory organs diseases was authentically higher among workers form the Workshop No. 1 than among their counterparts from the Workshop No. 2, as per TD cases ($t = 3.04$, $p < 0.05$), TD days ($t = 3.21$, $p < 0.05$) and IP ($t = 14.64$, $p < 0.05$). Calculation of RR and EF as per a number of workers who fell sick (RR 1.20 [1.04; 1.38], EF 16.5 %) also allowed detecting impacts exerted by working conditions existing in the Workshop No. 1 (the test group) on occurrence of respiratory organs diseases.

It is important to note that in spite of generally lower morbidity with TD in the Workshop No. 1 against country and branch levels, morbidity with respiratory organs diseases was authentically higher among workers from the Workshop No. 1 than in the country in general (as per cases, $t = 2.51$, $p < 0.05$; days, $t = 2.10$, $p < 0.05$; IP, $t = 11.89$, $p < 0.05$) and in the branch (as per cases, $t = 3.66$, $p < 0.05$; as per days, $t = 4.55$, $p < 0.05$; as per IP, $t = 15.59$, $p < 0.05$). Peculiarities in occurrence of respiratory organs diseases detected in the test group indicate that this pathology is an occupational one.

Morbidity with diseases in the musculoskeletal system and collective tissue were also statistically authentically higher among workers from the test group than in the country in general (as per cases, $t = 6.84$, $p < 0.05$; TD days, $t = 6.13$, $p < 0.05$; IP, $t = 19.89$, $p < 0.05$) and standards fixed for the branch (as per cases, $t = 8.66$, $p < 0.05$; TD days, $t = 3.41$, $p < 0.05$; IP, $t = 28.69$; $p < 0.05$). Workers from the test group also suffered from digestive organs diseases (as per cases, $t = 2.22$, $p < 0.05$; TD days, $t = 6.51$, $p < 0.05$; IP, $t = 5.63$, $p < 0.05$) and skin and subcutaneous tissue diseases (as per days, $t = 6.74$, $p < 0.05$; IP, $t = 3.58$, $p < 0.05$) authentically more frequently than the country population in general.

We analyzed data on morbidity with TD in both groups depending on gender differences and it allowed us to reveal the following peculiarities. Number of TD days and IP calculated for year-round female workers form the Workshop No. 1 were authentically lower than the same parameters calculated for male workers (as per days, $t = 2.77$, $p < 0.05$; IP, $t = 2.84$, $p < 0.05$). We compared the parameters in the test and reference groups and revealed that morbidity among men form the Workshop No. 1 was higher than among their counterparts from the Workshop No. 2 (as per cases, $t = 3.89$, $p < 0.05$; days, $t = 2.60$, $p < 0.05$; IP, $t = 6.32$, $p < 0.05$). On the contrary, morbidity among female workers from the test group was lower as per TD cases than among their counterparts from the reference group ($t = 2.05$, $p < 0.05$). The detected peculiarities may also indicate that registered diseases are occupational.

We examined age-related labor losses in the test and reference group and revealed that as workers' age grew, TD parameters went down in both groups. The highest morbidity in the Workshop No. 1 was registered among workers younger than 30 and was equal to 131.5 (95 % CI 115.75–147.30) TD cases per 100 workers and 958.1 (95 % CI 694.52–1,221.74) TD days per 100 workers. The lowest morbidity with TD was registered among workers aged "50 and older" and was equal to 63.5 (95 % CI 51.78–75.19) TD cases per 100 workers and 769.7 (95 % CI 543.52–995.80) TD days per 100 workers. These peculiarities revealed via analysis that took workers' age into account can be explained by activation of adaptation mechanisms in young workers who had to work in adverse working conditions.

We examined morbidity among workers as per different age groups and revealed that morbidity in the test group was authentically higher than in the reference group among workers younger than 30 (as per cases, $t = 2.86$, $p < 0.05$; IP, $t = 2.98$, $p < 0.05$); workers aged 40–49 (as per cases, $t = 2.07$, $p < 0.05$; TD days, $t = 2.12$, $p < 0.05$; IP, $t = 4.43$, $p < 0.05$); workers aged 50 and older (as per

TD days, $t = 2.33$, $p < 0.05$; IP, $t = 4.89$, $p < 0.05$). However, morbidity with TD among workers from the Workshop No. 2 aged 30–39 was higher than in the same age group in the Workshop No. 2 (as per cases, $t = 2.12$, $p < 0.05$; IP, $t = 2.59$, $p < 0.05$).

We analyzed labor losses depending on work experience and revealed that the highest morbidity in the test was detected among workers with their work experience being shorter than 5 years; it was equal to 112.6 (95 % CI 100.12–125.06) TD cases per 100 workers and 951.8 (95 % CI 728.03–1,175.57) TD days per 100 workers. As working experience became longer, morbidity with TD went down and it was minimal among workers with their work experience being 15 years and longer; it was equal to 50.5 (95 % CI 40.95–59.99) TD cases per 100 workers and 685.5 (95 % CI 502.50–870.39) TD days per 100 workers. These trends in labor losses depending on work experience are probably due to a period during which a worker's body adapted to apparent impacts exerted by adverse occupational factors and labor processes and development of compensatory mechanisms as their contacts with those adverse factors grew longer.

Comparative analysis of morbidity with TD in both groups depending on work experience revealed that it was authentically higher among workers from the test group than from the reference group for workers with their work experience being equal to 1–4 years (as per cases, $t = 2.23$, $p < 0.05$; IP, $t = 2.78$, $p < 0.05$) and 5–9 years (as per IP, $t = 2.59$, $p < 0.05$).

We calculated occupational health losses for workers from the Workshop No. 1 and No. 2 basing on average annual morbidity with TD and data on age and work experience of workers from the test and the reference group using a constant regression coefficient that characterized morbidity among workers who performed their tasks in optimal working conditions. We analyzed the obtained results and revealed that occupational health losses amounted to 32.3 % in the test group over the examined period (substantial losses, the 3rd category) and it was higher than in the reference group where they amounted to 14.9 % (acceptable losses, the 2nd category) ($\chi^2 = 523.9$, $p < 0.00001$, Chi-square).

Conclusions. Therefore, we analyzed dynamic processes and structure of morbidity with TD among workers employed at the workshop where heat-insulating materials were produced and compared the results with the reference (conventional control) group that included workers employed at the workshop where cell-concrete blocks were produced. We also compared the results with average country levels and standards fixed for the construction materials production branch; we assessed occupational risks and occupational morbidity. All that allowed us to make the following conclusions.

1. Analysis of morbidity with TD in the test group taken in dynamics over the examined 5-year period revealed an descending trend in number of TD cases that went down by 22.3 % and number of TD days that decreased by 10.0 %.

2. Morbidity with TD among workers from the test group was authentically higher than in the reference group over the whole 5-year period, by 15.0 % as per TD cases; as per TD days, by 24.3 %; as per IP, by 19.6 %. Morbidity with respiratory organs diseases was higher among workers from the Workshop No. 1 than among those from the Workshop No. 2 as per TD cases, TD days, and IP. Calculation of relative risk and etiological fraction as per a number of sick workers (RR 1.20 [1.04; 1.38], EF 16.5 %) also allowed establishing that working conditions exerted their influence on occurrence of respiratory organs diseases among workers from the test group.

3. Analysis of average long-term morbidity with TD allowed revealing statistically significantly higher number of workers who fell sick and accordingly lower "health index" in the test group against the reference one ($\chi^2 = 11.95$, $p = 0.0005$, Chi-square).

4. Morbidity with TD among workers from the test group was authentically lower as per TD days and IP than average annual morbidity taken for the country as a whole and standards fixed for construction materials pro-

duction. However, morbidity taken as per specific nosologies was statistically significantly higher in the test group than in the country and the branch as regards respiratory organs diseases, diseases of the musculoskeletal system and connective tissue; it was also higher than in the country as a whole as per digestive organs diseases and skin and subcutaneous tissue diseases.

5. RR and EF as per TD days (RR 1.24 [1.12; 1.38], EF 19.6 %) and as per a number of sick workers (RR 1.17 [1.09; 1.26], EF 14.8 %) indicate that morbidity with TD was statistically authentically higher in the test group than in the reference group. Occupational risk index indicates that occupational risk in the test group is moderate and specific measures are required to reduce it but it is not necessary to implement them immediately. Average long-term occupational health losses amounted to 32.3 % in the test group (substantial losses, the 3rd category) and it was higher than in the reference group where they amounted to 14.9 % (acceptable losses, the 2nd category) ($\chi^2 = 523.9$, $p < 0.00001$, Chi-square).

6. Overall number of workers who were ranked as "frequently sick" and "frequently sick for a long time" didn't have any discrepancies in the test group against the reference one; but an average long-term share of year-round workers from the Workshop No. 1 who were considered "sick for a long time" was authentically higher than in the reference group ($\chi^2 = 4.99$, $p = 0.026$, Chi-square). A share of workers form the Workshop No. 1 taken to in-hospital departments didn't have any statistically significant discrepancies from a number of TD cases that involved a worker from the reference group being taken to an in-hospital department.

7. Morbidity with TD in the test group had gender-related differences. Detected peculiarities could also indicate that registered diseases were occupational.

8. Morbidity with TD in the test group depended on a worker's age and work experience. As age and work experience grew, morbidity with TD tended to decrease; it is due to activation of adaptation mechanisms in young workers who had to work in adverse working conditions and development of compensatory mechanisms as their contacts with adverse factors grew longer.

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DESCRIPTION OF BIOLOGIGAL FACTOR IN OCCUPATIONAL ENVIRONMNET OF MEDICAL ORGANIZATIONS THAT CAUSES RISKS OF HOSPITAL-ACQUIRED INFECTIONS

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There is a pressing issue related to biological factors that influence medical workers' health and cause risks of hospital-acquired infections including those occurring among patients. Given that, we applied conventional techniques to perform microbiological examinations aimed at detecting and identifying microorganisms that circulate in the air inside hospitals. Microorganisms detected in the air in areas where medical personnel performed their working tasks were identified with chromogenic nutrient media and microbiological analyzers. To fully characterize microorganisms, we performed certain tests that allowed determining how sensitive the detected strains were to common antibacterial preparations.

As a result, we revealed that priority strains detected in the air inside medical organizations were those belonging to Staphylococcaceae and Micrococcaceae families. These microorganisms caused high risks of purulent septic infections. We also detected bacteria that belonged to normal human microflora such as Acinetobacterspp. and Streptococcusspp., as well as gram-negative bacteria, notably Stenotrophomonasmaltophilia, Ochrobacteriumspp., Pantoeaspp., and Pausterellaspp.

Staphylococcusspp. and Micrococcusspp. turned out to be resistant to oxacillin and erythromycin; gram-negative bacteria, to ceftazidime and amikacin; non-fermentative bacteria and Enterobacteriaceae family, to a combination of antibacterial preparation. It proves there is a necessity to examine qualitative properties of biological factors existing in medical organizations. We revealed that Streptococcusspp. were strongly resistant to ampicillin, clindamycin, imipenem, and cefepime; Acinetobacterspp., strongly resistant to cephalosporin (ceftazidime, cefepime), and they were moderately resistant to monobactam (aztreonam); Stenotrophomonasmaltophilia, to ceftazidime and aztreonam, and in certain cases, to cefepime, amikacin, imipenem, gentamicin, and ciprofloxacin; Ochrobacteriumspp., to cefepime, aztreonam, ciprofloxacin, amikacin, gentamicin, imipenem, and ceftazidime; Pantoeaspp. and Pausterellaspp. tended to have various resistance. All it means that the given strains circulating in the air inside medical organizations are more resistant than they are considered to be according to literature data.

Key words: *microorganisms, air, biological factor, medical workers, resistance to antibiotics, microbiological examinations, antibiotics, medical organizations, hospital-acquired infections, resistance of microorganisms.*

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Biological factor or a biological agent is a spectrum of microorganisms, pathogenic and opportunistic pathogenic bacteria, viruses, fungi, helminthes, protozoa, live cells, spores, etc., that exert adverse impacts on human health.

Microbiological monitoring over species of infectious agents and their resistance to antibacterial preparations that is performed in medical organizations is a reliable tool for assessing this biological factor and its qualitative properties; it should be done in order to determine its influence on medical personnel and to select proper antimicrobial therapy for patients in a specific medical organization [1].

In the past antibacterial preparations were frequently used rather irrationally (they were admitted to be prescribed to patients unreasonably in 50–70 % in Canada, the USA, and Vietnam) [2]; antibiotics have been widely used in animal breeding; there has been an activation of adaptation mechanisms in in-hospital bacterial communities as they mutate and transfer extrachromosomal in heritance factors to each other. All these events result in a persistent growth in resistance of various infectious agents and circulation of resistant strains in medical organizations causing occupational diseases among medical personnel and hospital-acquired infections among patients [3, 4].

Over the last years there have been a lot of changes in the structure of etiologically significant agents that cause infections, purulent diseases, and postoperative diseases; at present a number of such species is growing, and there are changes in microorganisms' properties that cause postoperative and post-injection complications; poly-etiologic diseases are becoming more and more widely spread among purulent and septic infections including hospital-acquired ones [1].

Circulation of resistance to antibiotics among opportunistic pathogenic in-hospital strains is becoming more and more pressing in spite of certain activities being accomplished at the moment [5, 6]. Nowadays resistance to antibacterial preparations is considered to be an objective sign of genotypic and phenotypic peculiarities of a specific microorganism that causes a biological risk of hospital-acquired infections and occupational diseases [3].

Data and methods. Our goal was to examine properties of a biological factor existing in medical organizations. To do that, we accomplished microbiological examinations of air inside medical organizations in Kazan within state surveillance performed by the Federal Service for Surveillance over Consumer Rights Protection and Human Well-being. Air samples were taken prior to a working shift started and during it according to MG 4.2.2942-11 "Procedures for sanitary-bacteriological examinations of environmental objects and air and for controlling sterility in medical organizations"[1]. Microorganisms extracted from air inside treatment rooms in different medical organizations were identified up to their species ($n = 62$). Identification was performed with chromogenic nutrient media produced in India and Spain and tests with microbiological analyzers produced in Czech Republic and France. We applied the disk diffusion test to check how sensitive microorganisms were to antibacterial preparations according to MG 4.2.1890-04 "Determining sensitivity of microorganisms to antibacterial preparations"[2].

Results and discussion. Figure 1 shows the structure of microorganisms that were extracted from air inside medical organizations.

The given data make it obvious that microorganisms from Staphylococcus species prevailed in microflora existing in medical

[1] MG 4.2.2942-11. Procedures for sanitary-bacteriological examinations of environmental objects and air and for controlling sterility in medical organizations. Moscow, The Rospotrebnadzor's Federal Center for Hygiene and Epidemiology, 2011, 12 p.

[2] MG 4.2.1890-04. Determining sensitivity of microorganisms to antibacterial preparations. Methodical guidelines. Moscow, The Federal Center for State Sanitary and Epidemiologic Surveillance of the RF Public Healthcare Ministry, 2004, 91 p.

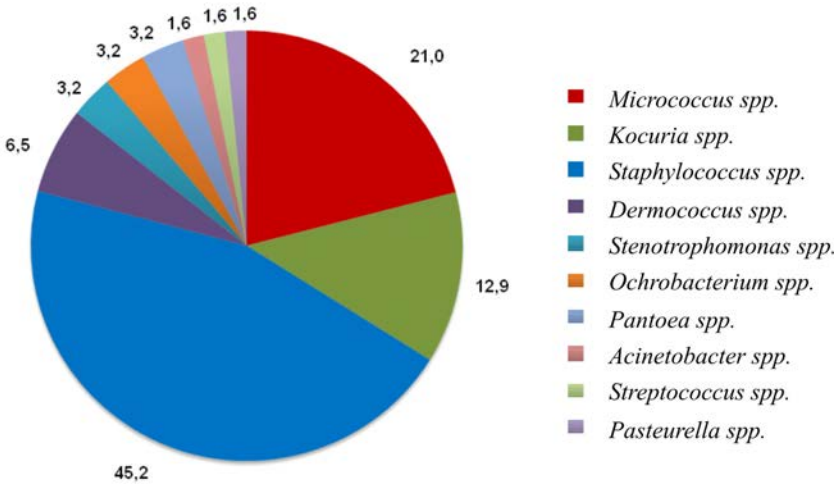

Figure 1. The structure of microorganisms that were extracted from air inside medical organizations (%)

organizations in Kazan as there were totally 28 strains such as S.hominis (11.3 %), S. epidermidis (9.7 %), S. haemolyticus (8.1 %), S.saprophyticus (4.8 %), S.aureus (1.6 %) and some others (6.4 %). Data on Staphylococcus resistance were different for different medical organizations; in most cases such difference, as Afanasiev et al. think (2014), is due to a policy on how to apply antibacterial preparations.

When we characterize a biological factor in a medical organization, we should note that Staphylococcus spp. were resistant to Erythromycin (in 50 % cases), Oxacillin (in 28.6 % cases), and to Fluoroquinolones (up to 7.1 % cases). It results in a high risk of infections caused by resistant strains including Methicillin-resistant Staphylococcus aureus (MRSA). Catalase-positive cocci belonging to this stem were the most sensitive to Vancomycin, Clindamycin, and Gentamicin (96.4–100 % cases). Our data are consistent with research works accomplished by most authors in the field who established that Staphylococcus spp. is resistant to Erythromycin and Oxacillin and sensitive to Vancomycin and Clindamycin [7–10]. Resistance to Oxacillin that has been examined by many experts is a marker showing that a Staphylococcus has a Penicillin-binding protein. There is an assumption based on research data that there are genetic data reservoirs for S.aureus coagulase-negative S.haemolyticus and S.epidermidis due to genes determining resistance to antibiotics being widely-spread in the population [3].

High resistance of Staphylococci to Oxacillin as a marker showing there is MRSA (Methicillin Resistant Staphylococcus Aureus) proves that all β-lactams are inefficient for treating infections caused by the given microorganisms and that it is necessary to develop more efficient therapeutic and anti-epidemic activities accomplished in medical organizations [1, 10].

Together with Staphylococcus spp., bacteria from Micrococcaceae family accounted for a considerable share among detected microorganisms (40.4 %). Micrococcusspp., that are frequently extracted from objects located inside medical organizations according to foreign experts [11–13], in all cases were sensitive to Ciprofloxacin and Clindamycin, not so frequently to Vancomycin, Levofloxacin, and Gentamicin (in 92.3 % cases), and Erythromycin (84.6 %) and they were resistant to Oxacillin (69.2 % strains). This fact proves that microflora circulating inside medical organizations is normal and highly resistant to Oxacillin; it requires further investigations of biological risks related to infections caused by Micrococcusspp.

There are representatives from Kocuriaspp. family that, in foreign researchers' opinion, cause catheter-associated endocarditic, urinary tract infections, peritonitis, and other

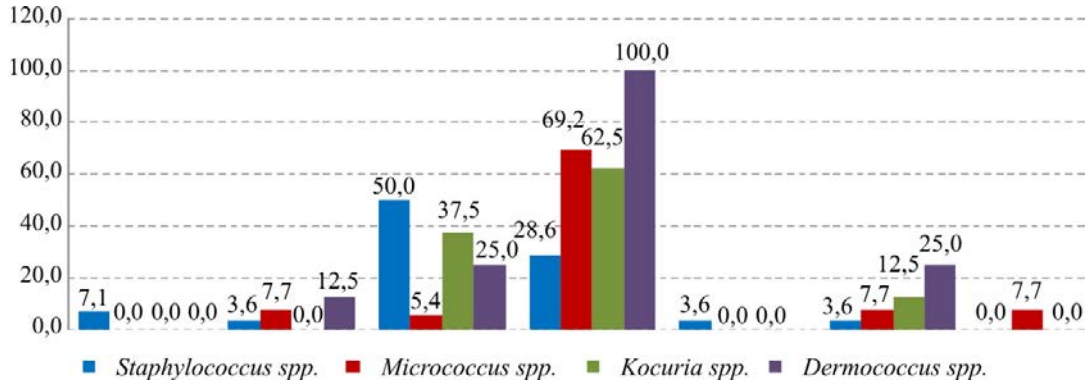

Figure 2. Specific weight of certain microorganisms' strains extracted from air that are resistant to antibacterial preparations (%)

purulent and septic infections and are resistant to [14–16] Fluoroquinolones, Tetracycline, Oxacillin, and Cefazoline and intermediately resistant to Cefotaxime [17]; in our research they turned out to be the most resistant to Oxacillin (62.5 % cases), Erythromycin (37.5 % cases), and were rarely resistant to Fluoroquinolones (12.5 % to Levofloxacin). Occurrence of Oxacillin-resistant strains inside hospitals creates a biological risk of infections caused by Methicillin-resistant microorganisms.

Other bacteria from Micrococcaceae–Dermacoccusspp. family extracted from air in 4 cases were also the most resistant to Oxacillin (resistance in all 4 cases), Erythromycin (in 1 case), and Levofloxacin (in 1 case). Data on Dermacoccus being sensitive to antibiotics are rarely found in literature sources available to us; however, there was a research work accomplished in Poland (2003) where the author showed that bacteria from this stem were resistant to Erythromycin [18].

Similar to other researchers' results, Streptococcusmitis, extracted from air in one case, was resistant to Ampicillin, Clindamycin, Imipenem, and Cefepime and sensitive to Vancomycin and Levofloxacin [3, 7]. As per data acquired by Afanasiev et al (2014), various resistances to Penicillin preparations as well as to Cephalosporin develop in Streptococcus due to lower affinity of Penicillin-binding proteins caused by mutations in bacteria's genome. It has been proven that interspecies transfer of genetic material occurring between commensal species of Streptococcus and S. pneumonia stems contributes to selection and creation of Penicillin-resistant strains of the latter [3].

Over the last years, gram-negative non-fermenting bacteria have been occupying the second place among agents causing different infections, including hospital-acquired ones, right after gram-positive cocci as it has been confirmed by our research [19].

When we characterize a biological factor that can cause HAI occurrence, we should note that gram-negative organisms that are a part of normal human microflora, such as Acinetobacterspp., extracted from air inside medical organizations, were sensitive to Ciprofloxacin (57.1 %), Amikacin, Imipenem, and Gentamicin, were moderately resistant to Monobactam (Aztreonam) and highly resistant to Cephalosporin (Ceftazidime and Cefepime). Research works performed by many authors prove that Acinetobacterspp. Extracted from human biological materials are the most resistant to Cephalosporin [19, 20]. We didn't reveal resistance to Carbapenem and Monobactam in this stem though it was previously detected by various authors in 35.6 % – 70.5 % bacteria belonging to various human biotopes [1, 6, 9, 19, 21]. Occurrence of resistant microorganisms from the given stem can cause infections both among medical personnel and patients.

Other gram-negative non-fermenting bacteria such as Stenotrophomonasmaltophilia that have been examined in multiple foreign research works are agents that cause hospital-

acquired infections and are poly-resistant to antibiotics, including Cephalosporin [22]. In both cases in our research they turned out to be resistant to Ceftazidime and Aztreonam; in one case, to Cefepime, Amikacin, Imipenem, Gentamicin, and Ciprofloxacin. As opposite to the research accomplished by HuangY.W. et al. (2017), we revealed that in both cases this microorganism was sensitive only to Erythromycin [23].

Ochrobacteriumspp., that have low virulence for healthy people and high one for those with weak immunity [8, 24], were extracted from air in medical organizations in tow cases. One strain was resistant to antibacterial preparations in all cases (Cefepime, Aztreoname, Ciprofloxacin, Amikacin, Gentamicin, Imipenem, and Ceftazidime); the other was resistant only to Amikacin. Pantoeaspp. and Pausterellaspp. that cause various diseases have been given a lot of attention by researchers in Europe and America; in our research they were revealed to have different resistance to antibacterial preparations. In one case we detected that Pantoeaspp. was resistant to Ampicillin, Ceftazidime, Amikacin, and Imipenem [25, 26]. The fact that the given strains are poly-resistant proves it is necessary to perform further investigations of this biological factor that exerts its influence on medical personnel and patients in hospitals.

