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Climate Change and Health in the Russian Far East

The article reviews the impact of climate change on the health of the population of the Russian Far East carried out within the framework of the project "Climate Change and Health" of the Association of Academies and Societies of Sciences in Asia. Problems of influence on human health of extreme temperatures, forest fires, floods, threats of infectious diseases, air and water pollution are considered. Measures are proposed for the adaprtation to the consequences of climate change and reduction of their negative impact.

Key words: climate change, health, respiratory and infectious diseases, Russian Far East, adaptation, mitigation.

Изменение климата и здоровье человека на Дальнем Востоке России. В.В. БОГАТОВ (Дальневосточное отделение РАН, Владивосток), П.Я. БАКЛАНОВ, С.А. ЛОЗОВСКАЯ (Тихоокеанский институт географии ДВО РАН, Владивосток), М.Б. ШТЕЦ (Дальневосточное отделение РАН, Владивосток).

Представлен анализ материалов о влиянии климатических изменений на здоровье населения Дальнего Востока России, выполненный в рамках проекта «Изменения климата и здоровье» Ассоциации академий наук и научных сообществ Азии. Рассматривается влияние на здоровье людей экстремальных температур, лесных пожаров, наводнений, угрозы инфекционных заболеваний, загрязнений воды и воздуха. Предлагаются мероприятия по адаптации к последствиям изменения климата и снижению их негативного воздействия.

Ключевые слова: изменения климата, здоровье, респираторные и инфекционные заболевания, Дальний Восток России, адаптация, митигация.

In recent years, it was accumulated a huge amount of factual evidence indicating the impact of global climate change on human health. Climate variability and change have been found to lead to illness and death due to natural disasters such as heatwaves, floods and droughts. Moreover, many serious diseases are highly sensitive to changes in temperature and rainfall patterns.These diseases include vector-borne diseases such as malaria and dengue, as well as malnutrition and diarrhea, which are other leading causes of death. Climate change is contributing to an increase in the global burden of disease, and this trend is expected to worsen in the future.

It is considered that the impact of climate on human health will not be uniform around the world. Populations in developing countries, especially small island states, arid and high mountain areas, and densely populated coastal regions, will be particularly vulnerable to global warming.

Many health hazards can be avoided through existing national and international health programs and activities. In 2019, InterAcademy Partnership (IAP) has launched an inter-regional project focused on climate change adaptation and mitigation strategies that bring health co-benefits. Each regional network of IAP (NASAC – Africa, IANAS – Americas, AASSA –

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Asia, EASAC – Europe) has formed a regional expert group of scientists, policymakers and practitioners and held a workshop to draw together broader scientific and health expertise to sharpen the regional focus of each report. Considering the importance of the challenges facing humanity, the working group of the Association of Academies and Societies of Sciences in Asia (AASSA) in 2019 decided to join IAP initiative to formulate national reports on climate change and public health in Asian countries, including the Asian part of the Russian Federation, to develop general recommendations and a plan for further action. On behalf of the Russian Federation, specialists from the Far Eastern Branch of the Russian Academy of Sciences (FEB RAS) took part in the work under the leadership of member of the AASSA Executive Board, Academician RAS Viktor Bogatov.

In June 2020, the report on the climate change and health in the Russian Far East (RFE) was prepared by FEB RAS and submitted to AASSA. AASSA member countries reports were consolidated by working group and preliminary findings of the project were presented by AASSA working group Chair Academician of Academy of Sciences Malaysia, Prof. Dato' Dr. Khairul Anuar b. Abdullah at the online session on Climate Change and Health at the World Health Summit on 26th of October 2020. Regional reports from AASSA and other IAP regional associations will be published and launched in 2021, and then will be used to engage with regional policy-makers, the scientific community and other stakeholders. The global IAP synthesis report will be ready by the end of 2021, and will be presented to the World Health Organization and other global and regional stakeholders.

Considering the importance of the issues raised in the reports, the AASSA Executive Board recommended its member academies that the main provisions of the country reports be published in national scientific journals.

This article is a capsule version of the main positions of the Russian national report prepared by a group of specialists from the Far Eastern Branch of the Russian Academy of Sciences. The material of the article is divided into sections and subsections corresponding to the structure of the AASSA template report. The report was based on the results of comprehensive medical and geographical studies of changes in population health under the influence of various environmental factors (natural, ecological, socio-economic), which are carried out at the Pacific Geographical Institute FEB RAS in all regions of the RFE: from Primorsky Territory in the south to the Russian Arctic in the north. Moreover, the report included materials on the impact of climate on natural systems and human health, provided by the Federal Research Center of Biodiversity of Terrestrial Biota of East Asia FEB RAS, A.K. Chaika Federal Research Center of Agrobiotechnology, Institute for Complex Analysis of Regional Problems FEB RAS and the Far Eastern Scientific Center of Respiratory Physiology and Pathology, as well as data published in the following sources [1–29].

General Issues of Climate Change and Health

The course of climates change in Russia is characterized by prolonged heating accompanied by an increase in occurrence of dangerous meteorological phenomena. The growth rate of the average annual surface air temperature in the Russian Federation over the period of 1976–2019 equalled 0.47 °C per 10 years. This is 2.5 times higher than the growth rate of global temperature over the same period: 0.18 °C per 10 years. The temperature grew most rapidly in the North Polar Region, especially in recent decades: according to the Arctic and Antarctic Research Institute, over the past thirty years (1990–2019), the growth of average annual temperature here is 0.81 °C / 10 years, i.e. 2.43 °C for 30 years [24].

The territory of East Asian Russia is characterized by a large differentiation of climatic conditions – from Arctic ice deserts in the north to subtropics in cedar-broadleaved forests in the south. Many areas are categorized by extreme natural phenomena: earthquakes, tsunamis, floods, storms, low temperatures, permafrost, sharp fluctuations in weather conditions, etc. The region is distinguished by vast spatial distribution (length from north to south is more than 5 thousand km, from east to west – more than 4 thousand km), low population density (slightly more than 1 person/km^2) and poor connection of the territories (by railway lines and motor roads).

The main part of the RFE is located north of the ecological optimum zone, mainly in the Arctic region with a harsh climate, and therefore the region is characterized by high environmental vulnerability and discomfort [24, 27].

Against the background of global changes, there is a change in the demographic situation in the region, an increase in migration processes, and a decrease in the level of public health.

The economic exploration of the region is accompanied by an increase in anthropogenic impact on the natural environment and leads to an exacerbation of existing and the emergence of new ecological problems and diseases, especially its northern regions, requires the elaboration of measures aimed at improving the quality of life of the population, as well as enhancement of methods for predicting and preventing disastrous emergencies of a natural and man-made nature under the conditions of climate changes.

Climate Change and Environment

Permafrost Thawing

Permafrost occupies at least 25 % of the entire land area of the world. 1/3 of the world's permafrost is located in Russia. This is about 10–12 million km^2 or 65 % of the country's territory. It is most widespread in Eastern Siberia and the Far East. With global warming, the melting of permafrost is accelerating, which results in the release of greenhouse gases, the formation of giant sinkholes, such as the Batagai crater in Yakutia, and the likelihood of man-made disasters increases.

In the Arctic zone, with given increase in air temperature, thawing of permafrost and the release of greenhouse gases accelerates. The level of CO_2 concentration, according to the Russian background stations, is constantly growing (on average 2.2 ppm/year) and in 2018 reached its next maximum: more than 410 ppm. At the same time, in 2018, there was a significant slowdown in the growth of methane concentration observed compared to the period of a significant increase in 2014–2017 [24].

The indicator of the state of permafrost soils, reflecting the meteorological conditions of individual years, is the thickness of the seasonally thawed layer (STL). The results of objective observations available at the stations of Hydrometeorological Center in the Arctic zone of the Russian Federation show that at more than half of the stations (63 %), the STL values in 2019 exceed the long-term average. Despite a slight decrease in the growth rate of the STL power, the trends at almost all stations (35 out of 39 sites) retain positive values, which indicate that the trend towards an increase in the depth of permafrost thawing continues in the XXI century [24].

Permafrost degradation in the catchment areas of the Great Siberian Rivers (Ob, Yenisei, Lena, Indigirka, Kolyma) affects the inclusion in the modern biochemical cycle of a huge amount of ancient organic matter lying on the shallow shelf of the seas of the Eastern Arctic, where more than 80 % of underwater permafrost is concentrated. More than 80 % of the predicted Arctic hydrates occur in this area, the reserves of which, according to Russian scientists, range from 500 to 1000 billion tons of carbon. For comparison, the atmosphere contains about 5 billion tons. This means that on the Earth, in the event of destabilization of only 1 % of Arctic hydrates, the concentration of methane in the atmosphere may double. International scientific expeditions carried out in recent years aboard the research vessel "Akademik Mstislav Keldysh" have noted a sharp increase in the number of large jets of methane in the seas of the Eastern Arctic. In areas of such emissions, the concentration of methane in the atmosphere is many times higher than the average planetary values. Thus, obtained new data confirms the decisive role of the degradation of underwater permafrost and the destabilization of hydrates in the discharge of methane into the water column and the atmosphere [25, 26].

The most important influence on the degradation of underwater permafrost is exerted by the runoff of Siberian Rivers into the Arctic. In particular, compared to 1980–2000, in 2000–2020, it increased from 3900 cubic km per year to 4300 km, which had a serious impact on the formation of seasonal ice, which area has more than halved over the past 20 years. Thus, the Russian sector of the Arctic is the only region in the world where the river runoff affects global climatic processes, which indicates the need for more intensive study and control over the degradation of ground and underwater permafrost in this region.

Climate and Freshwater Ecosystems

Freshwater ecosystems of the RFE region historically are under the influence of extreme environmental phenomena (especially floods, droughts and riverbed freezing) that define the characteristics of their structure and functional organization. The highest water content of most rivers of the southeastern part of the RFE is observed during floods in the summer-autumn period, when up to 80 % of their annual runoff passes [9]. The most flood hazardous in the Far East may occur in Primorsky and Khabarovsk Territories, Amur and Sakhalin Regions.

Many large rivers in Arctic region (the territory of Yakutia, regions of the Magadan, Kamchatka, Chukotka, and north of the Khabarovsk Territory) during spring floods are characterized by mash floods that occur once every 2–3 years. Occasionally, congestion caused by ice accumulation during ice drift can cause a rise in water level to 10 % security marks.

During floods, massive accumulations of sediment damage or kill many organisms and setting them a drift, and during periods of strong floods, on some rivers mudflows can form – violent mud-stone streams with tremendous destructive power.

A characteristic feature of rivers of the southeastern part of the RFE is the eutrophication process (massive development of algae and cyanobacteria) during in a prolonged period of low water. Eutrophication occurs even in low snow winters under the ice cover. After the winters with little snow, the spring floods are very small and the eutrophication process get the further extension. Intensive algal and cyanobacteria proliferation has an adverse impact on populations of many aquatic invertebrates and fish fry. During this period, in the riverbed we observed a growth of periphyton or formation of metaphyton communities. In floodplain lowland lakes, the rapid bloom of algae and cyanobacteria causes fish deaths, as well as poisoning of animals and people [6].