Conclusions

1. Priority microorganisms extracted from air in medical organizations in Kazan in 2016 were bacteria from Staphylococcaceae (45.2 %) and Micrococcaceae (40.4 %) families;

2. Staphylococcusspp. and Micrococcusspp. were most resistant to Oxacillin (28.6 % – 100.0 % cases) and Erythromycin (5.4–50.0 %). Gram-negative bacteria extracted from air in medical organizations in rare cases were most resistant to Ceftazidime (Acinetobacterspp., Stenotrophomonasspp., and Pantoeaspp.) and Amikacin (Ochrobacteriumspp and Pantoeaspp.); several non-fermenting bacteria and bacteria from Enterobacteriaceae family tended to be resistant to different combinations of antibacterial preparations;

3. Occurrence of strains that are resistant to various antibacterial preparations and circulate in air inside medical organizations causes a high biological risk of hospital-acquired infections and occupational diseases among medical personnel including infections caused by MRSA (Methicillin-resistant Staphylococcus aureus).

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INFLUENCE EXERTED BY BIOLOGICAL AND SOCIAL RISK FACTORS ON MORBIDITY WITH TICK-BORNE ENCEPHALITIS IN SOME REGINS IN THE URALS FEDERAL DISTRICT

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Tick-borne encephalitis (TBE) as an infectious disease remains a significant issue in the Urals Federal District (the UFD). To correctly describe impacts exerted by risk factors on TBE epidemic process, it is necessary to analyze both common and individual peculiarities related to how TBE epidemic process develops on endemic administrative territories.

We assessed impacts exerted by biological and social factors on morbidity with TBE in four endemic regions in the UFD (Sverdlovsk, Chelyabinsk, Tyumen, and Kurgan regions) over 2007–2017.

To quantitatively assess contributions made by specific factors into morbidity with TBE, we calculated chances for people who suffered tick bites to fall ill with TBE; it allowed us to apply standard procedures within generalized linear models theory (GLM), namely logistic regression. Our analysis included aggregated data on quantity of people who were bitten by ticks and fell will with TBE in all the examined regions. We also assessed data for each specific region as all these endemic territories had both common and specific regularities related to TBE endemic process development.

We showed statistically significant impacts exerted by specific manageable risk factors (vaccination, immune prevention, and acaricide treatment performed on a territory) on a possibility of TBE occurrence among people bitten by ticks on endemic territories. The examined UFD regions differ as per effects produced by natural and social risk factors on TBE development. Mass vaccine prevention is a key factor in the control over morbidity with the disease.

Risk-oriented approach provides significant additional data for analyzing an epidemiological situation and planning efficient preventive activities in TBE natural foci.

Key words: *tick-borne encephalitis, the Urals federal District, logistic regression, morbidity, odds ratio, natural and social risk factors, statistical modeling, specific prevention.*

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Domestic and foreign scientists have managed to achieve excellent results in examining epidemic processes occurring in natural foci infections and their determinants. Despite that, tick-borne encephalitis (TBE) is a still persisting transmissible infection transmitted by ticks.

48 out of 85 regions in the Russian Federation (RF) are endemic as per TBE [1]. The Urals Federal District remains a territory where the situation with TBE is the worst as most administrative regions included into it have high morbidity with TBE among their population. Over the last years the structure of this morbidity has been changing as large foci have occurred due to urban population being infected; the endemic process has been involving new groups of employable population [2]. TBE has ceased to be a solely occupational disease which was typical for workers with specific (forest-related) occupations [3].

Endemic regions located on huge areas in Russia and intra-regional foci differ both as per cyclic nature of morbidity and a risk for population to catch TBE virus. It makes it necessary to work out a differentiated approach to determining administrative territories and a set of anti-epidemic activities [4].

TBE epidemic process is a complicated and multifactor phenomenon. There are several factors that are conventionally considered to determine morbidity with TBE: they are number of ticks, dynamics in number of ticks-feeding animals, spread of contamination among carriers, vaccination scopes, efficiency of immune prevention and acaricide treatments, changes in the structure of reservoir animals, as well as climatic and heliogeophysical (solar activity) conditions [5–10].

Correct description of impacts exerted on TBE epidemic process by the above-mentioned factors as well as by any other unaccounted ones requires analyzing general and regional regularities in epidemic process development for endemic administrative territories [11].

Our research goal was to assess effects produced by natural and social risk factors on morbidity with TBE in Sverdlovsk, Chelyabinsk, Tyumen, and Kurgan regions in 2007–2017.

Data and methods. We analyzed morbidity with TBE among people living in Sverdlovsk, Chelyabinsk, Tyumen (without autonomous areas), and Kurgan regions in 2007–2017 basing on data taken from the Form No. 2 of the State Statistical Reports which is called "Data on infectious and parasitic diseases"[1]. We also analyzed data from annual reports issued by Rospotrebnadzor regional offices over the same period on sanitary-epidemiologic welfare of the population, specifically: people applying for medical aid after they had been bitten by ticks; number of vaccinated and revaccinated people and people who were injected with anti-tick immunoglobulin as emergency prevention. We assessed a share of infected ticks as well as data on acaricide treatment scopes in the examined regions.

In order to quantitatively assess contributions made by specific risk factors into morbidity with TBE, we calculated what chances there were for people who had been bitten by ticks to fall sick with TBE. These chances were a ratio of a number of sick people (N_1) to the overall number of people who had been bitten but didn't fall sick after it (N_0). It allowed us to apply such a standard tool of generalized linear models (GLM) [12] as logit regression:

$$Ln\ (N_1/N_0) = b_0 + \Sigma b_i X_i. \qquad (1)$$

We assessed effects produced by the following predictors (X_i): a region (Sverdlovsk, Chelyabinsk, Tyumen, or Kurgan region); number of vaccinated and revaccinated people; a per cent of people who were injected with anti-tick immunoglobulin; a share of infected ticks in natural populations; and an area where there were acaricide treatments against the overall territory of a region (в ‰). Uninterrupted variables which were measured with

[1] Form No. 2 "Data on infectious and parasitic diseases". *Medicine & Practice: Practical application of regulatory documents in public healthcare*. Available at: http: //mpraktik.ru/forma-2-svedeniya-ob-infekcionnyx-i-parazitarnyx-zabolevaniyax/ (date of visit June 18, 2019).

different scales were standardized (we centered them with a mean value and standardized with standard deviation). As a result, all uninterrupted variables were reduced to a more convenient dimensionless scale. A zero value at the transformed scale corresponded to a simple mean in an initial data series. And here a free member in a regression equation became interpreted and gave a possibility to estimate an expected value of a dependent variable when all the predictors were equal to zero (to mean values for uninterrupted signs).

Odds ratios (*OR*) and their confidence intervals (95 % CI) were given after the following transformation: $OR = \exp(b_i)$ or $OR = 1/\exp(b_i)$, where b_i are logit regression parameters (odds ratio logarithms).

As both common and individual regularities related to TBE epidemic process development are typical for endemic territories, we needed to raise statistic reliability of logit regression results; to do that, we jointly analyzed data on the examined regions as well as gave results for each specific one.

We statistically processed and visualized all the obtained results with "Statistica v. 10.0" applied software (StatSoft, Ink) and the statistical medium R (v. 3.4.4) [13].

Results and discussion. We created statistical models showing TBE probability for people who had been bitten by ticks with multiple logit regression. It allowed us to estimate a specific effect produced by each factor together with performing control over effects produced by other predictors. Overall, almost all effects turned out to be statistically significant for four regions in the Urals Federal District (UFD), namely, Sverdlovsk, Chelyabinsk, Tyumen, and Kurgan region, excluding only a share of ticks infected with TBE (Table 1).

Prevailing predictors (risk factors given with descending significance) are the following: "Acaricide treatments"; "Number of vaccinated and revaccinated people"; "A share of bitten people who were injected with Ig". When a square where acaricide treatments took place increased by a standard deviation (0.19 ‰ from the overall territory of a region), a person who had been bitten by a tick ran 1.4 times lower risk to fall sick with TBE (confidence interval (CI): 1.26–1.45) (Figure 1–D). If a number of vaccinated and revaccinated people grew by 308 thousand people (one standard deviation), a person who had been bitten by a tick ran 1.21 times lower risk to have TBE (CI: 1.18–1.25). Should a number of vaccinated and revaccinated people exceed one million, chances to get TBE would decrease by 2 times on the examined territory, CI (CI): 1.78–2.18 (Table 1 and Figure 1–A).

Provided that a number of people who were provided with emergency immune prevention increased by 21 % (a limit of one standard deviation), chances to get TBE would fall by 1.2 times with CI: 1.16–1.25 (Table 1 and Figure 1–B). Overall, our calculations revealed that a share of ticks infected with TBE didn't exert any significant impacts on TBE probability on all the examined territories (totally).

Table 1

Assessing impacts exerted by risk factors on TBE probability for people bitten by ticks in the UFD in 2007–2017 (logit regression: LR (4) = 767.24; $p < 0.0001$)

Predictor	*b*	*SE (b)*	*Z-Wald statistics*	*p-value*	*Odds ratio*		
					OR	*95 % CI*	
b_0	**– 5.00**	**0.02**	**– 322.48**	**< 0.0001**	–	–	–
Кол-во V и RV	**– 0.19**	**0.01**	**– 13.42**	**< 0.0001**	**1.21**	**1.18**	**1.25**
					1.94®	**1.78®**	**2.18®**
% people who got Ig	**– 0.18**	**0.02**	**– 10.35**	**< 0.0001**	**1.20**	**1.16**	**1.25**
A share of TBE-infected ticks	0.01	0.02	0.91	0.37	1.02	0.98	1.05
Acaricide treatments (‰)	**– 0.34**	**0.02**	**– 19.41**	**< 0.0001**	**1.40**	**1.36**	**1.45**

N o t e : b_0 is a free member; *V* is a number of vaccinated people, *RV*, revaccinated; ® – odds ratio, when *V* and *RV* quantity grows by 3.5 standard deviations (provided that more than 1 million people are vaccinated); *LR* (*df*) likelihood ratio test, with degrees of freedom number being equal to a number of factor in a model

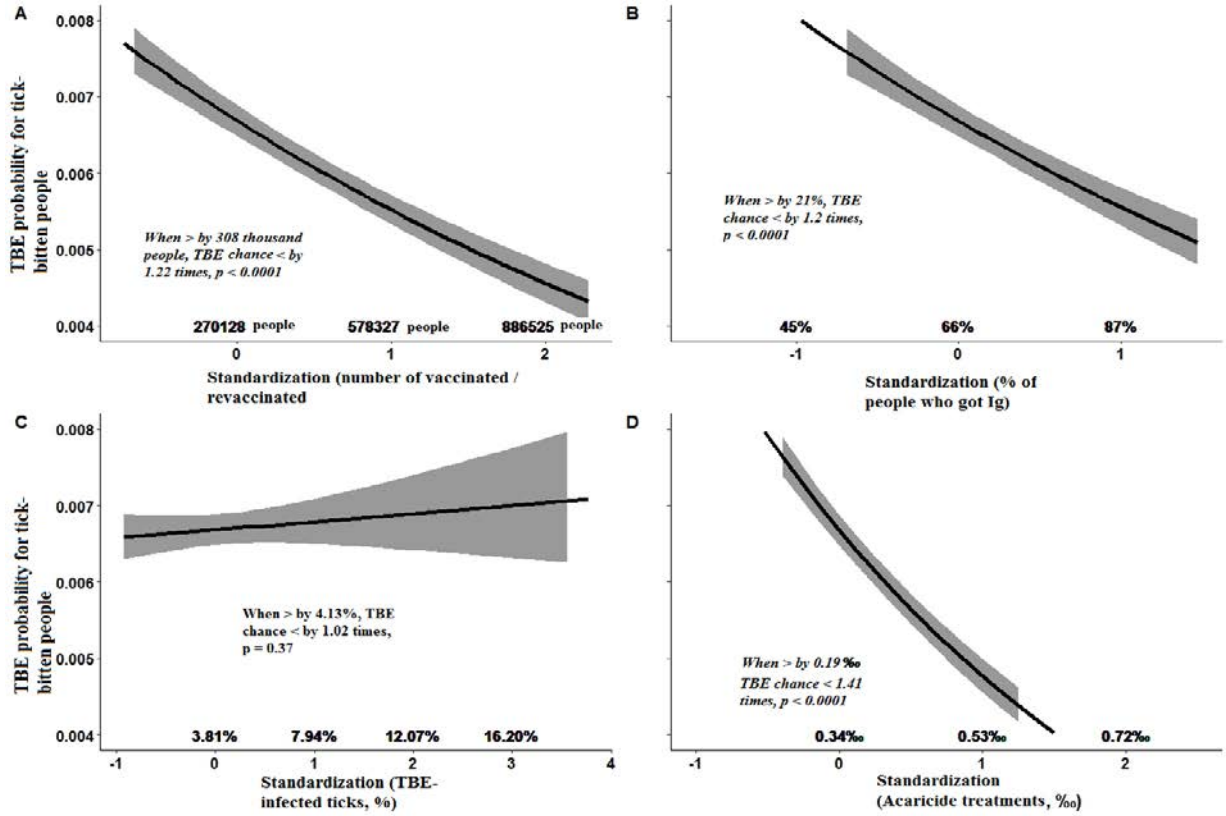

Figure 1. Impacts exerted by risk factors on TBE occurrence among tick-bitten people in the UFD regions in 2007–2017

We created statistical models for an epidemiologic situation in a specific region and revealed that TBE probability for people living in Sverdlovsk region who had been bitten by ticks was substantially associated with vaccination and acaricide treatments scopes. Should squares exposed to acaricide treatments increase by one standard deviation (0.1 ‰ of the overall region territory); than a chance that the disease occurred would go down by 1.26 times (CI: 1.20–1.33; Table 2 and Figure 2–D). Should a number of people vaccinated against TBE grow by 141 thousand, TBE probability would go down by 1.09 times (Figure 2–A). Should a number of vaccinated people increase up to 1 million people (more than by two standard deviations), TBE probability would decrease by 1.19 times (Table 2).

In Chelyabinsk region, similar to Sverdlovsk region, vaccination and acaricide treatments scopes were the primary factors influencing TBE probability. We should note that the said predictors had a more apparent positive effect. Thus, if a number of people who had been vaccinated and revaccinated increased by 23 thousand people (Figure 3–A), TBE probability dropped by 1.2 times. Should a number of vaccinated people reach 210 thousand people (two standard deviations), a share of those who fell sick with TBE would decrease by 1.44 times. If squares exposed to acaricide treatments increased by 0.15 ‰, TBE probability would fall by 1.32 times (Table 2, Figure 3–D).

The situation existing in Tyumen region was rather opposite to those in Sverdlovsk and Chelyabinsk regions. As per our calculations, we determined that a share of infected ticks and emergency immune prevention were the primary predictors there. Vaccination and acaricide treatments didn't exert any statistically significant impacts on a growth or fall in TBE probability. Over 11 years a number of vaccinated people in Tyumen region was several times lower than in Sverdlovsk and Chelyabinsk regions (68 thousand people against 780 and 164 thousand accordingly). Probably, it was this fact that determined ab-

sence of any statistically significant effects produced by vaccination on TBE probability on this territory (Table 2, Figure 4–A). A wide scope of emergency immune prevention is quite typical for Tyumen region as on average over 11 years 93 % people who had been bitten by ticks got injected with anti-tick Ig. Should this figure grow by 4 % (one standard deviation and a probable limit for the predictor effect to level out when it has been reached), TBE probability in Tyumen region would go down further by 1.1 times. Average share of infected ticks amounted to 2.77 % (data collected in 2007–2017); a further increase in the parameter by 1.37 % would result in a 1.13 time growth in number of people sick with TBE (Table 2, Figure 4–C).

In Kurgan region the existing situation is the most adverse at present as regards morbidity with TBE. Average long-term morbidity (per 100 thousand people) is 1.3–2.6 times higher than in other regions (7.82 $^{0}/_{0000}$). As per predictive estimates only effects produced by acaricide treatments can influence morbidity with TBE and somehow reduce it. Should squares exposed to such treatments increase by 0.05 ‰, TBE probability would go down by 1.6 times (Table 2, Figure 5–D). A share of infected ticks which was 6.44 % on average over 11 years was also the highest in Kurgan region. Should there be a rise in a share of infected ticks by 4.23 %, we can expect a 1.13-time growth in number of people who fall sick with TBE (Figure 5–C).

Table 2

Assessment of impacts exerted by risk factors on TBE probability for people bitten by ticks in four UFD regions in 2007–2017 (logit regression)

Predictor	*b*	*SE (b)*	*Z-Wald statistics*	*p-values*	*Odds ratio*		
					OR	*95 % CI*	
Sverdlovsk region; LR (4) = 83.52; $p < 0.0001$							
b_0	**– 5.39**	**0.02**	**– 216.06**	**< 0.0001**	—	—	—
Number of V and RV	**– 0.09**	**0.03**	**– 3.08**	**0.002**	**1.09**	**1.03**	**1.15**
					1.19®	**1.06®**	**1.32®**
% of bitten people who got Ig	0.02	0.03	0.88	0.38	1.03	0.97	1.08
A share of infected ticks	0.03	0.03	0.97	0.33	1.03	0.97	1.08
Acaricide treatments (‰)	**– 0.23**	**0.03**	**– 8.87**	**< 0.0001**	**1.26**	**1.20**	**1.33**
Chelyabinsk region; LR (4) = 60.68; $p < 0.0001$							
b_0	**– 5.29**	**0.03**	**– 170.72**	**< 0.0001**	—	—	—
Number of V and RV	**– 0.18**	**0.04**	**– 4.59**	**< 0.0001**	**1.20**	**1.11**	**1.30**
					1.44®	**1.12®**	**1.69®**
% of bitten people who got Ig	0.003	0.05	0.06	0.95	1.00	0.91	1.11
A share of infected ticks	0.02	0.04	0.52	0.60	1.02	0.94	1.10
Acaricide treatments (‰)	**– 0.28**	**0.06**	**– 4.31**	**< 0.0001**	**1.32**	**1.16**	**1.50**
Tyumen region; LR (4) = 46.07; $p < 0.0001$							
b_0	**– 5.11**	**0.03**	**– 148.86**	**< 0.0001**	—	—	—
Number of V and RV	– 0.15	0.10	– 1.44	0.15	1.16	0.95	1.41
% of bitten people who got Ig	**– 0.10**	**0.05**	**– 2.11**	**0.04**	**1.10**	**1.01**	**1.20**
A share of infected ticks	**0.12**	**0.04**	**3.13**	**0.002**	**1.13**	**1.05**	**1.22**
Acaricide treatments (‰)	– 0.01	0.10	– 0.05	0.96	1.01	0.83	1.23
Kurgan region; LR (4) = 125.81; $p < 0.0001$							
b_0	**– 4.36**	**0.04**	**– 100.07**	**< 0.0001**	—	—	—
Number of V and RV	**0.18**	**0.06**	**2.85**	**0.004**	**1.20**	**1.06**	**1.36**
% of bitten people who got Ig	**0.11**	**0.04**	**2.62**	**0.01**	**1.12**	**1.03**	**1.21**
A share of infected ticks	**0.12**	**0.05**	**2.59**	**0.01**	**1.13**	**1.03**	**1.23**
Acaricide treatments (‰)	**– 0.47**	**0.05**	**– 9.39**	**< 0.0001**	**1.59**	**1.45**	**1.77**

N o t e : b_0 is a free member; *V* means vaccinated people, *RV* means revaccinated; ® – odds ratio, when *V* and *RV* quantity grows by 2 standard deviations (provided that more than 1 million people are vaccinated); *LR* (*df*) likelihood ratio test, with degrees of freedom number being equal to a number of factor in a model

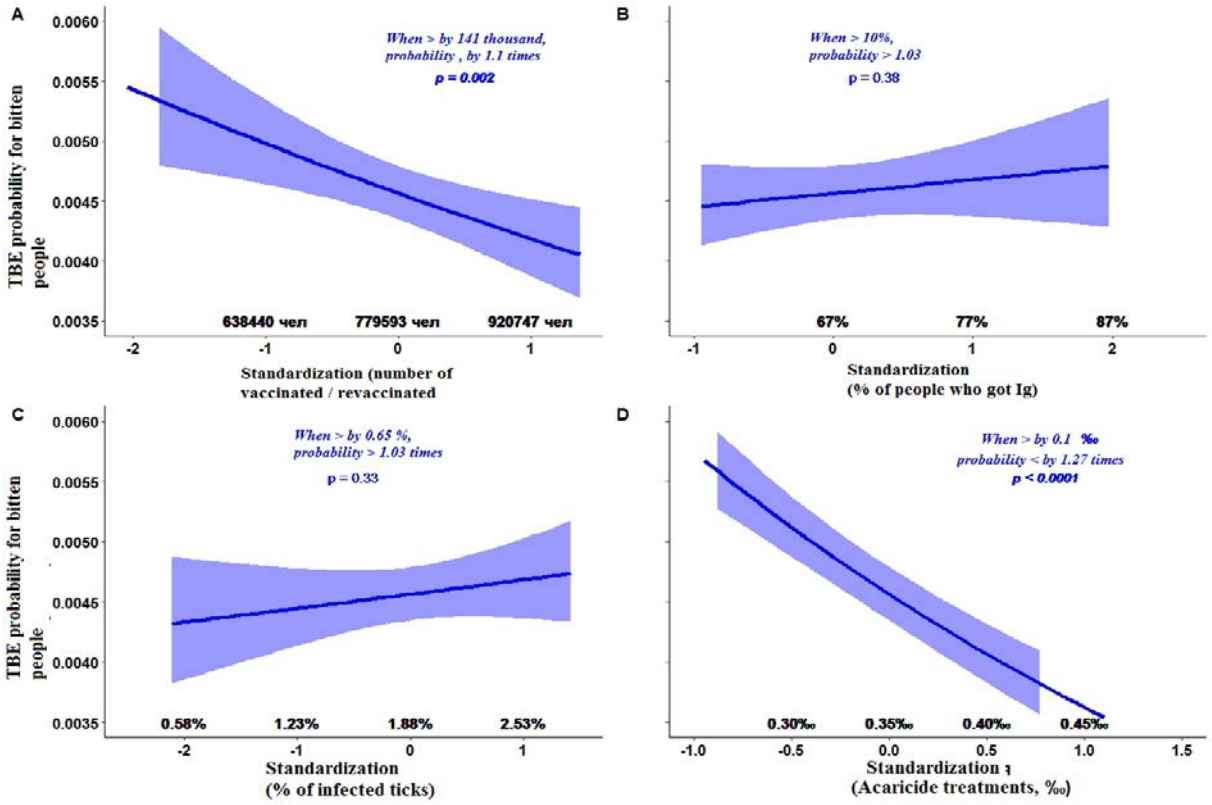

Figure 2. Impacts exerted by risk factors on TBE occurrence among people bitten by ticks in Sverdlovsk region in 2007–2017