In head water of the rivers of forest zone, riparian canopies partially or fully cover the channels and eutrophication processes do not develop due to low illumination. At the same time, during periods of low flow, in areas that have lost the forest canopy (the result of felling or fires) you can observe the intensive development of algal-bacterial fouling of the soil [6, 9].

In general, prolonged droughts increase the likelihood of forest fires, which lead to a huge loss of forest resources and desertification of territories, provoke shallowing of streams and rivers, freezing of Pacific salmon spawning grounds in winter, and, as a result, have a negative impact on fisheries. These changes can be especially dangerous against the background of other types of human impact on forests: felling, mining, water pollution, etc.

It is now generally accepted that global warming will significantly alter the effects of monsoons on natural flood cycles: flood severity is expected to increase, but the likelihood of dry season showers decreases (i.e. more extremes are expected).

Definitely, in the Far East region in the last years, both an abnormal high-water and low-water years and seasons has been observed. Among them: an abnormal low-water of 2007 and 2008 and extraordinary flood of the Middle and Lower Amur in the autumn of 2013; and extremely high water levels in the Khanka Lake during 2013–2017. Extremely high floods on the rivers of Primorsky Territory in late autumn 2012, as a result of which many rivers went under the ice with a large filling of their channels, which had not happened before, also belong to anomalous phenomena.

In the context of global climate change, increased anthropogenic load and in the absence of preventive measures in the freshwater ecosystems of the Far East, it is expected:

• significant degradation of biodiversity;
• decrease in the quality of drinking water and the fishery importance of water bodies;
• increased infestation of commercial fish species with helminths;
• displacement to the North of the southern boundaries of the Pacific salmon ranges;
• intensification of invasions of alien species into aquatic ecosystems;
• changes in the physiology and pathogenicity of microorganisms, which will contribute to the spread of previously unknown diseases of both humans and commercial aquatic organisms [7].

Strategic provision of the productive potential of fresh waters and the preservation of their quality should primarily be achieved by optimizing the use of water resources. At the same time, special attention should be paid to the layouts of hydraulic structures and water-intensive enterprises. It is necessary to intensify activities to protect forest resources, reduce the level of freshwater pollution, including transnational, and preserve favorable hydrological, hydrochemical and hydrobiological regimes in rivers and lakes of fishery and recreational importance [7].

Forest Fires

The huge forest resources of the RFE have led to the creation of one of the largest forest complexes, which plays a significant role in the region's economy. The total timber reserves here are 20.6 billion m^3 (27.1 % of the reserves of the Russian Federation [14]), which makes the Far East region one of the leading timber producers in Russia.

More than 40 % of the area of all Russian forests is occupied by larch forests. Moreover, in the permafrost zone, characterized by permafrost and shallow seasonal thawed layer, up to 80 % of taiga forests are formed by larch. In the southern part of the Far East, dark coniferous forests of cedar, fir and spruce prevail. The forest ecosystems of the mountainous country Sikhote-Alin, located in the extreme southeast of the mainland of the Russian Federation, in terms of the diversity of forest-forming species, the richness and originality of flora and fauna, significantly surpass all others in Russia.

Forest vegetation acts as the most powerful geological factor that renders exclusive influence on the water flow of the rivers, the quality of water as well as physical properties of the soil and the atmosphere. While maintaining of the total amount of precipitation, global warming leads to a more intense loss of natural moisture in the forests, an increase in the duration of the fire-hazardous season and consequently to an increase in the burning of forests. In the Far Eastern Federal District of Russia, this is reflected in the form of an increase in the number of forest fires and an increase in the total area of forest fires in recent decades. Thus, from 2000 to 2018 the annual number of recorded forest fires in the Far Eastern Federal District increased 1.79 times (from 1960 to 3526), and the area of burned-out forests per year increased 8.31 times (from 653 to 5428 thousand ha), respectively. As we move to high latitudes, the number of fires decreases, but the area covered by fire increases up to the latitude of the Arctic Circle [4].

Generally, three types of forest fires are distinguished: upper (covers the entire crown of trees), grass-roots (forest litter, lichens, mosses, fallen branches, etc.) and underground (peat). In the harsh ecological and climatic conditions of the permafrost zone, forest stands are usually sparse; therefore, ground fires prevail here. In larch, living tissues of the trunk are protected from such fires by a thick crust, therefore, under certain conditions, ground fires contribute to the renewal and rejuvenation of the ecosystem of larch forests. Unlike larch, the trunks of dark coniferous species are poorly protected by a crust from ground fires, and a dense crown, often sinking to the ground, saturated with essential oils, contributes to the transition of ground fires into devastating crown fires [16].

Forest fires cause significant damage to the natural environment: they interrupt the natural process of reforestation and soil formation; the products of combustion are washed off into the rivers, polluting them, and valuable wood species perish. During combustion, the concentration of carbon monoxide (sweetdamp) in the air increases, as well as nitrogen oxides, phenols and suspended solids. Fumes and dust from fires cause severe breathing discomfort and can significantly affect the health of people with allergies and respiratory diseases. Smoky smog is especially dangerous for children (especially newborns and infants), the elderly and those who suffer from chronic diseases of the respiratory system, cardiovascular system, and allergy sufferers.

Under the conditions of climate warming, the damage from fires will increase, and the possibility of their complete suppression will decrease. In this regard, significant changes are required in the strategy and tactics of fighting fires in forests, including zoning of forest areas according to the level of preference for extinguishing fires. It is necessary to identify priority areas, focus on the protection of areas with high social, natural and economic value, taking into account the importance of endangered forests, including their off-market value, the presence of industrial infrastructure and settlements, the impact of smoke on human health, as well as the cost of fire suppression work.

Environment and Health

Low Temperatures: Northern Territories

The area of the northern territories around the world equals 22 million km^2. About 12 million people live on it. In the Russian North, the area of which exceeds 11 million km^2, a bit more than 11 million people reside – 93 % of all the world northerners. January temperatures over almost the entire territory of the Far East are below – 16 °C, which corresponds to the 2nd and 3rd degree of harmfulness for outdoors work in calm weather according to the hygienic classification of labor. In North America, the population density to the north of this isotherm normally equals less than one person per km^2, while in Russia such harsh areas overlap with the main settlement zone of the country and include such cities with a million-plus population as Omsk and Novosibirsk, as well as many other major cities.

Low-comfort and uncomfortable living conditions of the population formed a chronic pathology of the population, leading to temporary and permanent incapacity to work and forming high mortality rates. In the mechanism of this effect, it is not so much the absolute discomfort values of the physical parameters of the environment (temperature, humidity, etc.) that count for, but their sharp changes in a short period of time. These weather changes, typical of the Far East, disrupt the dynamic balance between the body and the environment, leading to various functional disorders and subsequently to diseases.

Low temperatures provoking the pituitary gland to stimulate the endocrine sphere, lack of insolation and pronounced seasonal asymmetry of the light regime, in combination, contribute to desynchronization of biorhythms and chronic stress of psychophysiological adaptive mechanisms, gradual depletion of the body's compensatory capabilities, dysadaptive failures, immunodeficiency, increased life expectancy and reduction in the incidence. In the Arctic, especially among the indigenous population, the likelihood of injury, drowning, frostbite and other external causes of illness and death is increased, and the risk of contracting infectious and parasitic diseases transmitted through local food, water and contact is increased. Additional health risk factors for northerners are associated with limited and imbalanced diet, vitamin and vegetable fiber deficiency, low water mineralization, combined with increased exposure of the population to pollutants of global, regional and local origin. Contamination of the natural food of the aborigines, which is an important element of physical survival and the preservation of ethnocultural traditions, against the background of a violation of the usual way of life, devaluation of life values, decreased social activity, lack of money, alcoholism, leads to an increase in morbidity and mortality among indigenous peoples [12, 13].

Climatic risk factors affecting the health of the population of the Far East form two types of response of the body – immediate, within hours, days and prolonged – for weeks, months (seasons). Throughout the entire territory of the Far East, mortality in the winter months is higher than in the summer by an average of 2 %. These differences are mainly determined by an increase in the level of respiratory diseases in the cold season. They range quite significantly: from 48.8 % in September to 145.6 % in January. The mortality rate from diseases of the circulatory system coincides with the general seasonal fluctuation in mortality: a maximum of cases is observed in winter (29 %) and spring (26 %), and a minimum – in summer (19 %). These differences should be considered when conducting bioclimatic predictions and working on prevention of meteotropic reactions in patients.

Pollution of the atmosphere, water and landscapes with wastes from the chemical and metallurgical industries against the background of modern climatic changes significantly changes the nature of human interaction with the environment, placing additional requirements on the adaptive capabilities of the human body in northern conditions. The nature of adaptation under such prolonged stress is not only quantitatively, but also qualitatively different from the adaptive responses to acute stress.

It was revealed that the structure of adaptive psychoemotional states of the indigenous and newcomers of the individual regions of the Arctic and subarctic zones differs from each other. The percentage of the indigenous population in prenosological and premorbid conditions, directly leading to impaired adaptation and disease, was significantly higher than that of the newcomer population.

In addition, under the influence of changing environmental factors, the psycho-emotional background of a person's state (maladaptation processes) first of all changes, which leads to a violation of certain physiological health indicators, and then to the formation of diseases [13].

Water and Air Pollution and the Health

The level of health of the population in Pacific Russia continues to decline. It is connected with the prevailing unstable socio-economic conditions, pollution of the environment (mainly water and air) and to the natural dynamics of natural processes [3, 7, 8, 13, 18, 20–22].

Drinking water pollution from mineral extraction waste in the Arctic regions of the Far East of Russia negatively affects the immunity of the local population – the number of oncological diseases in the population of uluses receiving drinking water from the region's large rivers is increasing. From 2001 to 2015, the increase in incidence in the Anabar region was 3 %, in Eveno-Bytansky – 8 %. The largest increase in the incidence was observed in the Ust-Yansky district – 45 %. About 40 % of the increase was in the Upper, Middle and Lower Kolyma regions. In the southern regions of the RFE (Amur Region, Jewish Autonomous Region, Khabarovsk and Primorsky Territories), natural waters are used as the last link for sewerage systems and industrial pollution discharges, which also negatively affects the health of the population and causes an increase in the cost of drinking water preparation. In recent years, the problem of surface water pollution in the south of the RFE has acquired a transnational character.