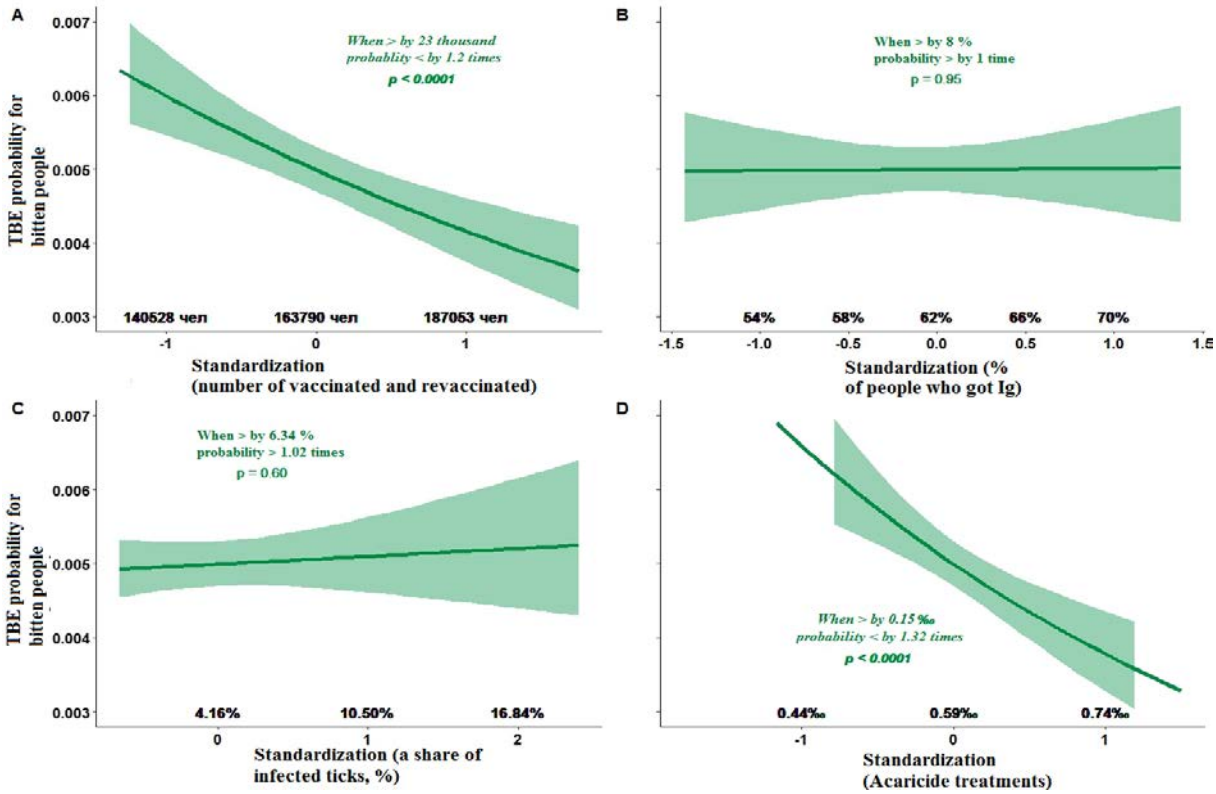

Figure 3. Impacts exerted by risk factors on TBE occurrence among people bitten by ticks in Chelyabinsk region in 2007–2017

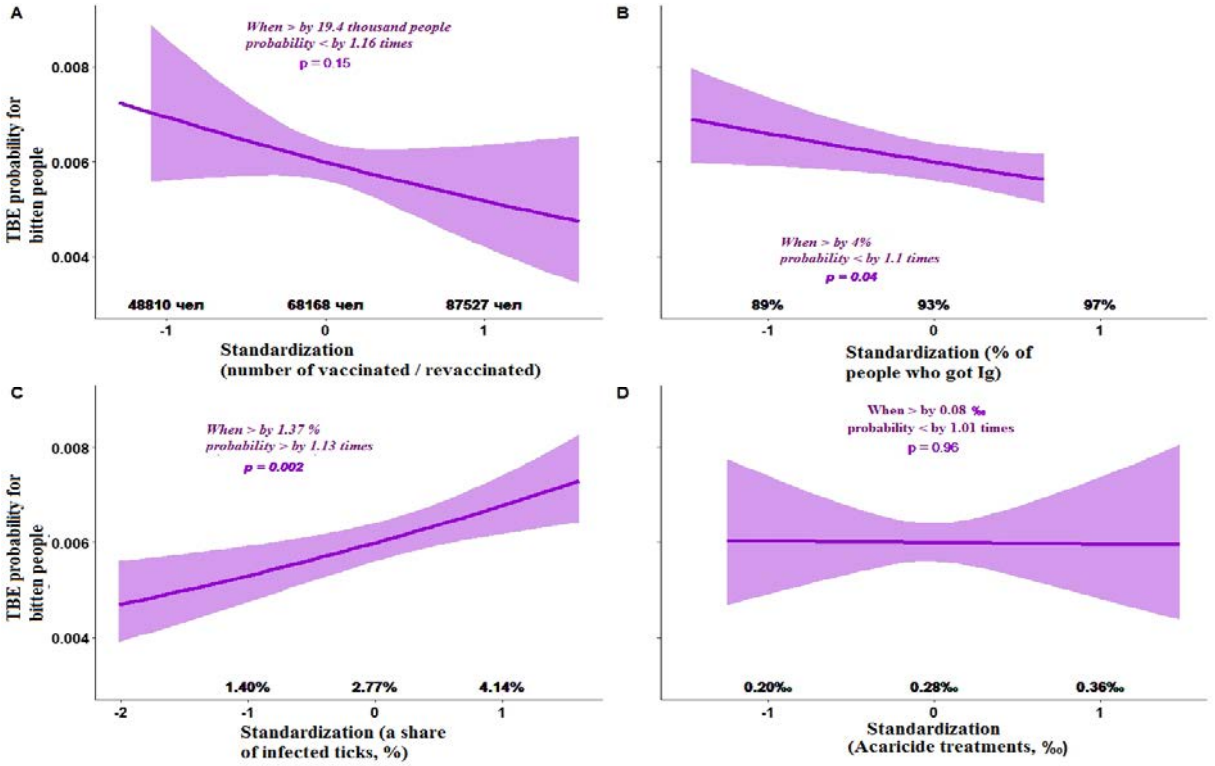

Figure 4. Impacts exerted by risk factors on TBE occurrence among people bitten by ticks in Tyumen region in 2007–2017

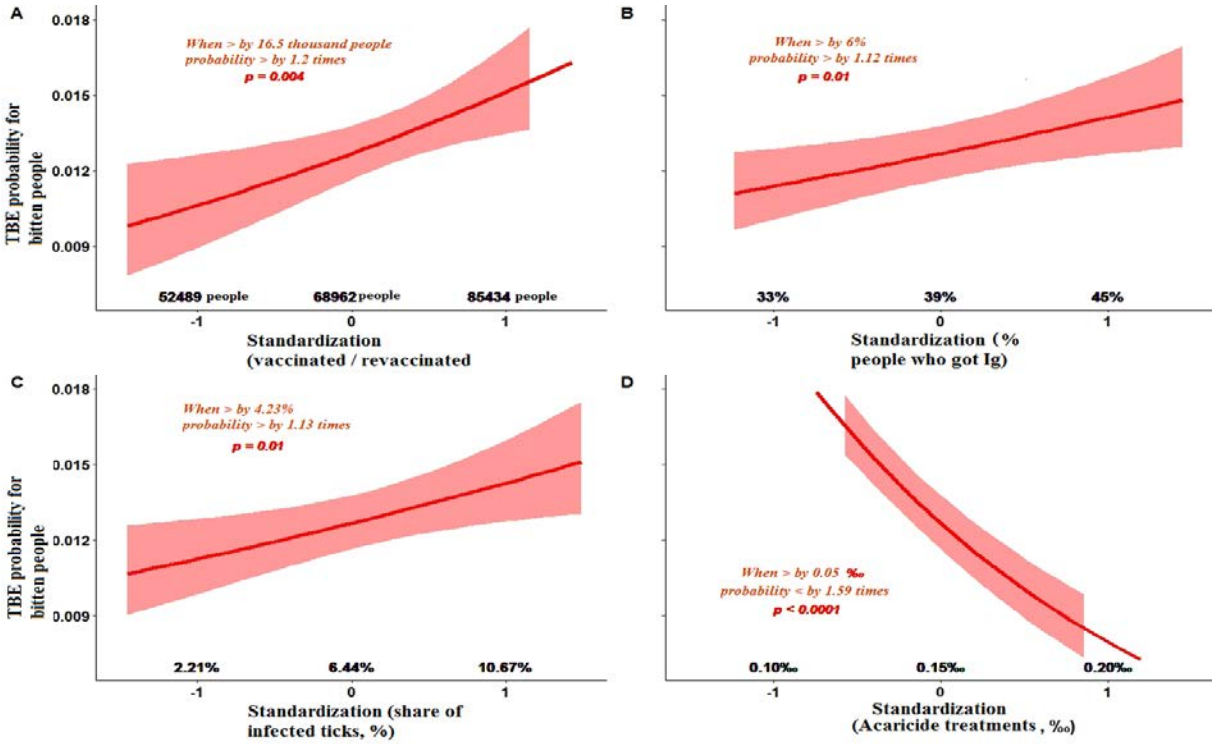

Figure 4. Impacts exerted by risk factors on TBE occurrence among people bitten by ticks in Kurgan region in 2007–2017

As regards such factors as vaccination and emergency immune prevention, logit regression results revealed a rather paradox situation that existed in Kurgan region. When there was an increase in number of vaccinated people and people provided with immune prevention, TBE probability also grew (Figure 5–A, B). However, we should note that a number of vaccinated people and immune preventions scopes were the lowest in Kurgan region over the examined 11-year period.

Therefore, the examined regions in the UFD differ in terms of effects produced by natural and social risk factors on TBE occurrence.

In Sverdlovsk and Chelyabinsk regions mass immunization program for population has been implemented since 2009 and 2012 accordingly and it is a key component in the system of measured aimed at preventing the disease; it influences epidemiologic process substantially [14].

Despite emergency prevention is also implemented in wide scopes in Sverdlovsk region, according to our calculations it doesn't have any significant effects on TBE probability, and it requires further and more profound investigation.

L.I. Volkova et al. [15] also revealed that emergency prevention was inefficient in Sverdlovsk region. They determined that only active immunization provided for population in an endemic region would allow achieving a substantial decrease in morbidity with TBE [15, 16].

Significant effects produced by acaricide treatments on TBE occurrence are most likely to be indirectly caused by their influence on infection carriers (ticks). Nevertheless, it is well known that it is rather difficult to estimate contribution made by these prevention activities into a fall in morbidity with TBE. Squares exposed to acaricide treatments are substantially smaller that the square of a whole region; besides, such treatments are usually accomplished in places specifically designed for people's rest (forest camps, for example) and people usually get infected beyond such places [17].

Literature data and long-term observations allow concluding that immune prevention against TBE in Tyumen region is accomplished in a scope that is one of the highest in Russia and it obviously indicates that results of laboratory examinations performed on ticks removed off bitten people are not taken into account when immunoglobulin is prescribed [18].

A significant effect produced by a share of infected ticks in morbidity in Tyumen and Kurgan regions is, in our opinion, caused by two basic reasons: population living in steppe and forest-steppe zones contact ticks more frequently (people who fall sick pare predominantly from rural areas). Several species of infections carriers (ticks) are typical for southern steppe and forest-steppe zones in Tyumen and Kurgan regions (*Ixodes* and *Dermacentor* families). Periods when a lot of people apply for medical aid as they have been bitten by ticks are determined by female ticks from both families being extremely active. Ticks from *Dermacentor* family are an additional TBE vector; they are more numerous and their seasonal activity is longer and it can make for a growth in a share of infected *Ixodes* [19, 20].

In Kurgan region on average over 11 years only 69 thousand people were vaccinated and it amounted to 7.6 % of the overall region population; probably, insufficient vaccination and small scopes of immune prevention (only 39 % of all the people who had been bitten by ticks got immunoglobulin) [20] result in annual high morbidity with the disease among population and, consequently, in a growth in a share of people who fall sick after being bitten by ticks[2]. Low number of population vaccinated against the disease and violations in accomplishing official vaccination schemes can lead to a decrease in immunity against TBE in the nearest future and make effects produced by vaccination more remote [21].

[2] The Order by the deputy to the Chief Sanitary Inspector in Kurgan region "On enhancing surveillance over diseases caught from tick in Kurgan region" No. 71 dated April 22, 2016. Available at: http://www.45.rospotrebnadzor.ru/rss_all/-/asset_publisher/Kq6J/content/id/470206 (date of visit June 18, 2019).

Conclusions:

1. We created a common logit regression model to assess effects produced by risk factors on TBE probability for people bitten by ticks in four regions located in the UFD. The model revealed statistically significant influence exerted by such manageable factors as vaccination, immune prevention, and acaricide treatments. Mass vaccination provided for population in these regions is a key component in control over morbidity with TBE.

2. The examined regions located in UFD are different regarding contributions made by risk factors into morbidity with TBE. In Sverdlovsk and Chelyabinsk regions primary impacts on any changes in TBE probability are exerted by vaccination and acaricide treatments. In Tyumen region primary factors are high scopes of emergency immune prevention and a share of infected ticks in natural foci. In Kurgan region the existing situation regarding morbidity with TBE is rather adverse and it is caused by insufficient vaccination and immune prevention as well as by a high share of infected ticks and infection carriers (ticks) being highly active.

3. Our analysis of social and biological factors in UFD regions with different morbidity indicates it is truly vital to implement a risk-oriented approach for planning efficient prevention activities.

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ASSESSING SENSITIVITY OF *CAMPYLOBACTER JEJUNI* TO ANTI-MICROBE EFFECTS TO REDUCE RISKS OF FOOD PRODYCTS CONTAMINATION WITH CAMPYLOBACTERIOSIS AGENTS

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We aimed to assess efficiency of various anti-microbe effects on pathogenic microflora; to do that, we performed comparative study on how sensitive Campylobacter jejuni test strains were to ultraviolet radiation and biocides based on peracetic acid (PAA). PAA-based biocides suppressed significant numbers of Campylobacter; however, preset treating modes didn't allow achieving complete inactivation of the test strains. Efficiency of effects produced by ultraviolet radiation on C.jejuni strains depended on exposure duration: 20-minute treatment of plates with broth bacterial suspensions caused a decrease in a number of viable cells which was equal to 1.5–2,0 logarithmic orders; 60-minute treatment resulted in a decrease in C.jejuni contents that amounted to less than 200 CFU/cm^3.

Polypeptide antibiotics produced by lactic-acid bacteria (bacteriocins, nisin, etc.) have some useful properties and it makes them applicable for suppressing adverse microflora in food products manufacture. We applied an 'associate growth" model to examine peculiarities related to C.jejuni growth in milk that, beside this pathogen, was simultaneously inoculated with mesophilic lactic-acid lactococci or thermophilic lactic-acid bacteria that were bacteriocins producers. Depending on quantity of introduced lactic-acid bacteria, such as Lactobacillusplantarum, Lactobacilluslactis and Lactococcuslactis, C.jejuni growth was substantially inhibited. We revealed a relationship between anti-bacterial activity and nature of inhibiting effects and concentrations of the above-mentioned lactic-acid microorganisms, temperature, an amount of time during mixed cultures were cultivated together, and properties of used strains which became the most apparent when lactobacteria were introduced in a dose equal to 10^8 CFU/cm^3.

Our study on an ability of C.jejuni to survive under exposure to an adverse environment revealed that microbe populations had variable physiological properties, Campylobacter were greatly resistant, and it was difficult to make a relevant choice on efficient tools and procedures for anti-microbe treatment.

Key words: *Campylobacter jejuni, in vitro model, biocides, anti-microbe effects, ultraviolet radiation, contamination, biofilms, lactic-acid bacteria.*

Bacteria from *Campylobacter* stem have considerable epidemiological significance and it makes it necessary to establish whether these microorganisms are able to survive contemporary technological processes in food products manufacturing under exposure to various technogenic or biological factors. It is advisable to examine how bacteria from *Campylobacter* stem develop their stress tolerance as it allows more efficient assessment of microbiological risks and more efficient monitoring over food products

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contamination with campylobacteriosis-inducing agents.

Bacteria from *Campylobacter* stem are widely spread in the environment and can be found on surfaces of any equipment and tools applied at food manufacturing enterprises [1, 2]. As objects located within production workshops are frequently contaminated with live *Campylobacter* bacteria, there is a potential hazard that they can be additionally infected due to non-cultivated forms and biofilms occurring under exposure to technological stress factors such as sub-lethal doses of antibiotics, acids, disinfectants, biocides, etc. [2–4]. This process is seen as a mechanism microorganisms apply to adapt and survive in natural and artificial ecosystems [5–7]. Irradiation that is widely used to perform bactericidal treatment of objects at production facilities and packing materials can also stimulate a stress response in bacteria; this response not only induces tolerance in bacteria to such exposure but also make them resistant to other techniques applied to treat raw materials and finished products [8, 9].

Influence exerted by adverse environmental factors on vital functions performed within a bacterial cell occurs at various regulatory levels and it can be accompanied with induced tolerance of microorganisms to exposure to these or those bactericidal factors. Bacteria can become tolerant in nature or during sanitary treatment of water or equipment under exposure to different antibacterial agents including chlorine, acids, alkali, preservatives, antioxidants, bacteriophages, colicins, acrylates, and metal ions [10–12].

At present treatment with chlorine-containing substances is quite often used in food production as a tool to decrease contamination with pathogenic microorganisms [8, 9, 13, 14]. Free chlorine and substances that evolve it (sodium hypochlorite, calcium hypochlorite, magnesium hypochlorite, chlorinated lime, chloramines, chlorine dioxide, sodium dichloroisocyanurate, and calcium dichloroisocyanurate) have substantial anti-microbe properties and are efficient against most pathogenic bacteria; they are widely used as disinfectants in medicine and veterinary, to treat drinking water and sewage waters, as well as in food production where they are applied to treat equipment and even to reduce microbe contamination on surfaces of raw materials [13–15].

Treatment with chlorine-containing biocides prevents cross contamination of products with infectious agents that cause alimentary infections and toxic infections and allows achieving longer shelf life for food products. However, application of chlorine also produces certain adverse effects such as occurrence of trihalomethanes that are toxic and carcinogenic, for example, chloroform, dichlorobrommethane, di bromchloromethane, and bromoform [6, 13]. In general, when such compounds are found in residual quantities conforming to maximum permissible levels, it allows avoiding direct health risks such as toxic, allergic or any other reactions when people consume food products that contain such residual quantities. However, at present it is proven that potentially microorganisms that contaminate food and drinks can have both acquired lower sensitivity to biocides and co-resistance to anti-microbe preparations [10, 16]. Experts also think that biocides application can have several negative consequences, for example, making bacterial pathogens evolve faster and causing occurrence of new infections that are hazardous for people [11, 12].

These phenomena indicate that remote risks related to application of anti-microbe means in technological processes are somewhat underestimated. Such issues as whether conventional concentrations of biocides applied in food industry are safe or various contaminants becoming tolerant to them as well as changes in phenotypic properties of the most significant microorganisms groups haven't been studied in depths.

To reduce risks caused by the given adverse impacts, it is vital to make a well-substantiated choice on efficient and safe tools for decontamination of raw materials and sani-

tary treatment of equipment used in food manufacturing.

Data and methods. We assessed how efficient various anti-microbe preparation were in terms of suppressing pathogenic microflora; to do that, we comparatively analyzed how sensitive test-strains of *Campylobacter* and salmonella (bacteria-indicators of food pathogens) were to exposure to biocides based on hypochlorite and technological auxiliary agents "Food Clean Peroxy" and "Kriodez" based on peracetic acid (PAA). We applied a previously developed laboratory model *in vitro* [17] to determine how sensitive *C. Jejuni* bacteria were to adverse impacts; to do that, we simultaneously cultivated several sub-populations of the examined strains under different parameters of gas medium and incubation regimes. We determined a ratio of viable colony-forming units (CFU) to overall number of cells in a population via calculating genome DNA contents in samples with qualitative real-time PCR [18].

We assessed efficiency of anti-microbe effects produced by active chlorine solutions on salmonella as per occurrence or absence of growing test-strains in dextrose-peptone medium with bromthymol blue indicator after a biocide had been introduced and samples had been cultivated for 18 hours under 37 ^{o}C. To vary two factors, namely biocide concentration and bacterial suspension density, we applied 96-well sterile immunologic plates [19]. A medium becoming turbid and changes in its color from blue-green to yellow indicated there was growth. We measured optical density of media with "Sunrise" automated plate spectrophotometer.

We determined *C. jejuni* strains ability to create biofilms with a previously developed *in vitro* laboratory model [20]. Strains were cultivated on polystyrene 96- and 24-well plates; we applied Mueller-Hinton broth as a cultivating medium with 5 % defibrinated blood being added into it as well as growth additives "Mersk" and "HiMedia" that contained sodium pyruvate, sodium metabisulfite, and iron sulfate. We determined film creation intensity with chromogenic technique using a plate spectrophotometer.

Obtained results were statistically treated with Student's t-test and Mann-Whitney non-parametric rank test. Discrepancies were considered to be authentic at $P < 0.05$. We made all the calculations with EXCEL and SPSS 18.0 software packages.

Results. We assessed inhibiting effects produced by disinfectants as per intensity of test strains growth depending on biocides concentrations and bacterial population density (Table 1).

Figure 1 shows assessment of effects produced by active chlorine on salmonella in a chromogenic model *in vitro*.

"Kriodez" had weaker effects on campylobacter in comparison with "Food Clean Peroxy" and its application resulted in a fall in test-strains quantity that was equal only to 1–2 logarithmic orders (from 1.0×10^{9} CFU/cm^3 to $1.0 \times 10^{7-8}$ CFU/cm^3). Results obtained via our comparative assessment of anti-microbe effects produced by PAA-based biocides prove that it is necessary to optimize modes of contact cooling that are applied to cool raw materials at poultry-processing enterprises; it is also necessary to make relevant selection on working concentrations of disinfectant solutions.

After *S.enteritidis* and *S.typhimurium* strains were treated with chlorine, we detected that there was no film-creating whereas *C. jejuni* tended to have stronger ability to created biofilms (Figure 2).

So, as we concluded, application of chlorine-contained disinfectants didn't provide proper and efficient treatment of substrates contaminated with campylobacter; therefore, we tested other anti-microbe impacts. To do that, we examined how sensitive campylobacter test strains were to UV-radiation as compared with affects produced by PAA-based biocides.

We assessed inhibiting effects produced by bactericidal means as per intensity of test strains growth depending on UV treatment duration and PAA concentration (Table 2).

Table 1

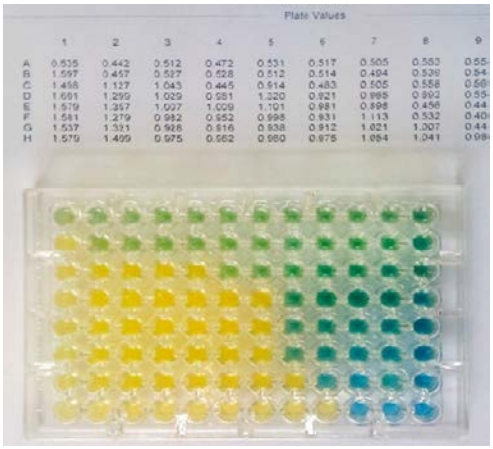
Effects produced by biocides on *C. jejuni* and *Salmonella* spp.

Test strains	Cultivation of initial test-cultures suspension *									
	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}
Control (without biocides)										
Salmonella enteritidis	+	+	+	+	+	+	+	+	+	+
Salmonella typhimurium	+	+	+	+	+	+	+	+	+	–
C.jejuni 13p	+	+	+	+	+	+	+	+	+	–
C.jejuni 5p	+	+	+	+	+	+	+	+	–	–
Hypochlorite (active chlorine concentration is 50 mg/dm^3, exposed for 25 minutes at +2°C)										
Salmonella enteritidis	+	+	+	+	+	–	–	–	–	–
Salmonella typhimurium	+	+	–	–	–	–	–	–	–	–
C.jejuni 13p	+	+	+	–	–	–	–	–	–	–
C.jejuni 5p	+	+	–	–	–	–	–	–	–	–
"Food Clean Peroxy" (0.04%-solution, exposed for 25 minutes at +2°C)										
Salmonella enteritidis	–	–	–	–	–	–	–	–	–	–
Salmonella typhimurium	–	–	–	–	–	–	–	–	–	–
C.jejuni 13p	+	+	+	+	–	–	–	–	–	–
C.jejuni 5p	+	+	+	–	–	–	–	–	–	–
"Kriodez" (0.04%-solution, exposed for 25 minutes at +2°C)										
Salmonella enteritidis	–	–	–	–	–	–	–	–	–	–
Salmonella typhimurium	–	–	–	–	–	–	–	–	–	–
C.jejuni 13p	+	+	+	+	+	+	+	–	–	–
C.jejuni 5p	+	+	+	+	+	+	–	–	–	–

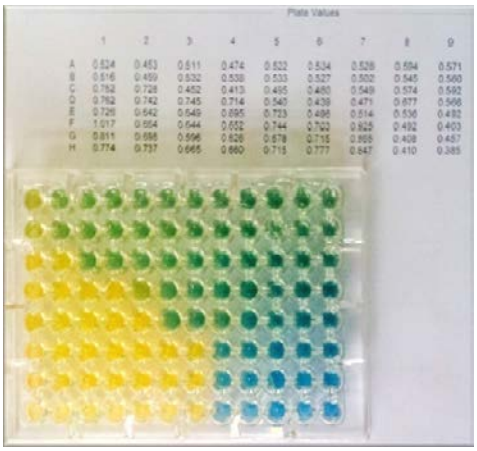
Note:

+/– means absence or occurrence of growth in relevant cultivated test-strains suspensions after exposure to a biocide;

* means that initial broth culture contains bacteria in a quantity not less than 1 x 10^9 CFU/cm^3.



S. enteritidis



S. typhimurium

Figure 1. Growth in collection salmonella test strains under exposure to active chlorine within concentrations range equal to 10–200 mg/dm^3 in an experimental chromogenic model

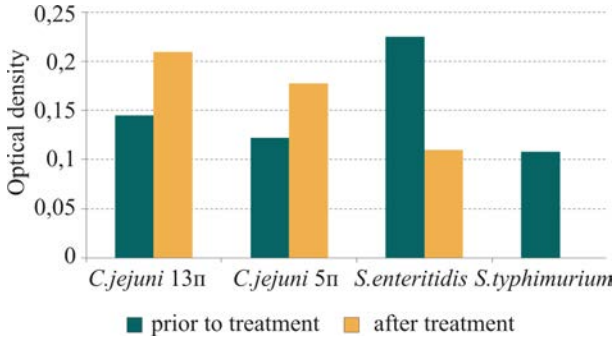


Figure 2. Ability of campylobacter and salmonella strains to form biofilms

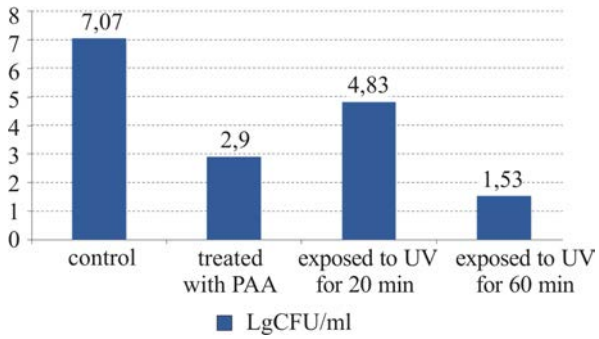


Figure 3. Bactericidal impacts on *C.jejuni* survival

PAA-based biocides with working solution concentration being equal to 0.04% inhibited a considerable number of *C.jejuni* bacteria *(*from $10^{6.5\text{-}8}$ to $10^{2\text{-}3}$ CFU/cm^3); however, preset treatment modes didn't make test-strains completely inactive. Efficiency of impacts exerted by UV-radiation on campylobacter strains depended on exposure duration; after plates with broth bacterial suspension were treated for 20 minutes, quantity of viable cells went down by 1.5–2 logarithmic orders from their initial concentration which was equal to 10^7–10^8 CFU/cm^3; after 60-minute treatment *C.jejuni* concentration decreased drastically and amounted to less than 200 CFU/cm^3 (Figure 3).

Table 2

Growth of *C.jejuni* strains under exposure to different anti-microbe impacts

Determined parameters	Number of strains / repetitions				Mean values, $M \pm m$ (test)
	NCTC 11,168 (control) $n = 3$	17p $n = 3$	23p $n = 3$	5.2 $n = 3$	
Test strains cultivation at +37°C under microaerophilic conditions (control)					
Bacterial suspension density, lg CFU/cm^3	7.99	6.9	6.8	6.6	7.07±0.31
PCR results / (Ct)	+ (14.5)	+ (14.8)	+ (17.5)	+ (16.3)	(15.78 ± 0.7)
Treatment with PAA (0.04%-solution, exposed for 25 min at +2°C)					
Bacterial suspension density, lg CFU/cm^3	3.6	2.6	2.1	3.3	2.90 ± 0.34
PCR results / (Ct)	+ (21.6)	+ (17.3)	+ (23.1)	+ (21.0)	(20.75 ± 1.2)
Inhibition, lg orders from initial level	4.4	4.3	4.7	3.3	4.1
Exposed to UV-radiation for 20 min					
Bacterial suspension density, lg CFU/cm^3	4.3	5.6	5.1	4.3	4.83 ± 0.32
PCR results / (Ct)	+ (28.8)	+ (29.8)	+ (28.6)	– (32.7)	(29.07±0.37)
Inhibition, lg orders from initial level	3.7	2.3	1.7	2.3	2.1
Exposed to UV-radiation for 60 min					
Bacterial suspension density, lg CFU/cm^3	1.9	2.1	1.1	<1.0	1.53 ± 0.28
PCR results / (Ct)	+ (29.0)	+ (26.2)	+ (27.1)	+ (30.7)	+ (28.25 ± 1.0)
Inhibition, lg orders from initial level	6.09	4.8	5.7	5.6	5.4

Table 3

Detection of *C.jejuni* during souring of experimentally contaminated raw milk

Lactic-acid microorganisms	Lactic-acid microorganisms concentration, cells/cm^3	*C.jejuni* concentration, cells/cm^3					
		10^2		10^3		10^4	
		6 h	24 h	6 h	24 h	6 h	24 h
Lactobacillusplantarum	10^4	+	–	+	+	+	+
	10^6	–	–	+	+	+	+
	10^8	–	–	–	–	+	–
Lactobacilluslactis	10^4	–	–	+	–	+	+
	10^6	–	–	+	–	+	+
	10^8	–	–	–	–	+	–
Lactococcuslactis	10^4	+	–	+	+	+	+
	10^6	–	–	+	–	+	+
	10^8	–	–	–	–	–	–

Note: "+" means *C.jejuni* grow , "–" means *C.jejuni* don't grow.

We performed comparative examinations aimed at assessing anti-microbe impacts on bacteria from *Campylobacter* stem; the results indicate it is necessary to select up-to-date and more efficient means for decontaminating industrial environment at food-making productions.

Available data on impacts exerted by physical, chemical, and biological factors on bacteria from *Campylobacter* stem stimulated research on abilities possessed by certain microorganisms, namely their ability to demonstrate symbiotic or antagonistic properties within complicated biocenosis with food pathogens. The greatest attention here is paid to lactic-acid bacteria with apparent anti-microbe effects and substances extracted from them. Antagonism that lactic-acid bacteria seem to have is predominantly explained by specific antibiotic substances with polypeptide essence; these substances can produce certain anti-microbe effects and have different chemical structure. Bacteriostatics produced by lactic-acid bacteria (bacteriocin, nisin, etc.) have a set of benign features and it gives an opportunity to use them for inhibiting adverse microflora in food production.

Data on interactions between campylobacter and lactic-acid microorganisms are scarce due to difficulties related to simulating a natural microbial background of this complicated biotechnological process in experimental conditions. A model of "associated growth" was applied to examine peculiarities of *C.jejuni* reproduction in milk that was, in addition to this pathogen, simultaneously inoculated with either mesophilic lactic-acid lactococcus or thermophilic lactobacillus. Campylobacter reproduction was inhibited considerably depending on a quantity of lactic-acid bacteria introduced into a culture and incubation temperature (Table 3).

Anti-bacterial impacts exerted by *Lactobacillusplantarum* cultures were similar to those produced by bacteriocin; they were detected in experiments *in vitro*, but *C. jejuni* bacteria didn't die, that is, the effect was only bacteriostatic. Growth of pathogenic campylobacter strains was also detected when they were cultivated in milk together with *Lactobacilluslactis* and lactic-acid lactococcus *Lactococcuslactis. C. Jejuni* were inactivated after 6–24 hours of incubating in mixed populations as their initial level dropped by 1–3 lg. Anti-bacterial activity and essence of inhibiting effects were established to depend on concentrations of the above-mentioned lactic-acid microorganisms, temperature, a pe-

riod during which mixed cultures were cultivated, and properties of used strains which became the most apparent when lactic-acid bacteria were introduced in a dose equal to 10^8 CFU/cm^3.

Studies on *C. Jejuni* ability to survive under adverse environmental exposure revealed that physiological properties of microbe populations were variable and bacteria from *Campylobacter* stem were highly resistant; therefore, it was difficult to select relevant and efficient means and procedures for anti-microbe treatment. So any further research should concentrate on transferrable resistance of bacteria from *Campylobacter* stem and influence exerted on their survival and transfer into non-cultivated forms by stress factors in industrial environment; it is also important to examine specific mechanisms of phenotypic adaptation (tolerance) to sub-lethal concentrations of anti-microbe agents.

Conclusion. General protective properties possessed by *Campylobacterspp.* can become apparent via different interactions between bacteria and the environment thus making for occurrence of resistant microorganisms both *in vitro* and in real industrial conditions under exposure to stress technogenic or biological factors.

The most apparent trend in changes that occur in *C. jejuni* properties is an increase in their resistance to bactericidal effects caused by wide use of anti-microbe preparations (AMP), including antibiotics and biocides.

A model of "associated growth" was applied to show dependence between antibacterial activity and inhibiting effects and concentrations of lactic-acid bacteria

Lactobacillusplantarum, Lactobacilluslactis and *Lactococcuslactis*, temperature, a period during which mixed cultures were cultivated, and properties of used strains that became the most apparent when lactic-acid bacteria were introduced in a dose equal to 10^8 CFU/cm^3.

To assess efficiency of impacts exerted by pathogenic microflora by various anti-microbe means, we conducted a comparative study on how sensitive campylobacter test-strains were to UV-radiation and PAA-based biocides. PAA-based biocides inhibited a considerable number of *C.jejuni* bacteria; however, preset treatment modes didn't make test-strains completely inactive. Efficiency of impacts exerted by UV-radiation on campylobacter strains depended on exposure duration and anti-microbe exposure conditions.

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SANITARY-HYGIENIC CHARACTERISTICS OF HEALTH RISK AND CLINICAL ASSESSMENT OF DAMAGE TO HEALTH DONE TO POPULATION LIVING IN A SPECIFIC GEOCHEMICAL PROVINCE UNDER LONG-TERM EXPOSURE TO ARSENIC INTRODUCED WITH DRINKING WATER

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In Russia geochemical provinces where arsenic is found are located in Yakutia, Siberia, Transbaikalia region, the Primorye, in the Urals, and Chukotka. Our research goal was to give sanitary-hygienic characteristics of health risk and perform clinical assessment of health damage done to population living in a specific geochemical province under long-term exposure to arsenic introduced with drinking water. We conducted our research in settlements where increased arsenic concentrations were detected in drinking water taken from centralized water supply systems taking into account also hygienic standards for arsenic contents in non-centralized water sources; those increased concentrations were caused by the structure of deep underground layers in the earth crust. We applied a set of sanitary-hygienic techniques and performed clinical examination of 147 people living in a specific geochemical province. We detected excessive arsenic concentrations in drinking water taken from centralized water supply systems; those concentrations were equal to 50–86 MPC whereas arsenic contents didn't exceed 1 MPC in water taken from non-centralized water sources. We revealed that long-term consumption of water with arsenic contents being equal to 2.5 mg/dm^3 and higher caused unacceptable carcinogenic (up to $4.09 \cdot 10^{-2}$) and non-carcinogenic (HQ up to 494.4) population health risk. Potential risk turns into health damage when arsenicosis occurs; it usually happens after 17–19 years of exposure among adults and after 2–3 years among children. There are several basic clinical types of diseases caused by exposure to increased arsenic concentrations; adult people suffer from skin arsenicosis as per poikiloderma type or arsenic melanosis, polyneuropathy, cardiovascular pathology, ands carcinogenesis; children mostly suffer from skin arsenicosis that is usually leucomelanosis. Arsenicosis occurrence is 1.3–9.0 times more frequent among people living in a specific geochemical province who consume water with arsenic concentrations being equal to 2.5 mg/dm^3 and higher in comparison with people who consume drinking water with arsenic contents being within their hygienic standards. Health damage is assessed as grave in 44.4 % cases (oncologic processes, polyneuropathy, and arsenic melanosis); as average, in 46.3 % cases (arsenic dyschromia); and as insignificant, in 9.3 % cases (vegetative-vascular dystonia or autonomous dysfunction, and functional disorders of the nervous system).

Key words: *geochemical province, arsenic, drinking water, health risk, health damage, population morbidity, arsenic melanosis, arsenic polyneuropathy, oncologic processes.*

Millions of people all over the world are chronically exposed to increased arsenic concentrations caused by geochemical peculiarities existing on territories where they live. At present large geochemical provinces of copper and arsenic ores are detected in Italy, the USA,

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Sweden, Norway, Japan, Georgia, and Kazakhstan; arsenic and cobalt ores, in Canada; arsenic and tin ores, in Bolivia, Chile, and England; gold and arsenic ores, in the USA and France. In Russia there are arsenic geochemical provinces in Yakutia, Siberia, Transbaikalia, Primorye, Urals, and Chukotka [1].

According to scientific research, drinking water is a primary way for arsenic to be introduced into a human body in geochemical provinces; the leading hygienic problem on such territories is drinking water supply sources being contaminated with arsenic [2–5]. Nowadays the situation with drinking water quality as per arsenic contents is the most serious in Bangladesh and the East Bengal (India) where its concentration in drinking water reaches 50 μg/l or even higher while the WHO recommendations fix this concentration at 10 μg/l maximum. According to official statistic data more than 20 % deaths in rural areas in Bangladesh are caused by consuming drinking water with high arsenic contents [6]. The existing situation in several districts in Dagestan is also rather serious as arsenic contents in drinking water reaches 222–504.1 μg/dm^3 there [7]. In Canada standardized permissible arsenic concentration should not exceed 25 μg/l; in Russia and the USA, 10 μg/l [8, 9].

Data obtained via clinical research performed in various RF regions prove that morbidity among population living in geochemical arsenic provinces is 1.3–3.8 times higher regarding diseases of the endocrine, urogenital, nervous, and cardiovascular system as well as the gastrointestinal tract diseases and skin diseases; mortality caused by oncologic pathologies is also 1.2–4.7 times higher than in the country on average [10]. Experts revealed an authentic correlation between increased arsenic concentrations in drinking water and occurrence of skin diseases, immune system diseases, and cardiovascular pathology in population exposed to them [11].

When arsenic enters a body, it disintegrates or destabilizes more than 200 enzymes that participate in different metabolic cell processes and DNA synthesis; activates peroxidation; binds thiol (sulfhydryl) groups in tissue proteins thus causing multi-system damages involving the cardiovascular and nervous systems, liver, lungs, kidneys, spleen, gastrointestinal tract, and skin, carcinogenesis being the most serious outcome [12, 13].

At the same time our analysis of domestic and foreign literature sources indicates there hasn't been a sufficient scope of complex hygienic and clinic research describing correlations between health disorders among population living in geochemical provinces and long-term consumption of drinking water with increased arsenic concentrations [13].

Our research goal was to give sanitary-hygienic characteristics of health risks and clinically assess damage to health of population living in a specific geochemical province caused by long-term exposure to arsenic introduced with drinking water.

Data and methods. We performed our research in a geochemical province located in Transbaikalia (an urban village) where drinking water from centralized water supply sources contained increased arsenic concentrations while water supplied from non-centralized sources contained the chemical in standardized concentrations[1, 2]. A well for centralized water supply system was usually 100–120 meters deep; non-centralized underground water supply sources (wells at private houses) were usually not deeper than 10–20 meters. We assessed quality of drinking water taken from centralized water supply systems and non-centralized water sources as per data of monitoring research obtained from the Regional

[1] SER 2.1.4.1074-01. Drinking water. Hygienic requirements to quality of water from centralized drinking water supply sources. Quality control. Hygienic requirements to providing safety of hot water supply systems (last amended on April 2, 2018) / approved by the Order by the RF Chief Sanitary Inspector No. 74 on June 28, 2010. Available at: https: //files. stroyinf.ru/Index2/1/4294846/4294846957.htm (date of visit December 01, 2019).

[2] HS 2.2.5.1315-03. Maximum permissible concentrations (MPC) of chemicals in water from water objects aimed at drinking and communal water supply (last amended on July 13, 2017) / approved by the Order by the RF Chief Sanitary Inspector No. 78 on April 30, 2003. Available at: http: //www.dioxin.ru/doc/gn2.1.5.1315-03.htm (date of visit December 01, 2019).

Center for Hygiene and Epidemiology as well as per field observations performed by certified laboratories at the Federal Scientific center for Medical and Preventive Health Risk Management Technologies with their results obtained with licensed equipment. Arsenic concentration was determined in drinking water samples, food products manufactured in the examined province, and biological media (blood) with mass-spectrometry with inductively coupled plasma according to conventional procedures with a ICP-MS spectrometer.

We assessed potential carcinogenic and non-carcinogenic health risks caused by increased arsenic concentrations in drinking water taken from centralized water supply systems according to conventional procedures fixed in the Guide 2.1.10.1920-04[3].

To comparatively assess structure and peculiarities of morbidity (as damage to people's health) among population who consumed drinking water with different arsenic concentrations, we created a test group consisting of 115 people living in houses with centralized water supply and consuming water with increase arsenic concentrations. Our reference group was made up of 21 people who lived in houses without centralized water supply and consumed water with arsenic concentrations in it not deviating from hygienic standards.

80.9 % people in the test group were adults aged from 16 to 81 (their average age was 51.8 ± 3.6); children (aged 5–15) accounted for 19.1 % (their average age was 8.3 ± 1.2). In the reference group adults (aged 16–57) accounted for 46.9 % (their average age was 40.7 ± 7.5; $p = 0.67$ against the test group); children (aged 5–11) accounted for 53.1 % (their average age was 7.2 ± 0.7; $p = 0.71$ against the test group).

A period of time during which adults lived in houses with centralized water supply varied from 6 months to 47 years (on average 22.0 ± 3.1); this period was longer than 10 years for 70.8 % examined people. Children from the test group lived in such houses for a period of time that varied from 9 months to 13 years (on average 6.6 ± 1.5), and 73.3 % of them lived in such houses for more than 5 years. Adults from the reference group lived in their houses for a period of time that varied from 1 to 57 years (on average 21.1 ± 6.6 years; $p = 0.54$ against the test group), and 83.3 % of them lived in their houses for longer than 10 years. Children from the reference group lived in their houses for a period of time that varied from 3 to 15 (on average 6.3 ± 1.5; $p = 0.83$ against the test group), 76.5 % of them lived in their houses for more than 5 years.

There were no authentic differences between the test and reference groups in terms of their socioeconomic and gender characteristics, ethnic structure and medical aid availability ($p = 0.01$–0.03).

Average daily consumption of drinking water by people from both groups varied from 1 to 5 liters and didn't differ between two groups; on average it was equal to approximately 2 liters (1.9 ± 0.2 liters in the test group; 1.9 ± 0.4 liters in the reference group; $p = 1.0$); children consumed from 1 to 2 liters depending on their age and there were no differences between two groups (1.3 ± 0.2 liters in the test group; 1.2 ± 0.3 liters in the reference one; $p = 1.0$).

We performed clinical and functional examinations of people from both groups (clinical examination by a therapist, pediatrician, neurologist, and oncologist; tonometry; EKG) according to conventional procedures and in conformity with ICH GCP[4] and ethical standards fixed in Helsinki Declaration (last edited in 2008).

Data were analyzed with variation and frequency analysis taking into account Pearson's test; authenticity of numerical values was estimated with Fischer's and Student's tests.

Results and discussion. We analyzed monitoring data on quality of water taken from

[3] G 2.1.10.1920-04. Guide on assessing population health risks caused by exposure to chemicals that pollute the environment. Moscow, The RF Public Healthcare Ministry, Federal Center for State Sanitary and Epidemiologic Surveillance, 2004, 143 p.

[4] State Standard52379-2005. Good Clinical Practice: The RF National Standard / approved by the Order by the Federal Technical Regulation and Metrology Agency issued on September 27, 2005. No. 232-st. (ICH E6 GCP). Available at: https://dokipedia.ru/document/5324107 (date of visit December 01, 2019).

centralized water supply system in the examined settlement and revealed persistent arsenic concentration in it varying from 0.002 to 4.3 mg/dm^3 (up to 86 MPC) while it was just above 1 MPC in water taken from non-centralized water sources. Field observation results also confirmed that arsenic occurred in water from centralized water supply systems in increased concentrations which were equal to 2.5 mg/dm^3 (50 MPC) while its contents in water from non-centralized water sources didn't deviate from hygienic standards (less than 0.05 mg/dm^3). We also examined food products that were locally manufactured and determined that arsenic contents in them conformed to hygienic standards; its contents in carrots amounted to 0.0042 ± 0.0003 mg/kg; potatoes, not found; beetroot, not found (MPL is lower than 0.2 mg/kg for vegetables); fish from local water basins, not found (MPL is lower than 1.0 mg/kg for fresh-water fish).

We assessed lifetime cancer risk caused by consuming drinking water with increased arsenic concentration and revealed that it was unacceptable in the test group and amounted to 4.09×10^{-2} for adults and -1.91×10^{-2} for children. Regarding non-carcinogenic risks, we revealed that they were substantially higher than acceptable quotient for arsenic both for adults and children ($HQ = 494.4$ and $HQ = 211.9$ accordingly); it indicated that people ran risks of skin diseases, diseases of the cardiovascular, nervous, and immune systems, and the gastrointestinal tract.

We assessed health risks for people in the reference group and it allowed us to reveal that cancer risks varied from negligible to maximum permissible ones both for adults and children ($1\times10^{-6} < CR < 1\times10^{-4}$); however, hazard quotient for children that described non-carcinogenic risks exceeded its permissible level ($HQ = 1.1$). It indicated that there was a risk of skin diseases ($HI = 1.66$); diseases in the immune, nervous, ($HI = 1.14$–1.66) and cardiovascular systems ($HI = 1.10$), and the gastrointestinal tract ($HI = 1.1$).

Our next task was to reveal damages to health of people living in the examined settlement caused by chronic oral exposure to arsenic; to do that, we performed comparative analysis of the results obtained via chemical-analytical and clinical examinations of people from the test and reference groups.

Chemical and analytical examination of blood serum revealed that arsenic contents median for adults from the test group amounted to 0.0065 mg/l, and to 0.0049 mg/l for children and it corresponded to average country level (0.0017–0.0154 mg/l)[5]. At the same time 7.9 % adults and 18.8 % children in the test group had arsenic in their blood serum in concentrations higher than the hygienic standards; these concentrations varied from 0.0171 mg/l to 0.0636 mg/l in adults' blood and from 0.0162 mg/l to 0.0377 mg/l in children's blood. As for the reference group, only one adult person from it had arsenic in his blood in concentration higher than on average in the country and it was equal to 0.0162 mg/l; all the examined children from the reference group had arsenic in their blood serum in concentrations which were 4.7–15 times lower than average arsenic contents in human blood plasma.

We examined case histories of people from both groups and revealed that each fifth person (18.3 % in the test group and 18.8 in the reference group; $p = 0.88$) had hereditary load with oncologic pathology as it was detected in the closest relatives (the 1st and 2nd degree). Mammary gland, digestive organs, and lungs were the most frequent organs where oncologic processes were localized for both groups; however, we didn't detect any skin cancer cases in family case histories.