When analyzing the territorial differentiation of the long-term rate of primary morbidity of respiratory organs of the adult population of the RFE, it was noted that the morbidity of the population of the northern regions is higher than the average for the southern regions and the city of Vladivostok due to more severe climatic conditions in these areas. In the Far Eastern region, the most common respiratory diseases, the share of which in the structure of the general and primary incidence in the Russian Federation was 24.1 and 43.4 %, and in the Far Eastern Federal District – 26.1 and 45.5 % (2015), respectively. In addition, in the Far Eastern region, the average annual growth rate of primary incidence was higher (+ 2.0 %) than in the Russian Federation (+ 1.5 %) as a whole. Here, the level of the primary incidence of respiratory diseases in the Far Eastern Federal District (336.0 ‰ – the average annual indicator for the period from 2005 to 2015) was 4.2 % higher than the Russian Federation as a whole (322.0 ‰).

Chronic obstructive lung disease (COLD) is one of the most notable nosoforms of the class of respiratory diseases and a serious public health problem worldwide. This pathology of the lung tissue arises and progresses under the harmful influence of external factors. The constant increase in the incidence of COLD over the recent years caused great concern in connection with early disability and high mortality due to this pathology. Deterioration of air quality represents one of the factors contributing to this trend. It was established that the effect of air pollutants on the respiratory system is manifested in the suppression of the local defense system, the damaging effect on the respiratory epithelium and the formation of a wide range of severe respiratory diseases. In various regions and cities of the region (Vladivostok, Nakhodka, Ussuriysk, etc.), significant technogenic pollution atmospheric air is recorded. Here, the average long-term level (2000–2016) of the incidence of the adult population of Vladivostok was 14.4 % higher than the regional value. Against the general background of an increase in the incidence of respiratory diseases in the Primorsky Territory, the incidence of COLD took 3rd place after acute respiratory infections and pneumonia. In general, during this period the incidence of COLD increased by 31.8 %. It was established that the marine monsoon climate of Vladivostok had the most negative effect on the COLD patients. The function of external respiration, as the body's most open system, was affected by air pollution by solid suspended particles, which was introduced to the atmosphere of the city of Vladivostok due to the high level of motorization.

The natural, ecological, socio-economic components of the living environment of the population of certain regions of the region, interacting with each other, give different spectra and levels of respiratory diseases, enhancing or weakening the manifestations of individual pathologies, which implies a comprehensive approach to studying changes in the health status of the population, allowing more accurately predict the risks and opportunities for reducing the danger to public health.

Based on the developed method of time-factor prediction, a study was conducted on the possibility of predicting critical incidence rates in 10 districts of the Primorsky Territory of respiratory diseases for the next year based on 5 environmental factors: 4 climatic (winter and summer indicators of temperature and humidity) and 1 ecological (air pollution by industrial emissions). It was shown that the quality of a positive prediction, accepted as a probability of exceeding critical incidence rates for this set of indicators, depended on the type of the impact factors and their combinations. Prediction by one or two climatic factors separately showed a low prediction quality, while when combined (1–4) provided more significant results. The prediction by one environmental factor (No. 5) was also quite low. At the same time, climatic indicators combined with ecological ones provided significantly higher prediction results than individual factors. Therefore, the forecast level increased significantly as a result of the total impact of factors of various nature (1–5), and climatic factors can intensify the impact of some ecological factors (the phenomenon of synergism) and lead to increased levels of incidence in certain territories.

In the context of global climate change, an increase in the growing season is expected in plants, the pollen of which can cause an allergic reaction, as well as the deliberate or accidental introduction of plants from various botanical and geographical regions of the world, which will undoubtedly affect the increase in the frequency of pollinosis among the population.

The connection between the incidence of pollinosis and other diseases of allergic origin is obvious. In particular, among patients with bronchial asthma, a combined disease – pollinosis – is detected in 40 % of cases. Of those who suffer from pollinosis, there are people who are allergic to certain foods, house dust and medicines, tobacco smoke and car exhaust fumes. Pollinosis as a seasonal allergic disease caused by pollen of flowering plants is most common in the southern regions of the Far East. For the Primorsky Territory, there are three periods of peak pollinosis registration, depending on the pollen maturation of various plants. The first period falls in April and May. At this time, allergies to pollen of woody plants prevailed: oak, birch, walnut, alder, poplar, maple. In the second period of the rise of allergic reactions among the population (June and July), cereal plants begin to bloom: rye, bluegrass, bonfire, fescue, orach, sunflower and others. The third period of an increase in the incidence of pollinosis occurs in the second half of the summer – beginning of autumn (August, September), which is very characteristic of the Primorsky Territory. During this period, an increased concentration of pollen from various weeds prevails in the air – ragweed, wormwood, orach [15].

In order to identify pollinosis, among the residents of the city of Vladivostok (children 0–14 years old, adults of 18 years and older), the results of skin scarification tests (1200 tests) were analyzed, 67.7 % of which were with pollen allergens (32 plants). Sensitivity sensitization test results were scored from one to five. The results of the study allowed us to conclude that the percentage of sensitization to plants – allergens among boys and girls aged 0–14 years was almost the same – about 15 %. However, the high level of sensitization for boys was almost two times higher than for girls. Allergens were a mixture of herbs and plantain, unlike other regions (a mixture of trees, a mixture of herbs and ragweed). Adult sensitization level was much higher – about 52 %. Half of them showed a high level of sensitization to many allergens (multiple allergy). After 50 years of age, sensitization with plant allergens was quite rare.

Infectious Disease Threats

Infectious diseases, which belong to the category of acute threats, under the conditions of global climate changes can create an emergency situation in the field of biological safety of the RFE [10, 23]. This situation is characterized by such patterns as abruptness, an explosive growth in the incidence of disease, the unpreparedness of society to perform countermeasures, severe socio-economic consequences, and a real threat to the biological safety of the entire world community.