We performed retrospect analysis of data on diseases people from both groups had suffered from in the past and revealed that 6.1 % patients from the test group had previously had oncologic diseases (basal cell carcinoma and melanoma, uterine cancer, kidney cancer, mammary gland cancer); only one female patient from the reference group (3.1 %; $p = 0.72$)

[5] Toxicological chemistry. Metabolism and analysis of toxicants: manual. In: N.I. Kaletina, Moscow, GEOTAR-Media Publ., 2008, 1016 p. (in Russian).

had suffered from basal skin cancer in the past. Overall, oncologic processes occurred 2.0 times more frequently in the test group than in the reference one ($OR = 2.12$; $p = 0.04$).

Patients from the test group most frequently complained about changes in color of their skin, namely occurring hyperpigmentation spots (0.2–0.7 cm) or depigmentation spots (0.3–0.4 cm, more frequently in children) which could be located discretely or everywhere; intense pigmentation of nipples in female patients with their color changing to dark brown or even black; axillary and inguinal folds becoming pigmented and coarse; pigmented spots (more rarely hyperemic ones) with their diameter up to 5.0 cm occurring on the face, neck, breast, and un the occipital region. Dermatological symptoms in adult patients were combined with hyperkeratosis of palms and/or feet in each third case. 44.4 % patients out of 115 people in the test group (9 children and 42 adults) had clinical signs of skin arsenicosis as per poikiloderma type or arsenic melanosis (leukomelanosis) at the moment they were examined (Photo 1).

Most patients stated that the first changes in their skin had occurred 3.5 years prior to our research. Polyneuropathy symptoms were detected in 9.6 % patients during clinical examinations, and ⅔ of them had clinical signs of polyneuropathy combined with damages to skin. There were no complaints about skin pigmentation/depigmentation made by examined people from the reference group; besides, clinical examinations didn't reveal any convincing signs of skin arsenicosis and/or polyneuropathy in them.

To get more precise data on prevalence of a pathology that was co-morbid with skin arsenicosis, we performed clinical and functional examinations of patients and studied their case histories. The examinations revealed that 44.9 % patients from the test group had elevated blood pressure (higher than 140/90 mm Hg); 8.2 % suffered from hypotonia (blood pressure was lower than 100/60 mm Hg). 15.7 % patients suffered from chronic cardiovascular diseases (primary hypertension, ischemic heart disease). Only 43.3 % children had their electrocardiogram conforming to physiological standards whereas 56.7 % had various sinus rhythm disorders. Only 27 % adults had standard ECG. Dysmetabolic and cicatrical changes were prevailing pathologies (39.9 %); 18.6 % patients suffered from functional disorders in the sinus node; 14.4 % had cardiac conduction system pathology. In the reference group only 21.9 % patients had elevated blood pressure, and only 3.1 % suffered from hypotonia; it was 2–3 times less frequent than in the test group ($p = 0.02$). Chronic cardiovascular diseases were diagnosed in 12.5 %

a *b*

Photo 1. Skin arsenicosis as per poikiloderma type (*a*) and leukomelanosis (*b*)

patients from this group and it didn't have any discrepancies with the test one ($p = 0.78$). 55.0 % children from the reference group had standard ECG ($p = 0.69$ against the test group); however, prevailing pathology (40.0 %) was only various sinus rhythm disorders ($p = 0.38$). Adults from the reference group had standard ECG 2.7 times more frequently (71.0 %) than their counterparts from the test one; they suffered from dysmetabolic and cicatrical changes in their cardiac muscle 2 times less frequently (19.4 %; $p = 0.04$); functional disorders in the sinus node (3.2 %) and cardiac conduction system pathology (6.4 %) were rare exceptions for people in the reference group ($p = 0.02$–0.03). Overall, people from the test group suffered from arterial hypertension 2 times more frequently ($OR = 2.14$; $p = 0.03$), and cardiac muscle damages, 9 times more frequently ($OR = 9.23$; $p = 0.01$) than people from the reference one.

20.0 % people from the test group and 18.8 % from the reference one had clinical signs of gastric diseases (chronic gastritis, duodenitis, stomach and duodenum ulcer, enterocolitis) and hepatobiliary diseases (chronic cholecystitis, cholangitis) ($p = 0.92$). The examinations revealed signs of mental and emotional instability, namely astheno-vegetative syndrome and astheno-neurotic syndrome, in 17.4 % people from the test group and 12.5 % people from the reference one ($p = 0.81$).

Overall, damage to health was estimated as grave in 44.4 % cases (oncology, polyneuropathy, arsenic melanosis); average, in 46.3 % cases (arsenic dyschromia); insignificant, in 9.3 % cases (vegetative-vascular dystonia, functional disorders in the nervous system).

Results and discussion. Research results revealed that people who lived in the examined geochemical province and consumed water from deep wells were more significantly exposed to arsenic than their counterparts who consumed water from shallow wells. It is likely due to arsenic ore deposits lying deep. Other authors who have examined peculiarities of geochemical provinces in India and Chile give similar data [3, 4]. According to the obtained results, water taken from a depth of 100 meter and more had arsenic in concentrations that reached 50–86 MPC whereas water taken from a depth of 10–20 meters corresponded to hygienic standards. Hazards caused by deep underground waters are also confirmed by examinations performed on locally produced food such as vegetables watered by local population with water taken from surface water basins and shallow wells as well as fish from local fresh-water basins; arsenic was contained in such products in concentrations that conformed to safety requirements.

Chemical and analytical research revealed that people who consumed drinking water from centralized water supply systems with elevated arsenic contents had arsenic concentrations in their fast-reacting biological media (blood serum) which were authentically higher than arsenic concentrations in blood serum of people who lived in houses without centralized water supply. Besides, we detected that each forth examined person in the test group (26.7 %) had arsenic in his or her blood in concentration which was substantially higher than on average in the country.

We assessed potential health risks caused by elevated arsenic contents in water taken form centralized water supply systems in the examined settlement and revealed that both carcinogenic risks (up to 4.09×10^{-2}) and non-carcinogenic ones (HQ up to 494.4) were unacceptable. As regards non-carcinogenic risks, we detected hazard quotients related to arsenic that were substantially higher than their permissible level both for adults and children ($HQ = 494.4$ and $HQ = 211.9$ accordingly) and it indicated that population ran elevated risks of skin diseases, cardiovascular, nervous, and immune system diseases, and gastric diseases. We should point out that carcinogenic risks for people who consumed water from non-centralized water sources didn't exceed maximum permissible levels; hazard quotients for non-carcinogenic risks were not higher than 1.1 ($HQ = 1.1$).

As per literature data chronic intoxication with arsenic has a diverse clinical picture due to systemic damages to a human body[5] [13]. Also, clinical signs of arsenicosis usually beco-

me apparent under long-term exposure [14–16]. Latent period can last for a long time, up to 60 years after exposure [17]. Our research allowed us to establish that average duration of exposure to arsenic amounted to more than 20 years for adults living in the examined geochemical province, and about 7 years for children; the first clinical signs of the diseases became apparent after 15–17 years for adults and after 4 years for children.

Dermatological signs of arsenicosis and polyneuropathy are the most frequent manifestations of the disease [14, 16]. Our research revealed arsenicosis symptoms in 44.4 % patients who consumed water from centralized water supply systems. These symptoms were hyperpigmentation or depigmentation spots located discretely or everywhere; intense pigmentation of nipple in female patients; axillary and inguinal folds becoming pigmented and coarse; pigmented (less frequently hyperemic) spots occurring on the face, neck, breast, and in the occipital region; 9.6 % patients had polyneuropathy signs. We should point out that people who consumed water from non-centralized water sources didn't have any signs of skin arsenicosis or polyneuropathy. Therefore, people who consumed water with arsenic contents being equal to 50 MPC or even higher had dermatologic or neurologic arsenicosis in each second case.

Chronic intoxication with arsenic can be accompanied with damages to the gastrointestinal tract and in this case gastrointestinal pathology is combined with skin changes and polyneuropathy [18]. In West Bengal 248 patients with chronic intoxication who had been consuming drinking water with elevated arsenic contents for 1–15 years had hepatomegaly in 76.6 % cases; biopsy results revealed that 91.3 % patients suffered from non-cirrhotic portal fibrosis [19]. In other research arsenic was established to be an etiological agent in 5 out of 42 patients with incomplete septal cirrhosis, non-active macronodular cirrhosis, and with frequent bleedings from varicose veins [20]. In our research we revealed clinical signs of gastrointestinal pathologies (chronic gastritis, duodenitis, stomach and duodenum ulcer, enterocolitis) in 18.8 % patients, and hepatobiliary pathologies (chronic cholecystitis / cholangitis), in 20 %.

As per literature data, chronic exposure to elevated arsenic concentrations is accompanied with an increase in cardiovascular pathologies [21–23]. There was a research work accomplished in "arsenicosis – hyperendemic villages" in Taiwan; it revealed a correlation between ischemic heart disease diagnosed in people living there and long-term exposure to arsenic [24]. Results of clinical and pathomorphological research indicate that arsenic causes direct damage to the cardiac muscle, heart rate disorders, and cardiomyopathy [25, 26]. We obtained the same results in our research as we established that adults and children who had been consuming water with elevated arsenic concentrations for a long time (the test group) suffered from arterial hypertension, dysmetabolic changes in the cardiac muscle, and functional disorders in the sinus node and cardiac conduction system 2–9 times more frequently than their counterparts from the reference group.

Carcinogenic effects produced by arsenic are one of the most serious consequences that chronic exposure to it might have [27]. In Bangladesh and India arsenic is associated with skin cancer, lung cancer, liver cancer, kidney cancer, and urinary bladder cancer [28, 29]. The same data have been obtained in South America, Central Africa, and European countries [30]. Though mechanisms of arsenic-related carcinogenesis have not been clearly identified, they probably exert adverse impacts on DNA reparation and methylation; stimulate free radicals production; activate c-myc proto-oncogene; act as co-carcinogen or promoter of tumors or progressing tumor processes [31]. Our research results revealed that chronic exposure to arsenic resulted in 2.0 times more frequent oncology occurrence in people who consumed water with increased arsenic concentrations than in those who consumed water that conformed to hygienic standards.

To sum up our research results, we should note that in specific geochemical provinces where drinking water contains arsenic in ele-

vated concentrations (50–86 MPC), lifetime cancer risk for population who consume this water reaches 4.09×10^{-2} and results in oncologic diseases with various localizations among adults 2 times more frequently than among adult people who consume water that conforms to hygienic standards. Non-carcinogenic health risks for population are unacceptable in such conditions ($HQ = 211.9$ for children; $HQ = 494.4$ for adults) and 2–3 times more frequently result in the diseases of the nervous and cardiovascular system and non-carcinogenic skin pathologies. Overall, damage to health is grave in 44.4 % cases; average, in 46.3 % cases; insignificant, in 9.3 % cases.

Conclusions:

1. In geochemical provinces in Transbaikalia arsenic contents in water taken from deep wells (100 meters and deeper) can reach 50–86 MPC.

2. Chronic consumption of drinking water with arsenic contents being equal to 2.5 mg/dm^3 creates unacceptable carcinogenic (up to 4.09×10^{-2}) and non-carcinogenic (HQ up to 494.4) health risk.

3. Lifetime cancer risk caused by consumption of drinking water with arsenic contents being equal to 50–86 MPC results in 2 times more frequent oncologic pathologies with various localization among adult population.

4. Non-carcinogenic risk is also unacceptable and 2–3 times more frequently results in the diseases of the nervous and cardiovascular system and non-carcinogenic skin pathologies.

5. On average, children have been exposed to increased arsenic concentrations for 4 years; adults, for 15–17 years; damage to their health is estimated as grave in 44.4 % cases (oncology, polyneuropathy, arsenic melanosis); average, in 46.3 % cases (arsenic dyschromia); insignificant, in 9.3 % cases (vegetative-vascular dystonia, functional disorders in the nervous system).

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PECULIARITIES OF PRENOSOLOGICAL CHANGES IN MENTAL AND PHYSICAL HEALTH OF STUDENTS FROM GENERATION *Z*

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Rapid digital technologies development, easily available Internet networks, and electronic gadgets being widely spread and extremely popular have resulted in creation of a new "digital environment"; this environment, within the theory of generations, has become a key factor in forming a new generation, so called Generation Z. At present children pursue a lifestyle that differs significantly from those of previous generations and is characterized with low physical activity, short amount of time spent outdoors, and great educational loads. All this, together with impacts exerted by new hygienic factors, for example, information and communication technologies being actively and profoundly used by modern children, causes risks for mental and physical health. We assessed mental and physical health of 80 children belonging to Generation Z (so called "indigo children"). They were all born in 2008 and were 10 years old at the moment of the examination that took place on April 05, 2018. We revealed that Generation Z children had certain psychological and personal traits. Here we should mention 3.5 times greater number of children with social-psychological deadaptation in the communicative and behavioral sphere; 2.4 times greater number of children with greater anxiety and 2.5 times lower sociometric status against the previous generation. We detected a decrease in physiometric parameters of physical development such as 14.7 % lower vital capacity of lungs and 22.3 % lower response hand grip strength; these negative trends were accompanied with overweight being more widely spread among Generation Z against the previous one. Children with normal body weight were 1.3 times less frequently detected among Generation Z, but 2.1 times more children had overweight than among children of the same age who were examined 10 years ago.

Key words: *digital environment, Generation Z, "indigo children", Generation Y, "millennials", a psychological profile of a contemporary generation, social and psychological adaptation, anxiety, communicative efficiency, physiometric and somatometric parameters of physical development, body mass index*

Actuality. Rapid digital technologies development, easily available Internet networks, and electronic gadgets being widely spread and extremely popular have resulted in creation of a new "digital environment"; this environment, within the theory of generations, has become a key factor in forming a new generation, so called Generation Z [1]. Live activities of children in the digital environment have no analogues in phylogenesis and involve persistent exposure to various physical factors (electromagnetic irradiations and acoustic impacts); physical strain of the nervous and muscular system caused by forced poses children have to assume while working with laptops, phones, and pads; "finger-writing" on gadget screens; static loads occurring due to necessity to hold a gadget in a position; intellectual and emotional stress [2]. According to foreign scientific data, contemporary children and teenagers have been growing in a hyper-information space and digital environment and, as it is assumed by foreign experts, it results in a peculiar psychological profile of this contemporary generation [3–6]. Meanwhile, there are no sufficient data available in domestic scientific works that could confirm this assumption and it makes our research truly vital. Data on the examined issue which we have managed to obtain from scientific literature indicate it is quite relevant to examine peculiarities related

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to health formation at the prenosological stage making comparison between the current generation and the previous one; to reveal psychological peculiarities of a personality, character, and perception of the world contemporary children might have. All this will help to scientifically substantiate efficient ways to raise and educate children from Generation Z.

Our research goal was to describe mental and personal peculiarities of students from Generation Z.

Data and methods. We assessed mental and physical health of 80 children (The 1st group, generation Z or "indigo children") who were born in 2008 and were 10 years old at the moment our research was performed (April 05, 2018). Mental health was assessed via examining social and psychological adaptation, communicative efficiency, and anxiety during lessons and in everyday life. The reference group was made up of 100 children (the 2ns group, Generation Y or "Millennials") who had been born in 1998 and who also had been 10 years old at the moment they had been examined (September 09, 2008). We examined social and psychological adaptation via questioning which was performed among school teachers; their answers were processed according to a procedure developed by A.A. Baranov et al (2005) and it allowed determining social and psychological adaptation in educational, communicative, and behavioral spheres [7]. Communicative efficiency of schoolchildren was determined via a sociometric experiment with a sociometric index measuring [8]. A child's sociometric index is determined via calculating positive and negative choices made about him or her by his or her classmates. Depending on it a status category was calculated for each child; I meant high status; II, average; III, low. We also applied questioning to examine anxiety as per CMAS questionnaire (The Children`s Form of Manifest Anxiety Scale) adapted by A.M. Prikhojan (1994) [9]. Physical health of the examined children was comparatively estimated via comparing physical development parameters such as height, body mass, vital capacity of lungs, response hand grip strength, as well as body mass index according to nomograms recommended by the WHO (2007).

Obtained data were statistically analyzed with Microsoft-MS Office MS Exiles software package and Statistica 7.0. Critical level of statistical significance was taken to be equal to 0.05. We controlled distribution of qualitative parameters in two examined groups with Kolmogorov – Smirnov test and Shapiro – Wilkes test. Qualitative parameters obtained for two examined groups were compared via calculating Student's t-test.

Results and discussion. We established that 55 % children in the 1st group and 63 % children in the 2nd group were normally adapted socially and psychologically. Prevalence of social and psychological deadaptation in different forms had some peculiarities among Generation Z children in comparison with the previous Generation Y (Figure 1). Thus, prevalence of social and psychological deadaptation in educational sphere amounted to 18.6 ± 1.2 cases per 100 children in the 1st group against 27.9 ± 1.1 cases per 100 children in the 2nd group and it was 1.5 times lower. It is probably due to Generation Z children being more efficient in terms of working with information, and their neuropsychic development is faster; it allows them to successfully adapt to contemporary educational environment which is full of digital technologies [3, 10]. Children from the 1st group had behavioral deadaptation 3 times more frequently than children from the 2nd group as it amounted to 48.6 ± 2.5 cases per 100 children against 16.2 ± 0.5 cases per 100 children ($p \leq 0.05$) accordingly; deadaptation in communicative sphere was 3.5 times more frequent among them (66.8 ± 1.9 cases per 100 children in the 1st group against 19.1 ± 0.9 cases per 100 children in the 2nd one, $p \leq 0.05$).

Greater social and psychological deadaptation in behavioral sphere detected among children from the 1st group can probably be due to their greater individualization and infantilism which is typical for Generation Z. They are intolerant to others, want their wishes

to be fulfilled at once, but fail to realize that it is impossible in real life and not as simple as it is in the digital environment. All this is consistent with scientific data that contemporary children are being hyper-protected by their parents and it results in them being egoistic and removes any social restrictions in their mentality [11]. Besides, experts note that contemporary children are prone to autism and it is an extreme manifestation of how the mankind is evolving in the digital environment [3].

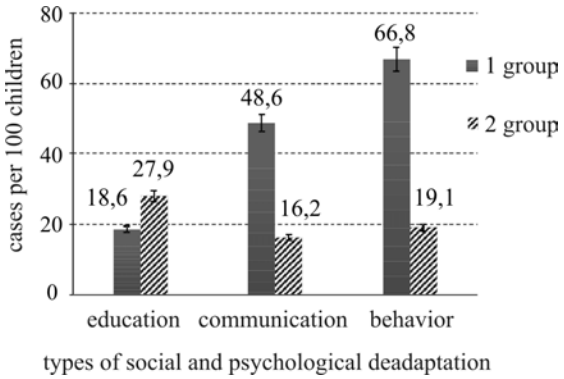

Figure 1. Prevalence of social and psychological deadaptation in children from the examined groups

A decrease in communicative activity was confirmed by only 3.5 % children in the 1st group having high communicative efficiency whereas there were 10.2 % with such communication skills in the 2nd group. 78.7 % children in the 1st group had low communicative efficiency and it was 2.6 times higher than in the 2nd group (30.3 %; Table 1).

Table 1

Children in the examined group distributed as per their communicative efficiency (%)

Communicative efficiency	Children groups	
	The 1st one	The 2nd one
Average	17.8	59.5
High	3.5	10.2
Low	78.7	30.3

It should be noted that average sociometric index was 2.5 times lower among children from the 1st group with high communicative efficiency against the children from the 2nd group with the same parameters; 1.5 times lower among children with average communicative efficiency; and 1.4 times lower among children with low communicative efficiency (Figure 2). Average sociometric index among children from the 1st group with low communicative efficiency was negative and it meant that those children were predominantly excluded from communication and didn't have any sympathies from their classmates. Negative sociometric index combined with 78.7 % children in the 1st group having low communicative efficiency can indicate that examined Generation Z children are mostly introverts.

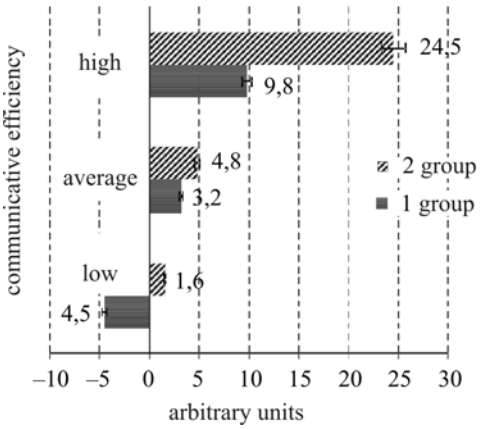

Figure 2. Sociometric index among children depending on their communicative efficiency

There was a research work published by the American Psychological Association; its authors determined that Generation Z representatives had higher neuropsychic strain and emotional sufferings in their personality profiles than people from previous generations [11]. It is also confirmed by our research. Thus, it was shown that average scores given to anxiety among children from the 1st group amounted to 25.8 ± 0.56 against 15.6 ± 0.33 among children from the 2nd group ($p < 0.05$). We established that only 10.3 % children from the 1st group had normal anxiety level whereas it was 40.3 % in the 2nd group. And extremely high anxiety was detected in 30.6 % children from the 1st group and only in 12.2 % children from the 2nd group (2.5 times lower). Apparently increased anxiety was detected 1.6 times more frequently among children from the 1st group against the 2nd one, 37.8 % and 23.6 % children accordingly (Figure 3).

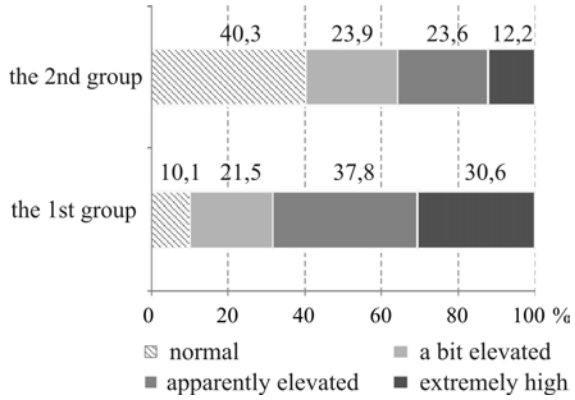

Figure 3. Children from the examined groups distributed depending on anxiety level

We detected an authentic increase in scores given to anxiety in each subgroup of children (subgroups were singled out depending on anxiety level) from the 1st group against those from the 2nd one (Table 2). Thus, average scores given to anxiety in children's subgroup with a bit elevated anxiety amounted to 20.3 ± 0.01 among the children from the 1st group against 19.8 ± 0.03 among the children from the 2nd one ($p < 0.05$); scores given to anxiety among children with apparently elevated anxiety amounted to 25.8 ± 0.02 in the 1st group and 24.5 ± 0.02 in the 2nd one ($p < 0.05$); average scores given to anxiety among children with extremely high anxiety amounted to 31.6 ± 0.09 in the 1st group against 28.3 ± 0.04 in the 2nd one.

Recent research has revealed that lifestyle pursued by contemporary children has changed drastically in comparison with previous generations [12]. Reduced physical activity and shorter periods of time spent outdoors make for a decrease in parameters that describe physical development [13, 14]; this phenomenon is predominantly caused by impacts exerted by new hygienic factors such as information and communication technologies [15, 16], and high educational loads as well [17–20]. Walking to school and back, some household chores, and physical training at school are often only physical activities for a considerable number of contemporary children [21, 22]. Additional physical training with a high dynamic component (sport clubs or dancing classes, for example) could somehow satisfy a biological need in natural locomotion; however, only each third contemporary child attends such clubs or classes [23].

Table 2

Scores given to anxiety among children from the examined groups

Children's subgroups singled out depending on anxiety level:	Examined groups	
	The 1st group	The 2nd group
Normal anxiety	17.5 ± 0.02	16.1 ± 0.01*
A bit elevated anxiety	20.3 ± 0.01	19.8 ± 0.03*
Apparently elevated anxiety	25.8 ± 0.02	24.5 ± 0.02*
Extremely high anxiety	31.6 ± 0.09	28.3 ± 0.04*

Note: * – $p < 0.05$ when the examined groups are compared.

We detected that only height didn't differ in two groups out of all the parameters that describe physical development; on average it was 123.8 ± 0.86 cm in the 1st group and 124.3 ± 0.8 cm in the 2nd one ($p > 0.05$) (Table 3). Body mass was by 13.6 % authentically higher among children from the 1st group and amounted to 25.1 ± 0.83 kg against 22.1 ± 0.61 kg in the 2nd one ($p < 0.05$). At the same time, physiometric parameters of physical development were lower among children from the 1st group in comparison with their counterparts from the 2nd one; thus, average vital capacity of lungs was by 14.7 % lower, and response hand grip strength, accordingly, was by 22.3 % lower. Most experts have recently pointed out that this decrease in physical abilities of a body is caused by contemporary children having no interest in doing active sports, their low physical activity, wide use of gadgets in everyday life, and improper nutrition [24–26].

All the above mentioned facts allowed us to distribute the examined children into subgroups depending on vital capacity of their lungs and response hand grip strength (Figure 4). Thus, there were 1.6 times more children with reduced vital capacity of lungs in the 1st group than in the 2nd one; with reduced response hand grip strength, 1.3 times more.

Table 3

Physical development of children from the examined groups

Parameters	Examined groups	
	The 1st group	The 2nd group
Height, cm	123.8 ± 0.86	124.3 ± 0.8
Body mass, kg	25.1 ± 0.83	22.1 ± 0.61*
Vital capacity of lungs, l	0.95 ± 0.4	1.09 ± 0.3*
Response hand grip strength	6.47 ± 0.45	8.49 ± 0.88*
Body mass index	26.3 ± 1.55	21.5 ± 1.14*

Note: * – $p<0.05$ when the examined groups are compared.

Besides, only 63.1 % children from the 1st group had normal body mass; 30.8 % had overweight, and 6.1 % had body mass deficiency; whereas 82.8 % children from the 2nd group had normal body mass, only 14.7 % had overweight, and 2.5 % had body mass deficiency.

Conclusion. We revealed that Generation Z children had mental and personal peculiarities which became apparent through a greater number of children with socio-psychological deadaptation in communicative and behavioral environment, with high anxiety and lower sociometric status; there were also more children with a decrease in phylometric parameters of physical development together with a trend for having overweight against the previous generation.

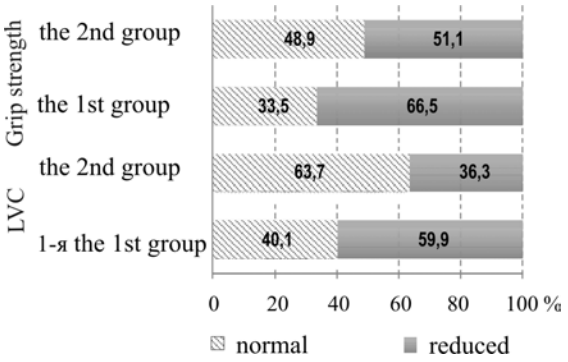

Figure 4. Children from the examined groups distributed depending on vital capacity of their lungs (LVC) and response hand grip strength

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METHODICAL PECULIARITIES AND PRACTICE OF DETERMINING ALUMINUM IN BLOOD AND URINE VIA MASS SPECTROMETRY WITH INDUCTIVELY COUPLED PLASMA

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Toxicants produce adverse effects on population health thus causing health risks; assessment of such risks is a relevant trend in contemporary hygienic research. A list of toxic elements that are to be controlled in biological media includes, for example, mercury, lead, cadmium, arsenic, and aluminum (this element belongs to the 2nd hazard category). Aluminum is one of those elements which are the most widely spread in nature and it most frequently occurs in emissions from aluminum, mining, varnish and paint, and other productions.

We developed a procedure for determining mass concentrations of aluminum in blood and urine via mass spectrometry with inductively coupled plasma (ICP-MS) (FR.1.31.2017.27357); the procedure allows determining aluminum contents in blood within a range from 20 to 200 μg/l with 31% precision; within 200–700 μg/l, with 23% precision; in urine, within a range from 0.1 to 10 μg/l, with 30% precision; within 10–1,000 μg/l, with 23% precision.

We analyzed 192 blood and urine samples taken from children (n = 96) and adults (n = 54) who lived in the Eastern Siberia in a zone influenced by a large metallurgic aluminum-producing enterprise. Simple mean (SM) of aluminum contents in children's and adults' blood amounted to 21 μg/l; 32 μg/l and 21 μg/l in urine respectively. The article also contains comparative assessment of aluminum contents in blood and urine of people living in Russia against reference concentrations applied in Europe and the USA when national programs for human biological monitoring (HBM) were implemented.

Key words: *aluminum,* blood, urine, children*, adults, mass spectrometry with inductively coupled plasma (ICP-MS),* reference concentrations, octopole reaction system (ORS), internal standard.

A priority task for the Russian economy is to intensify industrial production and implement new production technologies; it can often result in environmental contamination and produce negative effects on population health. Determination of chemicals in human biological media is an objective, reliable and evidential way to reveal these negative impacts.

Aluminum is a toxic element and one of the most widely spread metals in nature; it accounts for 8.8 % of the earth crust [1–6]. Aluminum is one of primary metals contained in emissions from metallurgical enterprises, including those located in cities which are in the priority list issued within "Pure air" Federal project. Aluminum toxicity is due to this metal being antagonistic to calcium and magnesium as well as its ability to easily form compounds with proteins and accumulate in the kidneys, bone, and nerve tissue [1–3]. Aluminum is among elements that are subject to control in blood and urine, together with such toxicants as mercury, lead, cadmium, and arsenic [1]. Aluminum compounds belong to the 2nd hazard category[1].

Element analysis of biological media involves applying practically all spectral techniques with different sample preparation; as a rule, they are sensitive and selective [4, 5, 7, 8–25]. The most widely used techniques are

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electrothermal atomic-absorption spectrometry (ET-AAS, GFAAS), atomic-emission spectroscopy with inductively coupled plasma (ICP-AES)[2], and mass spectrometry with inductively coupled plasma (ICP-MS)[3]. At present high resolution mass spectrometry or mass spectrometry with dynamic reaction cells (DRS) is considered the most efficient technique. ICP-MS technique has certain advantages such as focus on many elements, low limits of detection, short period of analysis, and small volumes of analyzed samples. GFAAS technique is just as sensitive as ICP-MS when it is applied to analyze biological media; but the technique focuses on only one element and is usually applied as an alternative one to determine certain elements, including aluminum, beryllium, chromium, and thallium [8, 9].

Aluminum is determined in biological media with ICP-MS with preliminary decomposition of a sample or without it. Obviously, when a sample is decomposed improperly, it can make any high precision technique meaningless [7]. Besides, recommended microwave mineralization can't prevent samples from being contaminated when accompanying reagents are added; however, it makes decomposition faster. Analysis without samples mineralization is more preferable as it helps avoid contamination, minimizes losses, and analysis itself requires less time. As a rule, blood is diluted 10–50 times with water solutions of Triton X-100, 1-butanol, EDTA, NH_3, or nitric acid; blood serum and urine are diluted 2–10 times with nitric acid solution thus making additional contamination of a sample quite possible [7]. Despite a great number of publications, practically all authors indicate it is difficult to determine aluminum but they often don't give any comments on obtained results [9, 21, 23].

We developed MG 4.1.3230-14[4] for quantitative determination of 12 chemical elements in biological media (blood and urine) with mass spectroscopy with inductively coupled plasma. The procedure for determining 12 elements in blood was patented[5]. But still, as determination of aluminum has its peculiarities related to sampling, samples being contaminated during storage, and high aluminum contents in water and reagents, we didn't include aluminum into the list.

Our research goal was to develop an up-to-date and highly sensitive procedure for quantitative determination of aluminum in blood and urine with mass spectroscopy with inductively coupled argon plasma; this procedure could be applied in clinical laboratories for diagnostics, treatment, and prevention of health disorders caused by negative impacts exerted by hazardous chemicals and for health risk assessment.

Data and methods. When applying ICP-MS for quantitative determination, biomaterials should be preliminary prepared so that matrix effects and polyatomic interferences are eliminated; these effects and interferences are due to not only ions of determined elements occurring in plasma but also ions of argon, hydrogen, oxygen, etc. that are present in plasma in big quantities [26, 27]. A basic aluminum isotope ^{27}Al has the following spectral folding: $^{12}C^{15}N^+$, $^{13}C^{14}N^+$, $^{12}C^{14}NH^+$, $^{12}C_2H_3^+$ [28, 29]. We applied our procedure for determining 12 elements which we had previously developed and it didn't yield us expected results. Aluminum occurred in water in high concentrations even if that water was intensely purified; introduced reagents (nitrogen acid and hydrogen peroxide) and solutions of elements for internal comparison, and laboratory dishes

[2] MG 4.1.1482-03. Determination of chemicals contents in diagnosed biological substrates, poly-vitamin preparations with microelements, biologically active additives to food and raw materials they are made of via atomic emissions spectroscopy with inductively coupled argon plasma. – M., 2003. – 28 p.

[3] MG 4.1.1483-03. Determination of chemicals contents in diagnosed biological substrates, preparations, and biologically active additives via mass-spectrometry with inductively coupled argon plasma. – M., 2003. – 36 p.

[4] MG 4.1.3230-14. Measuring mass concentrations of chemicals in biological media (blood and urine) with mass spectrometry with inductively coupled plasma. – M., 2014. – 32 p.

[5] N.V. Zaitseva, T.S. Ulanova, A.G. Veikhman, E.V. Stenno, O.V. Gilyova, A.V. Nedoshitova, M.A. Bakanina. The procedure for determining concentrations of cadmium, lead, arsenic, chromium, nickel, copper, zinc, manganese, vanadium, strontium, selenium, and thallium in blood with mass spectrometry with inductively coupled plasma. Patent No. 2585369 RU; 2015.

also made their contributions into aluminum concentrations being too high in a blank sample; those concentrations were often even higher than in an analyzed sample. Obviously, to determine aluminum in blood and urine, we require specific conditions which will allow eliminating spectral and non-spectral (matrix) interferences. It involves specific conditions for samples taking and storage; particularly pure reagents and water; specific degree to which a sample is diluted; a specific procedure for samples preparation before they are analyzed; different ways to prepare calibration solutions; a choice on elements for internal comparison (internal standard) etc.

We quantitatively determined aluminum in blood and urine with Agilent 7500cx (Agilent Technologies, USA) quadrupole mass-spectrometer with inductively coupled plasma and octopole reaction/collision cell (ORS). Plasma generator had power equal to 1,400 W. Samples were introduced via a two-channel spray chamber under 2.0 °C. The mass-spectrometer was equipped with a plasma torch with its injector tube diameter being equal to 2.5 mm. Samples were fed into the spray chamber at a speed equal to 0.4 ml/min. To get plasma burn, we applied extremely high liquid argon with its purity being equal to 99.998 % (TC-2114-005-00204760-99) and it was fed at a speed up to 20 l/min. Pressure in the gas-feeding channel was equal to 700±20 kPa. To calibrate the device, we applied ^{7}Li, ^{59}Co, ^{89}Y and ^{205}Tl solution in 2 % HNO_3 with concentration of its elements being equal to 1 μg/l. After sufficient sensitivity was reached in the standard mode, we switched the mass-spectrometer into the operation mode with reaction/collision cell functioning. We applied extremely pure helium as a gas-reagent (TC-0271-135-31323949). Maximum suppression of the background signal with optimal sensitivity being reached occurred when helium flow speed was equal to 4.3 ml/min. The distance between the plasma torch and the sampling cone was equal to 7.0 mm.

It is not advisable to use quartz dishes when aluminum is determined [23]. We took plastic dishes and washed them in Elmasonic S 100H ultrasound cleaner (Germany) at 45–50 °C, first with distilled water, and then with diluted HNO_3 solution.

We applied extremely pure polypropylene test tubes (Labcon, the USA, LOT 609CE-609C) to analyze blood and urine.

Water was purified with Milli-Q Integral (Millipore SAS, France) system. However, background elements still persisted in concentrations equal to 3.0 μg/l and even higher; therefore, we additionally purified water with Vodoley system (Khimelectronica, Moscow), and background concentrations decreased to 0.55 μg/l. Water should be purified directly before samples are diluted with it and then analyzed.

To prepare solutions of standard samples, we applied a solution of aluminum ions with mass concentration being 1.0 g/dm^3 (GSO - 7927-2001) and 1 % solution of high purity HNO_3 (Sigma-Aldrich, the USA). To prepare Internal Standard (IS) solutions, we applied a complex standard solution of ^{209}Bi, ^{73}Ge, ^{115} In, ^{6}Li, ^{45}Sc, ^{159}Tb, ^{89} Y with its concentration being 10 mg/l in 5 % HNO_3 water solution (Internal Standard Mix, the USA).

Impure dishes and an increase in aluminum contents that occurs when samples are stored make a primary contribution into blank sample value [30]. We prepared blank samples simultaneously with preparing samples for analysis.

We prepared calibration samples for determining aluminum in blood and urine out of aluminum solution with its mass concentration being 1.0 g/dm^3 (GSO - 7927-2001), IS solution, 1 % HNO_3 water solution, and blank sample solution. Concentration of aluminum in calibration solutions was equal to 0.0; 0.1; 0.5; 1.0; 5.0; 10.0; 50.0 μg/l. To prepare calibration solutions, we applied high purity Nitric acid 69 % (Sigma-Aldrich, the USA) or Nitric acid 65 % (PanReac, Espana).

Impacts exerted by non-spectral (matrix) interferences can usually be removed via applying calibration with a selection of calibration solutions matrix, internal standard, or both [10]. When selecting IS, it is necessary to adhere to the following rule: IS should have atomic mass that is as close to atomic mass of

determined elements as it's only possible, and the lower atomic mass of a determined element is, the stricter this rule should be followed [26, 27].

To prepare internal standard (IS) solutions, we applied a complex standard solution of ^{209}Bi, ^{73}Ge, ^{115}In, ^{6}Li, ^{45}Sc, ^{159}Tb, ^{89}Y with its concentration being 10 mg/dm^3 in 5 % water solution of nitric acid (Internal Standard Mix, the USA). Table 1 contains the results of determining aluminum in standard blood samples SERONORM L2 and L3 (Sero AS, Billingstad, Norway) and urine samples Seronorm^{TM} urine (LOT 0511545, Sero AS, Billingstad, Norway) with use of various elements for internal comparison (IS). Prior to analysis, certified control materials were prepared in the same way as samples for analysis (working samples).

Data in the Table 1 indicate there is quite satisfying coincidence between certified and detected concentrations without IS and with ^{73}Ge at blood level L2. ^{115}In application led to a considerable increase in detection error. Therefore, we didn't obtain any convincing evidence that it was necessary to apply IS when determining aluminum in blood and urine as well as this or that element for internal comparison having apparent advantages.

We introduced 0.5 ml of urine into tubes of an automated sampler with a dosing device, added 4.45 ml of HNO_3 water solution and 0.05 ml of IS solution [31, 32]. Any urine samples with sediment were centrifuged before dilution. Diluted samples were not to be stored. Besides, when aluminum is determined in urine, water should be purified directly before analysis and samples should be diluted on a day they are analyzed.

We took a blood sample with its volume 0.1 ml and added 0.1 ml of complex IS solution and 0.2 ml of concentrated HNO_3 to it. We then stirred a test tube with this mixture, kept it for 6–7 hours, added deionized water until mixture volume reached 10 ml and them centrifuged it for 10 minutes at a speed equal to 2,700–3,000 turns per minute on CLMN–P10–01–"Elekon" centrifuge (Russia).

Simultaneously we prepared a blank test for each series of samples; this blank test went through all the stages in sample preparation which involved applying all the reagents as it was the case with analyzed samples.

We should note that when a sample was dissolved with an acid, a structure of an examined sample matrix wasn't destroyed completely; however, it helps to reduce an amount of time required for samples preparation and to save reagents. Another significant aspect is that a volume of sample necessary for analyzing goes down to 0.1 ml and a blank test becomes almost insignificant when a sample is decomposed in such a way. It is another advantage of acid dissolution.

The procedure for determining aluminum in biological media was metrologically certified; to do that, we applied calculations with a known concentration for an average boundary of a measured range and the standard addition technique in accordance with RM[6] and GOST R ISO 5725–1÷GOST R ISO 5725–6–2002 (certificate No. 88-16207-11-RA.RU.310657-2017). The developed procedure for measuring mass

Table 1

Certified and determined average values of aluminum concentrations in standard blood and urine samples Seronorm ^{TM} (Norway), μg/l

Level	Certified average value, μg/l	Detected average value / error of the average, Δ, %		
		Without IS	^{73}Ge	^{115}In
Seronorm^{TM}blood L2 (n = 18)	70.9	82.3/16.1	83.6/17.9	119.6/68.6
Seronorm^{TM}blood L3 (n = 18)	105	106.1/1.0	117.9/12.3	–
Seronorm^{TM} urine L2 (n = 14)	103	105.2/2.1	115.4/12.0	110/6.8

[6] RMG 61-2003 GSI. Parameters that show precision, and correctness of procedures for quantitative chemical analysis. Assessment techniques [Web-source] // Kodeks: and electronic fund of legal and reference documentation. – URL: http://docs.cntd.ru/document/1200037651 (date of visit September 22, 2019).

Table 2

Aluminum contents (SM) in biological media of children and adults and validity of discrepancies form the reference territory, μg/l

Group (medium)	Test group, SM	Reference group, SM	P_1	Analysis of frequencies against the reference group		
				% higher	% The same	% lower
Children (blood)	21	<20	0.24	25	0	75
Adults (blood)	21	< 20	**0.01**	26	74	0
Children (urine)	32	7	**0.005**	90.1	6.6	3.3
Adults (urine)	21	2.4	**0.001**	100	0	0

Note: P_1 is validity of discrepancies as per SM between urban population and the reference territory

concentrations of aluminum with ICP-MS allows determining its contents in blood within a range from 20 to 200 μg/l with 31 % precision; within a 200–700 μg/l range, with 23 % precision. The procedure allows determining aluminum contents in urine within a range from 0.1 to 10 μg/l with 30 % precision; within a 10–1,000 μg/l range, with 23 % precision.

We established limits of detection and limits of quantification for our procedure. LOD for determining aluminum in blood amounts to 7 μg/l; in urine, 0.033 μg/l; LOQ for determining aluminum in blood amounts to 21 μg/l; urine, 0.1 μg/l.

Results and discussion. The developed procedure for determining aluminum in biological media (blood and urine) was tested in the East Siberia on population (adults and children) who lived in a zone exposed to a large metallurgical aluminum-producing enterprise; the research involved analyzing biological media. Overall, we analyzed 192 blood and urine samples taken from children ($n = 96$) and0 106 samples taken from adults ($n = 54$). We also had two reference groups, children ($n = 53$) and adults ($n = 30$) who lived in a zone beyond exposure to the said enterprise; Table 2 contains the results of our analysis. Simple mean (SM) of aluminum contents in blood of children and adults form the test groups amounts to 21 μg/l; children and adults from the reference groups, < 20 μg/l. Simple mean of aluminum contents in urine of children and adults amounts to 32 μg/l and 21 μg/l accordingly; ion the reference group, 7 and 2.4 μg/l. Aluminum contents in urine taken from children from the test group had authentic discrepancies from that in the reference group (90 % samples were higher than in the reference group, by 4.6 times). Aluminum contents in urine taken from adults form the test group also had authentic discrepancies from that in the reference group, 100 % having concentrations by 8.8 times higher.

The exposed territory where the examined population lives takes the 3rd rank place as per ambient air contamination both in the Siberian Federal District and among the RF regions as well. Ambient air contamination is caused by an aluminum-producing enterprise and a pulp and paper mill. Analysis of morbidity among population living on this territory over the last five years has revealed increased morbidity with respiratory diseases (chronic bronchitis and bronchial asthma) and musculoskeletal system diseases both among children and adults; the revealed morbidity has negative dynamics as it tends to grow. Our research results can be used to assess sufficiency of activities performed within “Pure air” Federal program in a zone influenced by metallurgic enterprises in the East Siberia as their emissions contain aluminum and it causes ambient air contamination with this metal.

Values obtained for the examined groups were statistically distributed; the results are shown in Table 3. Results were given as simple mean (SM); 25th, 50th, and 75th percentile; we also gave minimum and maximum values for a sampling. Median was close to a simple mean for aluminum contents in urine taken from urban population and it meant that distribution of values was normal. In all other cases values were in a range of smaller concentrations at

Table 3

Aluminum contents in blood and urine of children and adults, μg/l

Group	Test group						Reference group						Reference levels (range)				
	N	AM	q25	q50	q75	Min-Max	N	AM	q25	q50	q75	Min-Max	ALS Scandi-navia	Titz	HELIX	ARUP	Kalet-ina
Children blood	96	21	10	10	16	10–166	49	17	10	10	10	10–58.3	5–192	0–100	0–15	–	200
Adults blood	54	21	10	10	21	10–100	31	12	10	10	10	10–29.5					
Children urine	91	32	18.9	31	44.6	3.3–61.1	41	7	0.1	3.6	10	0.1–38.3	0.6–5.1	≤20	0–31	0–7	5
Adults urine	52	28	13.8	22	37.3	6.2–104	26	2.4	0.1	0.1	1.5	0.1–24.0					

LOQ/2. To give reference values, we took data from well-known scientific works by N.I. Kaletina, N. Titz, and data presented by such diagnostic laboratories as ALS Scandinavia (Sweden), ARUP (the USA), and HELIX (Saint Petersburg) [1, 33–35]. There have been numerous works focusing on difficulties involved in comparing analysis results and on standards for contents of many elements in biological media being only conventional [7, 36]. Reference values which we give in our works are no exception. Average aluminum contents in blood and urine vary within quite a wide range of concentrations. And if N.I. kaletina states that maximum permissible aluminum concentration in blood amounts to 200 μg/l, then N. Tizt gives another figure, namely 100 μg/l. Maximum aluminum contents which we detected in blood of exposed population do not exceed reference values given by the said authors whereas a reference concentration given by HELIX is practically 10 times lower than the concentration which we detected in blood of the exposed children. Simple mean of aluminum contents in urine in the reference group doesn't exceed reference values whereas aluminum contents in urine taken from urban population are 5–6 times higher than these values.

Table 4 contains data on aluminum contents in whole blood, blood serum, plasma, and urine of patients from different countries and RF regions obtained via variable analysis techniques [10, 11, 19, 20, 37–40]. These data are also shown in Figures 1 and 2 for adult population.

Aluminum contents detected in blood of exposed adults from the test group were 5 times lower than the reference level given by Titz but quite comparable with contents detected in population in Sweden. Non-exposed adults living in Croatia [37] had aluminum in their blood in concentration that was 2 times higher; exposed adults, 4 times higher. At the same time, those concentrations didn't exceed reference ones. Workers employed by aluminum-producing enterprises in Germany [39] had 2 times lower aluminum contents in their blood than people from the East Siberia. Aluminum concentrations in non-exposed people from France were comparable with data which we obtained for the reference group in our research.

Aluminum contents detected in urine of adults from the reference group were lower than reference levels given by ALS Scandinavia and ARUP diagnostic laboratories and N. Titz. Aluminum contents in urine of exposed adults from the test group was higher than any reference level and quite comparable with aluminum concentrations detected in urine of workers employed by aluminum-producing enterprises in Germany [39] and Croatia [37]. Aluminum contents detected in urine of non-exposed population in France were comparable with aluminum contents which we detected in the reference group.