Infectious diseases dangerous for humans which able to cause public health emergency situations, can be divided into three groups.

1. Diseases that form the external epidemiological risk – dangerous infectious diseases requiring measures for sanitary protection of the territory of the Russian Federation:

– COVID-19
– Smallpox
– Poliomyelitis due to wild poliovirus
– Human influenza caused by a new subtype
– Severe Acute Respiratory Syndrome
– Cholera
– Plague
– Yellow fever
– Lassa fever
– Marburg Virus Disease
– Ebola Disease
– Malaria
– West Nile Fever
– Crimean hemorrhagic fever
– Dengue fever
– Rift Valley Fever (Rift Valley)
– Meningococcal disease.

2. Diseases that form the internal epidemiological risk – dangerous infectious diseases, registration both single and mass indigenous events requires emergency response and using of additional forces and means of public health of the Region:

– Natural focal infectious diseases: plague, Crimean hemorrhagic fever, rabies, West Nile fever
– Diseases common to humans and animals: brucellosis, anthrax
– Cholera
– Malaria
– The risk of intralaboratory infection when working with PBA I-IV pathogenicity groups at biologically hazardous facilities

3. Infectious diseases of importance in regional pathology, prevention of which is to implement long-term programs: Natural focal infectious diseases: tularemia, leptospirosis, hemorrhagic

fever with renal syndrome, tick-borne viral encephalitis, tick-borne tick-borne borreliosis, tick-borne rickettsiosis, Q fever, parasitic diseases and others [12].

Spreading of infectious diseases is accelerating as a result of global warming. Particular danger can be infections from permafrost common for the Arctic zone of the Far East, corpses of animals that died in epidemics dozens and hundreds of years ago are preserved. Intensive thawing of permafrost can release prehistoric diseases, and in the last decade, cases of infection of domestic animals and people with anthrax were observed in the Arctic zone. Furthermore, previously unknown microorganisms, including giant viruses potentially hazardous to public health, were discovered in permafrost [19].

The thawing of permafrost opens up new, previously inaccessible areas for mining. Extraction of ancient soil layers to the surface during their development can also lead to the spread of infections.

Over the last 2–3 decades, there was a significant expansion in the range of mosquitoes and ticks, as well as other carriers of infectious diseases in Russia, including in the Arctic regions. Over the same time a sharp increase in the number of species of dangerous trematodes and other parasites was recorded in the fresh and brackish waters south of the RFE, which is apparently due to their expansion from the southern regions of East Asia [5].

Changing climate creates favorable habitat conditions for species previously unable to survive in the area. Accidental introduction into an ecosystem as a result of human activities may also result in spreading of alien species in the new ecosystem. For example, some alien species were brought to RFE with ballast water of ships. Arrival of alien species or new diseases may become a catastrophe for fishers and local residents.

Another cause of possible expansion of ranges of infectious diseases is changes in migratory routes of bird species that used to follow the same routes for generations. For example, some exotic Asian bird species, which potentially can be vectors of tropical fevers, began to visit Russian North annually.

Dangerous biohazards can be observed in reservoirs and in marine ecosystems during the flowering of harmful algae or the mass reproduction of toxic invertebrates, or the extraction of deep-sea bioresources.

Special risks are exposed to enterprises (and their surroundings) of mass reproduction of single-breed animals and birds, which requires special expertise in their planning and constant monitoring.

Systematic biohazards observations carried out in scientific institutions of the Far East made it possible to obtain unique databases on the distribution of pathogens of dangerous infectious diseases and foci of parasitosis, the risk of infection or damage to people and animals, to study the influence of various factors on the epidemiological situation, to identify unusual dangerous biotic factors that require deep study.

Mitigation

National Policy on Climate and Health

By the Decree of the President of the Russian Federation dated December 17, 2009 No. 861-rp, «The Climate Doctrine of the Russian Federation» was approved – a document that represented a system of views on the purpose, principles, content and ways of implementing the unified state policy of the Russian Federation within the country and in the international arena on issues related with climate change and its consequences. Given the strategic guidelines of the Russian Federation, the Doctrine is the basis for the formation and implementation of climate policy.

On December 1, 2016, the President of the Russian Federation signed a decree by which the head of state approved the Strategy for Scientific and Technological Development of Russia until 2035. According to the Strategy, the country's scientific potential in the coming decades will focus on solving a number of tasks, including the main risks associated with the anthropogenic load on nature; exhaustion of economic development opportunities due to extensive resource exploitation; requirements for increasing energy capacities, etc. Among the priority areas of development of Russian science, the transition to environmentally friendly and resource-saving sources of energy, personalized medicine were also highlighted.

Certain issues in the field of healthcare are regulated by the Federal Law of November 21, 2011 No. 323-FZ "On the Basics of Protecting the Health of Citizens of the Russian Federation", by the Decree of the President of the Russian Federation of 05.07.2012 No. 598 "On Improving the State Policy in the Field of Health" and others legal acts.

Each year, the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) submits official reports on the climate in the country to the Government of the Russian Federation. The reports represent a source of objective information on the state and trends of climate change in the Russian Federation, summarizing the results of climate research and operational climate monitoring conducted by scientific institutions of Roshydromet. The materials of the reports were based on the tested long-term data series of the state observational network of Roshydromet and the approved methods for processing and analyzing climate data. The reports contain information on the main features of climatic conditions on the territory of the Russian Federation and its regions and on current trends in their changes.

Sustainability and Health Gains under Discomfort Conditions

The RFE lags far behind the Russian average in terms of key social indicators. Thus, with an increase in life expectancy at birth to 70.2 years from 2013, in 2019 the RFE remains 3.1 years behind the national average. With a decrease in the mortality rate of the population of working age for the same period to 588 cases per 100 thousand people, the excess of the average values for the Russian Federation is 121.1 cases per 100 thousand people. With a decrease in infant mortality to 5.4 cases per 1,000 children born alive, this indicator on the RFE is 0.4 cases higher than the average for the Russian Federation.

The highest mortality rate was recorded in areas with severe discomfort, which is caused not only (and perhaps not so much) by the harsh climatic conditions, but also largely by demographic characteristics and lack of medical care.

These territories have a small-focal character of settlement; there is the highest concentration of the indigenous people of the North who have low health indicators that are not directly related to extreme living conditions, and the state of medical care due to extremely low transport accessibility.

Such territories are characterized by a low level of education, services of cultural and sports institutions, especially in remote settlements, there is no access to high-speed Internet. In the northern regions of the RFE, a significant decline in the population continues as a result of the migration outflow. In general, over the past 27 years, the population in the RFE has decreased by 1.3 times – from 10.5 million people in 1991 to 8.2 million people in 2019. Despite the decrease in the migration outflow of the population observed in recent years, the number of residents of the Far Eastern Federal District is decreasing by 0.3–0.5 percent annually. According to demographic predictions, the problem with the growth of the population of the North of the Far East will remain long-term. According to some forecasts, in 2010–2050, the total population of the RFE may decrease by 21.1 %, and the working-age population by 42.5 %.

Thus, on the RFE a significant deterioration of living conditions at higher latitudes is clearly visible compared to the southern regions. This well-known pattern, perhaps, would not be subject to such a detailed study, if not for positive examples of compensatory "social deterrence" of the adverse effects of natural factors on the population of Alaska. Of course, the natural conditions of Alaska are less extreme than those of the Magadan Region, however, in principle, they are comparable, while the differences in the health indicators of the population of these territories are very significant. In this regard, the main directions of future studies of the living conditions of the population of the Far East should be more focused on studying the experience of other countries and the possibility of its application in the RFE conditions.

Medical-Geographical Assessment and Environmental Medicine

The beginning of the XXI century was characterized by a tendency of researchers towards holistic, integrated, interdisciplinary study of a human and their relationship with the environment; however, there were very few targeted comprehensive medical and geographical research on the territory of the RFE. Therefore, the study of the medical and geographical situation of the northern regions and the analysis of the relations between the health of the population and the geographical features of the territory are of high relevance [20, 27, 29].

The methodological basis for the development of the research model consisted of the processes of health formation and adaptation of the population living in various regions of the RFE in the context of environmental transformation in referring to two interdependent sources of information on the processes of human adaptation to conditions of an environment [18]:

1) registered quantitative indicators of common and individual health of the population;

2) fundamental developments of neurophysiology – the theory of stress and the general adaptation syndrome by H. Selye in a modern interpretation.

The study of adaptation (maladaptation) of the population, especially of the northern territories, within the considered methodological approach included the assessment of mainly populational (grouped) and to a lesser degree individual adaptation reactions of the population in response to the impact of adverse environmental factors of varying degrees of intensity and duration.

The conceptual model of population adaptation included 5 blocks of indicators:

1 – public health, 2 – individual health, 3 – socio-economic factors, 4 – ecological factors, 5 – natural factors.

The component-by-component analysis of the options for the functioning of the model allowed one to identify previously unknown features of the interrelation in the system "human – the natural and social environment."

When considering the adaptation of the population as a complex system, it seemed important to determine the ratio of social and biological aspects of the study. There was a methodological problem related to the assessment of the adaptation levels during prolonged exposure of a body to adverse factors of low intensity or along with the use of protective equipment, technical solutions, etc.

A special feature of the suggested methodological approach is the following:

1. Representation of the environmental impact factors on the widest possible range of indicators of public health.

2. Assessment of the adaptation levels of various groups of the population that form the further state of health of the population living in various regions of the Eastern Asian Russia.

3. Assessment of the health state of the both territorial groups of the population as a whole and the most characteristic subgroups that differed in their reaction to environmental conditions.

4. Differentiation of the territory "from below", from elementary sections that were isolated, and consolidated only by those geographical characteristics that were reliably associated with biomedical phenomena.

Assessment of population adaptation on the basis of the stated methodological principles allowed to simulate situations that occurred in the process of climate change and economic activity in varied territories of the Far East and throughout Russia. Due to its complexity, medical-geographical assessment represented an integral and extremely important part of the regional management strategy, since no economic benefits that followed by a deterioration in the population health can be justified.

Over the recent years, a new thread of medical activity has emerged – environmental medicine, which required new methods of rapid diagnostics and monitoring the health status of residents of ecologically disadvantaged territories. The issues of express diagnostics of the intensity of adaptation processes, quantitative assessment of the effectiveness of human adaptation to the environment concerned not only medical professionals of various specialties, but also ecologists, geographers, teachers and psychologists. Studying the specific characteristics of adaptation among residents of ecologically disadvantaged territories is now becoming an important component of environmental monitoring, and typing of adaptive portraits of residents of extreme regions is considered as one of the urgent tasks of medical geography and environmental medicine.