Table 4

Aluminum contents in biological media of exposed and non-exposed population living on different territories, µg/l

Group (medium)	Territory, procedure, presentation of results						
	Croatia, 2010 ICP_MS,) NE/E, Me (range) [37]	Sweden, 2013, ICP-MS, NE, SM (Me) [21]	France, 2005, ICP-MS, NE Me (range) [12]	Germany, 1996, AAS ETA, NE/E, SM; Me (range) [39]	Central Russia, 2003, ICP-AES [22]*; ICP-MS, 2010 [11]**, NE; 2013, E [40]*** SM (range)	Norway, 2013, ICP-MS, [38]*; UK,2014, [25]**Me (range)	East Siberia, 2016 ICP-MS, NE/E SM (Me)
Children (urine)	Not available	–	Not available	–	14±2**	–	7 (3.6) / 32 (31)
Adults (urine)	15.7 (0–100.2) / 46.4 (6.3–110.2)	–	1.9 (0.16–11.2)	(2.4–30.8) / 29.3; 19.4 (1.4–159.4)	54.7 (10.5–223) ***	3.8 (1.3–25.73)**	2.4 (0.1) / 28 (22)
Children (blood)	Not available	–	Not available	–	3.3 ± 0.3**	–	17 (10) / 21 (10)
Adults (blood)	42.75 (8.15–108) / 87.6 (17.8–185.6; serum)	19.2 (17.25. blood) 11.48 (4.52. serum)	1.3 (1.3–6.4. blood); 3.1 (1.2–17.3. plasma)	(1.5–11) / 8.9; 7.3 (2.3–30.0. plasma)	56 (40–73) *	15.5 (10.8–21.7; plasma)*	12 (10) / 21 (10)

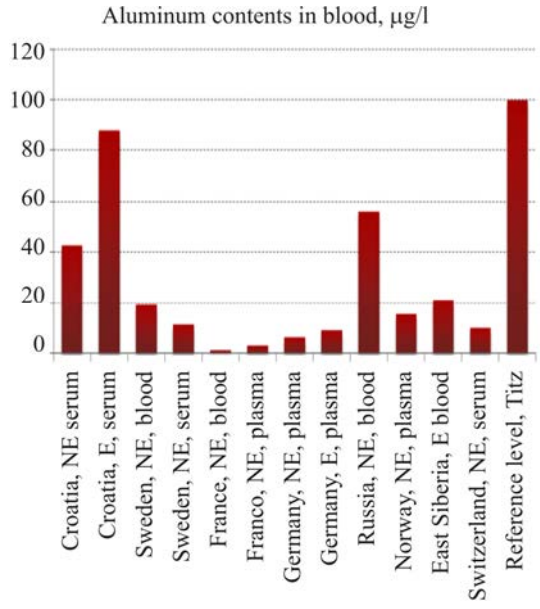

Figure 1. Aluminum contents in adults' blood, µg/l (E means exposed adults; NE non-exposed ones)

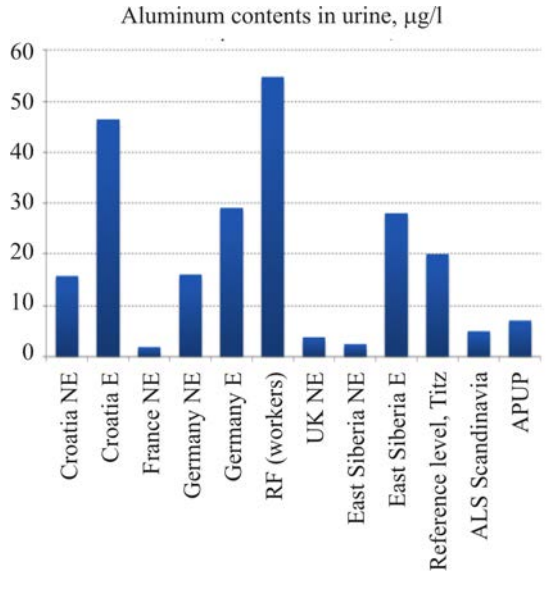

Figure 2. Aluminum contents in adults' urine, µg/l

Conclusions. We have developed a procedure for measuring mass concentrations of aluminum in biological media (blood and urine) with mass spectroscopy with inductively coupled plasma and reaction/collision cell with helium applied to correct polyatomic interferences (FR.1.31.2017.27357). The procedure for measuring aluminum concentrations in blood was metrologically certified for the following ranges: 20–200 μg/l and 200–700 μg/l with its precision being 31 and 23 % accordingly; in urine, for the ranges 0.1–10 μg/l and 10–1,000 μg/l with its precision being 30 and 23 % accordingly. We established limits of detection (LOD) and limits of quantification (LOQ) for the procedure. LOD for determining aluminum in blood is equal to 7 μg/l; in urine, 0.033 μg/l; LOQ for blood amounts to 21 μg/l; urine, 0.1 μg/l. The procedure was applied to analyze biological media of children and adults living in the East Siberia who lived in a zone influenced by an aluminum-producing enterprise (the examined territory). We analyzed 192 blood and urine samples taken from children ($n = 96$) and 106 samples taken from adults ($n = 54$). Our reference group included 53 children (100 samples) and 30 adults (60 samples) who lived in a zone which was not influenced by the said enterprise (the reference territory).

Simple average (SM) of aluminum contends in blood of children and adults living on the examined territory amounts to 21 μg/l; the reference territory, < 20 μg/l. Simple mean (SM) of aluminum contents in urine of children and adults living on the examined territory, amounts to 32 μg/l and 21 μg/l accordingly; the reference territory, 7 and 2.4 μg/l accordingly. We detected and authentic discrepancy regarding aluminum contents in urine between children from the test group and those from the reference one (concentration in 90 % samples was 4.6 times higher in the test group). There also was an authentic discrepancy regarding aluminum contents in urine between adults from the test group and those from the reference one (concentration in 100 % samples was 8.8 times higher in the test group). The procedure for measuring mass concentrations of aluminum on blood and urine with mass spectrometry with inductively coupled plasma can be applied by sanitary-hygienic, ecological, medical, and scientific organizations that deal with human occupational pathology and ecology; in can be used in evidence medicine; to organize biological monitoring; to assess anthropogenic loads; to assess efficiency of medical and innovative technologies; to assess population health risks.

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ROLE PLAYED BY A FAMILY IN CREATING HEALTHY LIFESTYLE AND ELIMINATING RISK FACTORS THAT CAUSE THREATS TO CHILDREN'S AND TEENAGERS' HEALTH

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The paper focuses on socializing potential than belongs to a family in creating attitudes towards health and healthy lifestyle among children and teenagers. The author describes basic behavioral risks for young people's health and a role played by the closest social environment in minimizing or aggravating them.

The author also provides an insight into concepts of health and healthy lifestyle and dwells on how important it is to perform constant monitoring over children's and teenagers' health as they represent quite a specific social and demographic group. The author analyzes data on morbidity growth among children and teenagers in Russia, how susceptible they are to addictive behavior and other risk factors, and also compares these parameters with world trends.

The latest statistical data and analysis of data available from literature allowed showing that, in spite of huge socializing potential that a family has as a social institution, at present parents are rather limited in terms of activities that can help them improve and preserve their children's health. It is caused by both transformations of a family as a social institution and weaker family relations in the contemporary world as well as by insufficient competences that parents have as regards health and overall decrease in living standards, poorer availability of medical services, unfavorable changes in the ecological situation etc.

The author concludes that it is necessary to provide support to a family as a social institution. It should be done by a state and society in general as they are to establish qualitative information channels that will allow providing parents with the latest scientific data on the most common risk factors for children's health and on ways how to minimize such risks. Any family, regardless of its social status, wealth, or any other characteristics, should be granted an opportunity to provide safety for their children.

Key words: *health, health risk, healthy lifestyle, family, children, teenagers, tobacco smoking, alcohol intake, overweight and obesity, injuries, addictive behavior.*

Population health is a key issue of the contemporary Russian society. It is especially alarming that health issues now occur among children and teenagers and not just among older people and it "undoubtedly contradicts any natural human development when health is deteriorated gradually as a person grows older" [1].

Population health is among the most significant signs indicating a state is truly developed; it is not only a parameter but also a most necessary condition for economic development [2–6]. Children and teenagers health is the most important as it is "the most significant indicator of a future labor, economic, cultural, and defense potential of any society" [7].

Children and teenagers' health in Russia causes a lot of concerns among medical experts, teachers and parents. Morbidity among children grows by 3.2 times faster, and among teenagers, by 4.4 times faster than among population in general [8]; mortality among children is 2 times higher in Russia than in "eight new EU countries" [9]. Over the last 15 years total morbidity among teenagers and young people grew by 1.7 times in our country [10]. According to official data, 28.9 % children aged 0–14 belong to the 1st health group (practically healthy); 56.2 %, the 2nd one (minor disorders); 12.6 %, the 3rd one (non-apparent chronic diseases and congenital mal-

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formations); 2.3 %, the 4th and the 5th ones (apparent chronic diseases, grave malformations, and oncology) [11]. However, these data do not show a true picture and actual children's health is significantly worse. Thus, A.A. Baranov and V.Yu. Al'bitskiy claim that "actual morbidity among children is 1.5–2 times higher than it is given by official statistics" [12].

There are a lot of various risk factors that make for health loss. However, researchers have not yet reached a common conventional opinion regarding risk factors typology, an extent to which they influence health and a nature of their influence as well as regarding procedures for examining this influence [13–17]. In any case, risk factors do not produce their effects separately but co-exist and interact with each other. Moreover, the same factor can simultaneously be a risk factor and an anti-risk one [18].

According to contemporary domestic research, children's health in Russia is significantly influenced by environmental factors (adverse environment) [19–22], biological factors (genetics) [23–25], and macro-social factors (peculiarities related to social institutions functioning, social differentiation, socioeconomic and social and political factors) [26, 27]. Behavioral health risk factors also play an important role; such factors are related to behavioral patterns that can be modified such as improper nutrition, low physical activity, smoking, alcohol intake, risky sexual behavior, etc. These and some other adverse factors related to a person's lifestyle in future will "determine morbidity and mortality among adults as well as their dynamics" [28]. It is impossible to completely eliminate behavioral health risk factors; however, an extent to which they can be minimized depends heavily on favorable environment and awareness among young generation about major health issues. And this, in its turn, depends on how competent the closest social relations are in the sphere. The primary significance here belongs to a family.

A family is a basic social institution responsible for personality formation, for a value system and a culture a person has. According to most people living in Russia (71 %), it is in a family where main personality traits are formed and where a child acquires his or her habits and attitudes in life [29]. This institution creates behavioral stereotypes that are a part of a person's lifestyle influencing his or her health: whether he or she has or doesn't have any bad habits; doing sports; nutrition habits; attitudes towards prevention and treatment of diseases; attitudes towards all other components of a healthy lifestyle. Results obtained via questioning accomplished among schoolchildren reveal that most of them think health to be the main value in life (73.4 %) and also consider a family to have a leading role in health preservation [30].

Decline in living standards, poorer availability of medical aid, adverse changes in the environment and other factors create much greater health risks and limit parents' capabilities to preserve and improve their children's health. Moreover, parents often don't have sufficient knowledge on how to educate their children regarding health preservation. Parents often tend to underestimate "how significant behavioral risk factors are as they pay too much attention to environmental risks" [31]. All the above mentioned factors, together with a family as a social institution being transformed in the contemporary world, parents being now not so authoritative as they used to be, and a gap between generations only growing, etc., lead to a significant decrease in a potential that a family has as an institution that can make for pursuing healthy lifestyle. Given that, it is quite essential to pay great attention to managing health, eliminating adverse factors, and making children and teenagers pursue healthy lifestyle.

Our research goal was to substantiate an opinion that at present as a family institution is being transformed parents don't have sufficient competence necessary for making their children healthy and convince children and teenagers to pursue a healthy lifestyle. Consequently a state and a society should provide a family with information and economic support.

The authors of the present work were most interested in studying behavioral health

risk factors for Russian children (0–14 years old) and teenagers (15–17 years old) as they are a rather specific social and demographic group. Another important issue here is a potential that a family institution has for managing these health risk factors and their elimination.

Our empiric data were taken from a study performed by the Department for Family Sociology and Demography, Sociology Faculty of the Moscow State University. It was entitled "Inter-regional studies on life values and intransitivity of attitudes towards having a family and children among women, men, and married couples based on ongoing analysis of comparable data" (hereinafter called CeDO for short). The first stage in the study was accomplished in summer 2018 in Moscow (CeDO-2018) and involved married couples questioning. The sampling included 729 people. Data were statistically processed with IBMSPSS 23.0 for Windows. In order to perform comparative analysis as well as obtain additional data on the subject, we also took data provided by the Public Opinion Fund, The Russian Public Opinion Research Center (VSIOM), the World health organization (WHO), the RF Public healthcare Ministry, and the Federal State Statistics Service (Rosstat).

Results and discussion. Healthy lifestyle is based on being educated how to preserve one's health; such education should start in the very early childhood and only in this case it will yield really good results. In this context a family is an institution that is potentially able to most efficiently instill a value-oriented approach to health in its members and minimize related risks.

As we have already mentioned, health to a great extent depends on everyday self-preserving behavior, and a person and his or her lifestyle is its mane regulator. According to data obtained via CeDO-2018, most responding parents (63.5–62.1 % fathers and 64.8 % mothers) agreed with that and considered that they bore a major responsibility for their own health and health of their children. As per data provided by VSIOM, Russians also tend to blame themselves for feeling bad and their health deterioration (47 %) [32]. However, people's actions aimed at their health preservation and improvement are often contrary to their understanding what should be done to achieve this goal.

Parents believed health was on the greatest values in life. When ranking 15 values in order of priority, 46 % respondents gave health the 1st rank place (51.9 % mothers and 39.5 % fathers). "health for myself" as a value had an average rank being equal to 3.2 (a bit lower than "family" as a value, 3.1; but the following group of values had significantly lower ranks with their average values being not less than 6). And health becomes even more valuable when it comes to children's health. When answering a question "In your opinion, what should be the most valuable for your children?" 61 % respondents stated it was "health" ("health for children" as a value had a rank equal to 2.5; for comparison, "family" had only 4.8). Overall, parents didn't think their health was poor (only 1.6 % mothers stated it was, and there were no fathers who gave such an answer) and considered it to be good (53.3 %). Most parents were quite satisfied with their health (36.9 % completely, and 54.1 % partially) and their children's health (51.2 % completely and 40.2 % partially) (Table 1).

Healthy lifestyle is a rather complicated and multi-dimensional concept but at the same time it is an integral one with all its elements being closely interconnected. Healthy lifestyle includes rational nutrition, giving up bad habits, physical activity, reasonable sexual behavior, diseases prevention, etc. In addition to physical and biological aspects we should also mention psychological ones such as minimizing stresses, positive thinking, ability to interact with other people etc. But at the same time it would be incorrect to reduce healthy lifestyle to individual aspects only. Sociological approaches to studying healthy lifestyle focus on social reasons, social institutions and behavioral patterns that result in occurrence of various attitudes [33].

Table 2 contains data on distribution of various healthy lifestyle elements according to opinions given by responding parents (CeDO-2018).

Table 1

Descriptive statistics of basic CeDO-2018 results, %

Self-evaluations of health and healthy lifestyle behavior	Parents in general	Fathers	Mothers
Satisfied with my health (completely or partially)	91.0	94.8	87.5
Satisfied with my children's health (completely or partially)	91.4	94.0	89.1
Think my health is good	53.3	56.0	50.8
Take regular care of my health	41.0	36.2	45.3
Pursue a healthy lifestyle	24.6	21.6	27.3
Try to pursue a healthy lifestyle but don't always succeed	61.1	62.9	59.4
Make my children pursue a healthy lifestyle via talking to them	36.5	38.8	34.4
Make my children pursue a healthy lifestyle via doing it myself	52.0	47.4	56.3
Think that improper nutrition is bad for health (bad/rather bad)	93.0	90.5	95.3
Think that low physical activity is bad for health (bad/rather bad)	98.5	96.6	97.5
Think that alcohol intake is bad for health (bad/rather bad)	87.3	81.1	93.0
Think that smoking is bad for health (bad/rather bad)	95.9	93.1	98.5
Smoke	21.7	31.9	12.5
Don't do sports / do it less than once a month	32.4	28.3	31.6

Table 2

Healthy lifestyle elements according to parents' opinions, in % (CeDO-2018)
Answering a question: "What does healthy lifestyle mean to you personally?
(not more than THREE options should be chosen)"

Healthy lifestyle element	Parents in general	Fathers	Mothers
Giving up bad habits	65.2	63.8	66.4
Healthy nutrition	63.1	59.5	66.4
Doing sports	42.6	44	41.4
Keeping up healthy day regimen	33.6	29.3	37.5
Adhering to hygiene rules	18.0	14.7	21.1
No promiscuous sexual contacts	13.5	12.9	14.1
Ability to manage one's emotions	12.7	13.8	11.7
Regular visits to a doctor to prevent diseases	9.4	6.9	11.7
Having reliable information on healthy lifestyle	5.7	7.8	3.9

Sociological concepts on health risk factors stress negative trends in lifestyles and the environment and include both behavioral risk factors and social contexts, as well as macro-sociological factors (such as low living standards, "social differentiation, peculiarities of socioeconomic, social-cultural, and social-political subsystems in a society") [18].

The present work primarily focuses on healthy lifestyle formation and eliminating health risks for children and teenagers. Hence, it seems advisable to pay primary attention to risk factors that can be modified such as addictive behavior, imbalanced nutrition, low physical activity, risky sexual behavior, risk of injuries, etc.

Smoking. Excess spread of smoking in Russia is a major issue related to healthy lifestyle. Smoking is a cause of untimely death in 16–17 % cases in Russia [34]. As per data provided by the RF Public Healthcare Ministry, a number of smoking people is going down (from 37.1 % in 2013 to 30.5 % in 2017): however, Russia is still among outsiders as per this parameter. Smoking is more widely spread only in Indonesia, Jordan, Kiribati, and Sierra Leone [35], and a number of cigarettes per capita (2,227) is one of the highest in Europe [36]. As per the WHO data, in 2017 in Russia 45 % men and 15 % women smoked. [37]. Selective examinations of female reproductive behavior in Russia revealed that 11.5 % women didn't

quit smoking even after they found out they were pregnant [38]. As per data obtained in international research, those women who managed to quit smoking during pregnancy were likely to start smoking again after a child was born (43 % during the first 6 months since delivery) [39].

According to the WHO, most adults started smoking when still being teenagers. A share of smoking teenagers among those aged 13–15 is still rather high in Russia as it amounts to 15.1 %, 17 % among boys and 13.3 % among girls; 26.3 % out of them started smoking when they were younger than 10 [40]. There is a clear dependence between smoking parents and a wish a teenager has to start smoking. "Two thirds of teenagers from families where parents smoke or used to do it in the past have tried smoking at least once; there are much fewer such teenagers in non-smoking families, only 41 %" [41]. Children who grow in families with smoking parents start smoking at an earlier age and they more often become regular smokers [42].

According to data obtained via CeDO-2018, 21.7 % adults smoked among Russians who had children, 31.9 % men and 12.5 % women. Smoking people tended to neglect health risks caused by smoking both for them and their children (only 57 % smokers believed smoking was hazardous for health against 91.7 % of non-smokers). Besides, almost one fourth of smoking parents claimed that they tried to persuade their children to pursue healthy lifestyle with their own example and it was considerably lower than among non-smokers (63.2 %), but still we can say it was rather presumptuous (Figure 1). It is interesting to note that it was smokers (40 %) who believed that a healthy lifestyle required a lot of time and money against 17.5 % non-smokers being of the same opinion.

Alcohol intake. Alcohol abuse is the next health risk factor that can be modified. Contribution made by alcohol into untimely death cases amounts to about 10 % [34].

According to official data provided by the RF Public Healthcare Ministry, alcohol consumption has reduced by 40 % over the last

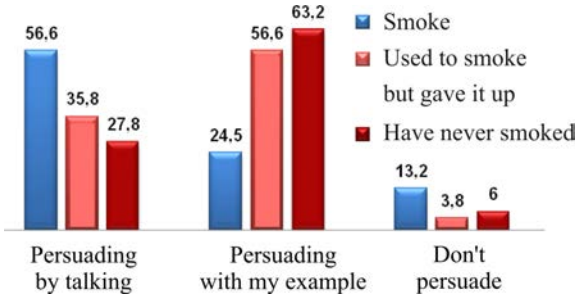

Figure 1. Persuading children and teenagers to pursue a healthy lifestyle by smoking and non-smoking parents, in % (CeDO-2018)

five years [43]. Data provided by the WHO confirm these statistical reports as according to them Russian now consumed by 3.5 liters fewer per capita (8.42 in 2016) than they used to 10 years ago (11.83 in 2006) [44]. Still, we should remember that these figures include only alcohol that is accounted for officially and the WHO experts believe that 30.8 % alcohol consumed in Russia (3.6 liters per capita) is unaccounted for (illegal). That is, actual consumption is about 12 liters [45].

CeDO-2018 revealed that only 8.4 % parents thought alcohol intake caused no health risks and didn't damage health at all; 87.3 % stated it was hazardous (51.6 % believed it was extremely hazardous, and 35.7 %, rather hazardous, Table 1). In spite of favorable trends and population becoming aware that alcohol is a risk factor, alcohol consumption, especially strong spirits consumption, is still rather high in Russia.

VSIOM conducted a questioning in 2018 entitled "What should we protect our children from?"; it revealed that it was alcohol and drug addiciton that took the 1st rank place with their share amounting to 37 % [46]. The research also revealed that, in Russians' opinion, it was parents who bore the greatest responsibility for protecting children's interests (44 %); however, it doesn't always happen and a situation in families where a child's relatives abuse alcohol is somewhat different.

There is an undoubted relation between adults in a family being addicted to alcohol and children's health. According to data obtained via a research work performed in the USA that focused on short-term and remote

consequences of a mother being addicted to various substances during her pregnancy, alcohol took the 1st rank place as per adverse effects exerted on a future child's body as it left behind even such drugs as marijuana, cocaine, opiates, and amphetamines [47]. Children of alcohol-addicted parents run greater risks to become alcoholics. Thus, frequency of alcohol addiction among adult sons who grew in families with alcohol-addicted parents amounts to 70 %; among adult daughters, from 5 to 25 % [48].

A lot of risk factors exert their adverse influence over a certain time lag; on the contrary, alcohol produces negative effects already among people aged 15–29. Mortality among young people caused by alcohol consumption reaches 13.5 %. In 2016 578,000 deaths of young people were caused by alcohol intake [49].

Low physical activity. Low physical activity is another health risk factor that occurred due to industrial production being modernized and living conditions having changed significantly.

In March 2018 P.A, Kolobkov, the RF Minister for Sport, said that 36.6 % Russians aged 3–79 did some sports. 6 years ago the figure was by 15 % lower, that is, the parameter now is closed to economically developed countries where it is not lower than 40 % [37] and where researchers detect that people, especially young ones, are becoming more and more involved into doing sports, attending sport clubs, and playing sport games [50–52]. According to data provided by VSIOM, over the last ten years sporty lifestyle has become much more popular in Russia. 25 % people in the country do sports regularly, and 30 %, from time to time (against 9 % and 17 % in 2008) [53]. A share of schoolchildren and students doing sports has also grown considerably, from 47 % in 2012 to 76.8 % in 2017 [37].

CeDO-2018 yielded the following results: 68 % fathers and 60 % mothers stated that they did some sports; 19 % fathers and 18.8 % mothers did it every day; 38 % and 31.3 % accordingly, several times a week; 10.3 % and 10.2 % accordingly, once a week. About half of parents (42.6 %) thought doing sports to be an integral part of healthy lifestyle (Table 2). As regards influence exerted by family members on children's health, parents assessed their contribution into their children's health lifestyle quite adequately. Parents who did some sports were inclined to think that they were making their children pursue healthy lifestyle (62 %). Confidence in it was directly proportionate to frequency of doing sports; there were 73.7 % parents who believed in it among those who did sports every day; 64.7 %, among those who did sports several times a week; and 47.8 %, among those who did sports once a week. 30.5 % respondents among those who didn't do sports also believed they persuaded their children to pursue healthy lifestyle with their own example.

Improper nutrition and overweight. Nowadays more and more people all over the world suffer from overweight and obesity. D. Callahan enlisted obesity among top five threats to the mankind, along with climatic changes, access to food and water, and diseases [54]. The problem is caused by people being less physically active and a global shift in nutrition rations towards high-energy products with high fat and sugar contents [55]. According to CeDO-2018 data, 93 % parents thought improper nutrition to be a risk factor; 68.8 % out of them believed it was extremely hazardous, and 26.2 %, rather hazardous (Table 1).

Overweight usually occurs in childhood and improper nutrition both at school and at home makes for it as children tend to consume a lot of fast food and carbonated drinks. All over the world, a share of children and teenagers aged 5–19 who suffered from overweight and obesity increased from 4 % in 1975 to 18 % in 2016; four out of each five children with the given problem would still have it in their adult life [56].

Nowadays in Russia parents don't think that their children having overweight or being fat is a serious problem and it is often neglected. But as domestic researchers reveal, 26.3 % schoolchildren think they are "too fat" [28]; a share of children aged 0–14 who suffered from obesity grew by 56 % from 2005 to 2016, and a share of teenagers aged 15–17 who had the same problem, by 47 % [11], and

we should also note that not each such case is registered as a diagnosed disease.

Risky sexual behavior. Sexual behavior has a specific role in the structure of factors that influence teenagers' health. Teenagers who are deprived of support from their closest social relations run the highest risks. "Parent – child" relations are especially significant in this respect and teenagers who are sexually active frequently state they don't have tight personal contacts with their parents. We should note that although most parents (68 %) admit they can talk with their children about sexual education [57], in reality only 10 % teenagers say that they were first enlightened on sexual matters by their parents [58].

As per data obtained in some domestic research, teenagers on average have their first sexual contact when they are 16.8 years old; about 30 % girls and 45 % boys already have sexual experience by 16; 10–13 % children already have it when they are 13–14 years old; and 4–9 % children younger than 13 [59]. The first sexual contact at an early age can produce adverse effects on teenagers' health as it causes high risks of sexual diseases, including HIV, as well as of early unplanned pregnancies and abortions [60–62]. When a teenager starts his or her sexual life too early, it results in much greater chances that in future he or she will not use any contraception [59] and will be prone to promiscuity [62].

Children and teenagers injuries. Injuries are one of the primary risk factors for children as they cause the greatest life-threatening risk and are the primary reason for children becoming disabled all over the world. As per WHO data, about 2,300 deaths among children younger than 18 are caused by injuries, and 90 % of such injuries result from unintentional incidents or casualties [63], most of them being potentially preventable; 88 % of parents in Russia whose children suffered from injuries claim that the last injury could have been avoided [64]. The situation gets even worse due to low living standards of many families in Russia who have certain difficulty with buying or even can't afford to buy such simple things as a car seat for a baby, or specific appliances or devices for providing children's safety at home or outdoors, etc. Together with parents having low competence as regards providing safety environment for their children, it results in much greater risks of children being injured. Children injuries should be prevented and it is necessary to start with adults who are to learn how to control their children's behavior more efficiently and adhere to basic rules for child-care. Medical and social workers, in their turn, are to timely provide parents with relevant information on a situation that can result in an injury; they should also educate parents on safe behavior and on how they can educate their children on the matter.

Conclusion. We have revised literature on the matter, analyzed data obtained via CeDO-2018 and other sociological research on parents influencing their children's health and their adherence to healthy lifestyle as well as parents' role in reducing adverse effects produced by health risk factors. Having done it, we can make the following conclusions:

– adherence to healthy lifestyle appears under influence exerted by the closest relations. A family is a primary institution that influences value orientations of children and teenagers in the sphere of health and health-preserving behavior;

– children and teenagers' orientation at preserving their health and pursuing healthy lifestyle should be an integral part of family education and should be based both on targeted activities accomplished by parents and aimed at informing children about advantages of healthy lifestyle and on motivating children and teenagers to pursue healthy lifestyle by giving them a personal example;

– parents are not sufficiently aware how to manage health risk factors that threaten their children's health and how to minimize their impacts; adults tend to underestimate influence exerted on their children's health by such behavioral risk factors as improper nutrition, overweight and obesity, and low physical activity;

– it is necessary to develop a reasoned policy aimed at making parents more educated as regards healthy lifestyle; it should include providing them with relevant and scientifically

grounded data on existing risks for their health and health of their children as well as on how to eliminate them; parents should be provided with such data as it is them who bear the main responsibility for future generations' health;

– the current situation in Russia with children's and teenagers' health is being made even worse by the fact that many families in the country don't have financial and other capabilities to provide basic conditions for preserving their children's health and safety for them; consequently, there should be aid provided directly to families depending on a specific situation;

– it is necessary to accomplish wide-scale modernization of material and technical base and social and cultural infrastructure required for preserving children's and teenagers' health; it includes developing public transports, constructing sport facilities, organizing health nutrition at educational facilities, creating comfortable conditions for studies and leisure etc.;

– making children and teenagers pursue health-preserving behavior requires combined efforts made by basic social institutions aimed at creating a common space where health-reserving competence can be acquired; at educating young people how to pursue healthy lifestyle and eliminating risk factors that threaten their health. All this requires a complex approach involving not only family members but also medical experts, sociologists, psychologists, and representatives of public and social organizations.

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NEW LEGAL, REGULATORY AND METHODOLOGICAL DOCUMENTS ISSUED IN THE RF IN THE SPHERE OF HEALTH RISK ANALYSIS

16.09.2019-13.12.2019

The Decision by the Eurasian Economic Commission (EEC) Council dated November 11, 2019 No. 191 "On making alterations into a structure of data on issued certificates confirming state registration of products which can be provided to customs authorities of the EAEU member states and a procedure for obtaining such data"

The documents specifies what data on issued certificates confirming state registration of products can be provided to customs authorities of the EAEU member states.

The Decision by the Eurasian Economic Commission (EEC) Council dated November 19, 2019 No. 198 "On the list of international and regional (interstate) standards, and in case of their absence, national (state) standards which, when applied, provide voluntary conformity with the Customs Union Technical Regulations (CU TR) "On safety of meat and meat products" (CU TR 034/2013), and the list of international and regional (interstate) standards, and in case of their absence, national (state) standards that contain rules and procedures for examinations (tests) and measurements, including rules for sampling, necessary for applying and meeting requirements fixed in the CU TR "On safety of meat and meat products" (CU TR 0.4-2013) and assessing conformity of objects which are subject to technical regulation"

Starting from June 01, 2020 updated lists of standards come into force; these lists contain standards which are necessary for meeting requirements fixed in the CU TR "On safety of meat and meat products" (CU TR 034/2013). Starting from June 01, 2020 The Decision by the Eurasian Economic Commission (EEC) Council dated May 26, 2014 No. 81 which approved on similar lists of standards is no longer valid.

The Decision by the Eurasian Economic Commission (EEC) Council dated November 26, 2019 No. 201 "On the list of international and regional (interstate) standards, and in case of their absence, national (state) standards which, when applied, provide voluntary conformity with the Eurasian Economic Union Technical Regulations (EAEU TR) "On requirements to mineral fertilizers" (EAEU TR 039/2016) and the list of international and regional (interstate) standards, and in case of their absence, national (state) standards that contain rules and procedures for examinations (tests) and measurements, including rules for sampling, necessary for applying and meeting requirements fixed in the Eurasian Economic Union Technical Regulations (EAEU TR) "On requirements to mineral fertilizers" (EAEU TR 039/2016) and assessing conformity of objects which are subject to technical regulation"

The document approves on the lists of standards which are necessary for meeting requirements fixed in the EAEU TR "On requirements to mineral fertilizers" (EAEU TR 039/2016). It concerns standards that contain rules and procedures for examinations (tests) and measurements, including rules for sampling, which are necessary for meeting requirements fixed in the Regulations and assessing conformity of objects which are subject to technical regulation.

The Decision by the Eurasian Economic Commission (EEC) Council dated December 03, 2019 No. 210 "On making alterations into the EEC Council Decision dated June 13, 2012 No. 79"

The document supplements a list of products which, when being under customs procedures, should be provided with a document confirming their conformity with the requirements fixed in the CU TR "On safety of individual protection means" (CU TR 019/2011). In particular, the document includes new subsections "Individual protection means for protecting hands from water and non-toxic substances" and "Individual protection means for protecting feet from water and solutions of non-toxic substances". The subsection "Crush helmets for motor bikes drivers and passengers" was excluded from the section "Individual protection means for the head"; and the phrase "declaration on conformity" was replaced with the phrase "certificate of conformity" in the subsection "Individual protection means for ears".

The Decision by the Eurasian Economic Commission (EEC) Council dated December 03, 2019 No. 211 "On making alterations into the Program on developing (making alterations and revising) interstate standards application of which will provide voluntary conformity with the requirements fixed in the CU TR "On safety of toys" (CU TR 008/2011), as well as interstate standards that contain rules and procedures for examinations (tests) and measurements, including rules for sampling, necessary for applying and meeting requirements fixed in the CU TR "On safety of toys" (CU TR 008/2011) and assessing conformity of objects which are subject to technical regulation"

The document supplements the program for developing draft standards which are necessary for meeting requirements fixed in the Customs Union Technical Regulations (On safety of toys" (CU TR 008/2011).

The Decision by the Eurasian Economic Commission (EEC) Council dated September 17, 2019 No. 154 "On the reference book specifying types of products which are subject to sanitary-epidemiologic surveillance (control)"

The document approves on the contents of the reference book that specifies types of products being subject to sanitary-epidemiologic surveillance (control). The reference book is included as a data source into the unified EAEU system for regulatory and reference information. It is obligatory to use codes given in the reference book when certain common processes are implemented within EAEU member states in the sphere of sanitary measures application. Specifically, the reference book contains the following:

– food products (raw or manufactured / processed), including those manufactured with applying genetically modified (transgenic) organisms;

– perfume and cosmetics, products for oral hygiene;

– materials for products (products) which come into contact with human skin, clothing, footwear;

– tobacco products and raw materials;

– pesticides and agricultural chemicals.

The Decision by the Eurasian Economic Commission (EEC) Council dated October 08, 2019 No. 169 "On making alterations into the list of standards that specify rules and techniques for examinations (tests) and measurements, including rules for sampling, which are necessary for applying and meeting the requirements fixed in EAEU TR "On safety of bottled water including natural mineral water" (EAEU TR 044/2017) and assessing conformity of objects which are subject to technical regulation"

The document enlarges the list of standards which are necessary for applying and meeting requirements fixed in the EAEU TR "On safety of bottled water including natural mineral water" (EAEU TR 044/2017).

The Decision by the Eurasian Economic Commission (EEC) Council dated October 08, 2019 No. 172 "On approving the list of products which, when being declared at the customs, should be provided with a document certifying assessment of conformity (or with data on a document that certifies assessment of conformity) with the requirements fixed in the CU TR "Requirements to safety of food additives, flavoring agents, and technological auxiliary products" (CU TR 029/2012)

The document specifies the list of products which, when being declared at the customs, should be obligatorily provided with a document that certifies their compliance with the requirements fixed in the CU TR "Requirements to safety of food additives, flavoring agents, and technological auxiliary products" (CU TR 029/2012). The approved list includes, among other things, food additives and complex food additives, flavoring agents, and technological auxiliary products.

The RF Government Order issued on December 05, 2019 NO. 1600 "On approving the Rules for granting and distributing other interbudgetary transfers from the Federal Budget to the budgets of RF regions for implementing activities on reducing aggregated emissions of contaminants into ambient air, reducing ambient air contamination in large industrial cities, and activities that should make for achieving targets fixed in "Pure air" Federal project as an integral part of "Ecology" National project"

Certain regions will be able to receive federal transfers for reducing contaminants emissions into the atmosphere. Transfers are to be spent on implementing complex plans on reducing emissions by December 31, 2023 in the following cities: Bratsk, Krasnoyarsk, Lipetsk, Magnitogorsk, Mednogorsk, Nizhniy Tagil, Novokuznetsk, Norilsk, Omsk, Chelyabinsk, Cherepovets, and Chita. Complex plans include the following: a growing share of economical and ecologically friendly cars; city transport switching to ecologically friendly

fuel; obtaining new vehicles for public transport systems; road infrastructure development; wider use of natural gas as fuel; equipping houses, buildings, and industrial objects with systems for gas supply; reconstruction of thermal power station and equipping them with gas refining units; reconstruction and building of boiler houses in cities; construction and reconstruction of treatment facilities for centralized sewage systems in settlements or municipal districts in large industrial centers; providing people living in houses with stove heating (not considered to be dilapidated) into new housing; planting trees and improving territories in settlements or municipal districts.

The RF Government Order issued on September 11, 2019 No. 1183 "On accomplishing an experiment on marking bicycles and bicycle frames with identification means and monitoring over distribution of such products"

Starting from September 16, 2019 and up to May 31, 2020 there will be an experiment accomplished on the RF territory; the experiment will involve marking bicycles and bicycle frames with identification means. The goals are to confirm authenticity of products; prevent illegal imports on the RF territory, as well as illegal production and distribution of bicycles and bicycle frames (including counterfeit ones); standardize and unify procedures for accounting distribution of bicycles and bicycle frames; determine whether it is advisable to introduce obligatory marking of bicycles and bicycle frames with identification means. Authorized federal executive bodies (including Rospotrebnadzor), manufacturers, importers of bicycles and bicycle frames, retailers, and "Operator – CRPT" LLC as an operator of an information system for monitoring and approbation of marking are going to participate in the experiment. Participation in the experiment is voluntary.

The RF Government Order issued on September 26, 2019 No. 1251 "On accomplishing an experiment on marking with identification means and monitoring over distribution of certain tobacco goods that are subject to obligatory marking starting from July 01, 2020"

Starting from October 01, 2019 and up to June 30, 2020 there will be an experiment accomplished on the RF territory; the experiment will involve marking certain tobacco products that are subject to obligatory marking starting from July 01, 2020 with identification means. Among other things, the experiment goals are: to develop unified procedures for marking and tracking tobacco products; to determine whether it is advisable to stop marking imported tobacco products with excise stamps; to determine what data on a product should be provided on a mark that allow unambiguous identification of a tobacco product. Authorized federal executive bodies (including Rospotrebnadzor), distributors, and an information system operator will participate in the experiment. The document also specifies the list of tobacco products which are to be marked during the experiment.

The RF Government Order issued on October 26, 2019 No. 1376 "On making alterations into the RF Government Order issued on November 22, 2000 No. 883"

The document updates the provisions on monitoring over quality and safety of food products and population health. In particular, it specifies the following: authorities that are responsible for organizing and performing monitoring over quality and safety of food products and population health; sources of information required for performing monitoring; a responsibility borne by authorized state bodies to annually, by March 31, submit necessary data to authorities responsible for monitoring. The document also specifies that interaction between involved parties is to be performed electronically, including use of the unified system for interdepartmental electronic interaction.

The RF Government Order issued on November 21, 2019 N 2764-r "On determining quantity of specific ozone-depleting substances in permissible volumes of ozone-depleting substances consumption in the Russian Federation and permissible volume of ozone-depleting substances manufacture in the Russian federation in 2020"

In order to meet the country obligations fixed by Montreal Protocol on ozone-depleting substances that envisages gradual reduction in ozone-depleting substances (ODS) quantity until a complete ban on them in 2030, the document fixes volumes of production and consumption for each ozone-depleting substance taking into account total permissible consumption volume fixed for 2020.

The RF Government Order issued on November 08, 2019 No. 2647-r "On making alterations into the RF Government Order issued on April 28, 2018 No. 792-r"

The document fixes the date for introducing obligatory marking on milk products; it is June 01, 2020. Milk products that are not marked with identification means and data on their marking are not

submitted into the information system for monitoring can be distributed only until December 21, 2020. By this date all milk products not marked with identification means should be taken out of distribution.

Assignments given by the RF Government on September 27, 2019 "On assignments given by Dmitry Medvedev following the discussions with businessmen and experts during "Dialogue" TV program shown by Russia 24 TV channel"

Following the discussions between the RF Government Head and businessmen, certain ministries and departments, among other things, will have to complete the following tasks:

– working out suggestions on how to revise "Sanitary-epidemiologic requirements to catering organizations, as well as manufacture and distribution of food products and food raw materials by such organization"; SER 2.3.6.1079-01 "Sanitary-epidemiologic rules and standards "Hygienic requirements to safety and nutrient value of food products"; SER 2.3.2.1078-01, "Sanitary-epidemiologic rules and standards SER 2.3.2.1324-03 "Hygienic requirements to shelf life and storage conditions for food products" and on how to facilitate transfer to application of requirements fixed in the ESEU technical regulations in providing catering services to population;

– working out suggestions on performing an experiment in several RF regions including Moscow, Tatarstan, and Kaliningrad region; the experiment starts on January 01, 2020 and involves imposing a certain limit on a focus of control and surveillance activities performed within the federal state sanitary-epidemiological surveillance regarding safety of food products manufactured by catering facilities, including manufacture, storage, transportation, and sales;

– preparing a draft of a federal law on making alterations into the RF Administrative Infractions Code regarding administrative ban on economic activities imposed for violating requirements to rendering catering services to population that resulted in damage to people's health.

The Order by the RF Chief Sanitary Inspector dated October 22, 2019 No. 15 "On approving on sanitary rules SP "Specific sanitary-epidemiologic requirements applied when assessing noise occurring due to aircraft flights"

The document fixes that conformity of aircraft noise to permissible levels should be assessed as per the standard for equivalent sound level for day and night time fixed for territories which directly adjoin housing districts. When aircraft noise levels are calculated, boundaries of the 7th zone in a near-aerodrome territory are to be substantiated taking health risks into account. Calculation and assessment of health risks caused by aircraft noise is to be performed according to the conventionally approved procedure taking into account all measures aimed at reducing aircraft noise.

The Information Letter by Rospotrebnadzor "On existing procedures for obligatory submission of certificates granting permission to visit a swimming pool"

Rospotrebnadzor has confirmed that a swimming pool owner has the right to demand obligatory submission of a certificate that grants permission to visit a swimming pool. The Letter clarifies that, according to item 3.12.2 SER 2.1.2.1188-03 "Swimming pools. Hygienic requirements to their construction, operation, and water quality. Quality control", it is necessary to submit a certificate issued by a medical and prevention organization that grants permission to visit a swimming pool in case a sanitary-epidemiologic situation in a given city or city district is not favorable as per diseases enlisted in SER. In order to prevent spread of infections, authorities responsible for state sanitary-epidemiologic surveillance give instructions to swimming pool managers not to allow visitors who haven't been examined by medical experts and haven't had relevant tests. Regardless of sanitary-epidemiologic situation preschool and junior school children are to be obligatorily examined and given a certificate that they don't have enterobiasis.

Still, sanitary legislation doesn't impose any limitations on a swimming pool owner's right to demand a certificate regardless of a sanitary-epidemiologic situation. There are no requirements to submit any other certificate apart from those enlisted in the SER 2.1.2.1188-03.

The Information Letter by Rospotrebnadzor "For customers' attention: temperature inside housing"

Rospotrebnadzor reminds that there are standards for comfortable temperature in a house that is safe for health. Permissible temperature during cold season is 18-24 degrees; during hot season, 20-28 degrees. Communal services and communal companies are to provide people with optimal microclimate inside their houses. There is an administrative penalty for violating the existing standards.

In case temperature in an apartment differs substantially from the existing standards, a person

should submit a written application to a communal company stating that inconformity. Should there be no satisfying results of such submission, a person can complain to Rospotrebnadzor Regional Office or Municipal Housing Inspection.

The Information Letter by Rospotrebnadzor "On performing control over hostels in apartment blocks"

Rospotrebnadzor reminds that starting from October 01, 2019 it is prohibited to locate hostels and render accommodation services in apartment blocks without an isolated entry to a hostel. Should a hostel functioning result in deteriorated living conditions for people living in an apartment block, they can complain to Rospotrebnadzor, and the authority will have to accomplish an inspection. Should any violations be detected, the inspection report is to be submitted to court for suspending or completely prohibiting a hostel functioning.

The Information Letter by Rospotrebnadzor "Providing schoolchildren with drinking water"

Schools should provide children with drinking water coming from drinking fountains or bottled one. The letter specifies requirements to quality of water, drinking fountains, and bottled water. Children should be provided with free access to drinking water during the whole period of time they spend at school.

The Information Letter by Rospotrebnadzor "For customers' attention: peculiarities related to buying goods via the Internet"

In particular, Rospotrebnadzor informs that having studied all the information on a product and having ordered it online, a customer has the right to refuse the product at any moment prior to it being delivered and during 7 days after it has been delivered. Should any information about a product provided on a web-site not conform to a product delivered to a customer, or should delivery terms be violated, a customer has the right to refuse the purchase, and a seller is obliged to return any payment made for the purchase to a customer. Should a delivered product be of improper quality, a customer has the right to either demand that drawbacks are eliminated immediately and free of charge or that any expenses required for their elimination by a customer or the third party be compensated for; a proportionate decrease in price; a product be replaced with its analogue with relevant recalculation of its price.

The Letter by the RF Ministry of Natural Resources and the Environment dated September 18, 2019 No. 12-47/22545 "On the necessity to adjust data in emission inventories"

The Ministry informs that the Federal Law issued on July 26, 2019 No. 195-FZ "On accomplishing an experiment on making quotas for contaminants emissions and making alterations into certain legislative documents in the RF regarding reduction of ambient air contamination" makes alterations into the Clause 22 of the Federal Law issued on may 04, 1999 No, 96-FZ "On ambient air protection" regarding necessary accomplishment of inventories taking into account emissions from mobile sources. The alterations come into force on November 01, 2019. According to item 42 in the Procedure for accomplishing an inventory of stationary sources and emissions of adverse (contaminating) substances into ambient air, adjusting its data, documenting and keeping data obtained via such inventories and their adjustment, approved by the Order issued by the RF Ministry of Natural Resources and the Environment on August 07, 2018 No. 352, data obtained via an inventory of emissions from an object that exerts hazardous impacts on the environment are to be adjusted, among other things, when there are alterations into the RF legislation in the sphere of ambient air protection related to inventories of hazardous objects.

The Letter by the RF Ministry of Natural Resources and the Environment dated August 01, 2019 No. 12-47/18168 "On using automated control system in industrial environmental control"

The Ministry clarifies what emission sources should be equipped with automated tools for measuring and accounting of emissions and (or) discharges. It informs that, according to the Federal Law issued on January 01, 2002 No. 7-FZ "On environmental protection", a program for industrial environmental control over objects belonging to the 1st hazard category that should be obligatorily equipped with automated tools for measuring and accounting of emissions (discharges also contains a supplementary program for creating an automated control system or data on such a system already existing at an industrial object.

A program for creating an automated control system is an appendix to a program for industrial environmental control; or the above mentioned data should be included into a program for industrial environmental control. The legislation doesn't require obligatory reports on implementing a program for creating an automated control system.

The Letter by the RF Federal Biomedical Agency dated November 05, 2019 No. 32-024/758 "On giving recommendations"

The Letter contains recommendations on how to prevent and treat mycoplasmal infection. Recommendations are developed due to foci of community-acquired pneumonia with mycoplasmal etiology being registered in children facilities; they are also aimed at timely prevention and anti-epidemic activities being accomplished among those people who caught the infections and people who contacted patients suffering from it. The Agency insists that great attention should be paid to the closest adherence to the requirements fixed in the Sanitary Epidemiologic Rules 3.1.2.3116-13 "Prevention of community-acquired pneumonia" regarding timely anti-epidemic activities taking place.

Methodical guidelines for participants in the experiment on marking certain light industry products with identification means and monitoring over their distribution in the Russian Federation" (approved by the RF Ministry of Industry and Trade on October 28, 2019)

The Guidelines specify the following:

– a procedure for marking certain light industry products with identification means; such products are clothing, including work wear, made of natural or composite leather, and some others;

– a procedure for participants in an experiment on providing data on products distribution to an operator of the state information system for monitoring over distribution of products that are subject to marking with identification means;

– a description of means for products identification;

– requirements to technical means applied by participants in the experiment, and to participants in the experiment who obtain technical means form an operator;

– a procedure for interaction between the state information system for monitoring and other state information systems and information systems of participants in the experiment.