Reducing the impact of global climate and environmental changes on the health of northerners through various socio-economic compensation mechanisms will lead to [28, 29]:

– a change in the balance of migration processes towards a new influx of migrants into the northern territories,

– improving the health of the indigenous and alien population,

– the growth of the economy of the strategically important northern territories of Russia,

– development of a new type of activity in the Arctic territories – Arctic tourism,

– development of the national culture of the indigenous population.

Sustainable Development and Climate Change

Economic Prospects

In recent years, at the government level to improve the current socio-economic situation programs are being developed to improve the quality of life, ensure security and sustainable development of Pacific Russia.

In 2013, the Russian President declared the development of Siberia and the Far East as the top priority for the country's development in the XXI century.

By order of the Government of the Russian Federation of September 24, 2020 N 2464-r, the National Program for the Socio-Economic Development of the Far East for the period until 2024 and for the future until 2035 was approved. The main goals of the program are to accelerate the development of the regional economy, improve the demographic situation, and stop the migration outflow. The program provides for improving the quality of life in the Far East to a level above the national average, including the development of human capital, human resources and the formation of a comfortable living environment, the development of the health care system, education and culture.

Sustainable Development and Green Economy

The economy of the RFE regions is mainly of a resource-based nature. Over 30 % of Russia's natural resource potential is concentrated on the territories and the sea shelf of the RFE, which, along with its geographical location, makes the region promising in terms of economic development and advancement of international relations. These factors indicate great opportunities and prospects for the successful development of the Far Eastern regions, which will inevitably increase the technogenic impact on the natural environment and lead to the exacerbation of existing and the emergence of new environmental and medical problems. Due to the vast territories and, consequently, various climatic conditions in the region, including seasonal and permanent frost, etc. natural ecosystems of the Far East are much less resistant to anthropogenic impacts, compared to the European part of Russia. Global climate change can only exacerbate existing environmental and economic imbalances in the future [1, 2].

This means that the rational, efficient use of natural resources, without which sustainable development is impossible, ought to be improved. Far Eastern regions with preserved natural resources and natural ecosystems, with their human resources, industrial, economic and scientific potential, can become a good testing ground for the implementation of a green economy. This requires sufficient economic support for environmental management both at the regional level and at the level of individual industries [3].

The successful development of the Far Eastern territories on the principles of a green economy and their implementation depend on the active position of state and regional authorities, the development of tax benefits and other preferences for a green business, and most importantly, on strict control and adoption of effective sanctions provided for by legislation.

This requires sufficient economic support for environmental management both at the regional level and at the level of certain types of industries, and strengthening environmental protection. This is one of the main factors in preventing and eliminating the risk of the occurrence and development of environmental problems, ensuring the sustainable development of industrial and natural relations. For realization of green economy principles, the following measures should be implemented:

1) targeted investment in this sector, with consideration of the existing regional and industrial problems;

2) the structure of investments in environmental protection and rational nature management should be determined by the current and predicted estimates;

3) the use of funds (from all sources) for environmental protection should be monitored by the relevant authorities and reporting should be available to both interested parties and the public;

4) it is necessary to make changes and additions to environmental legislation (significantly increase the amount of fines for violation or non-compliance with environmental laws, late payment of fines; toughen penalties for environmental offenses, false environmental information, etc.);

5) when forming a package of documents for starting any production, an environmental review should be mandatory for any type of activity, and for productions of I and II hazard classes, a public environmental review must be added as well;

6) it is necessary to increase the level of medical care for the population, especially those living in extreme territories, and medical institutions should have the adequate number of medical personnel, especially narrow specialists and modern diagnostic and medical equipment;

7) annual medical examination of the population, taking into account professional, age and national characteristics;

8) to predict possible changes in indicators of public health and the development of pre-nosological conditions that lead to diseases, constant monitoring of the processes of adaptation and maladaptation of the population under the influence of changing environmental factors using modern express methods and hardware-instrument complexes is required [1–3].

<u>Food and Nutrition Security and Agriculture</u>

The geographical location and soil and climatic conditions of the Southern part of RFE made it possible to grow a wide range of agricultural crops in this territory: soybeans, spring crops, fodder crops, corn, potatoes, rice, as well as vegetables and fruit, although for many cultures there was a northern distribution border located. The development of dairy and beef cattle breeding, pig and poultry farming is quite promising in the region, as well as horse breeding and reindeer husbandry in the northern regions. In addition, there is development of mariculture in the coastal areas of the seas of the southern Far East [17].

Climate warming could present new opportunities for agriculture, and new lands may become suitable for crops and profitable agricultural technologies. At the same time, climate warming and agricultural practices can increase water consumption, erosion and degradation of soil, agroecological risks associated with the emergence of new weeds, pests and pathogens. Agriculture will not only be altered by climate changes, but will also significantly increase its impact on the regional climate through increasing greenhouse gas emissions.

The problem of food self-sufficiency is characteristic of RFE for 1.5 centuries of its existence. During the period of industrial development of the RFE in the 1960–1985s, the crop area of agricultural land crops in the region was approaching 3 million hectares. During the crisis of 1990–2005, a significant part of the cultivated land was withdrawn from circulation and only in 2005 began to return to the agricultural sector turnover. To date, in main agricultural arable land are used in the Far Eastern Federal District area (Amur Region, Khabarovsk Territory, Primorsky Territory) of 2.5 million ha. This is about 2 % of the arable land of the Russian Federation and 10 % of Northeast China. That means that it is a resource of regional scale. That is important in its modern form for the Russian Federation and Northeast Asia (NEA). If it is socio-economic necessary, the natural and technological conditions of the south of the RFE allow increasing the area of arable land: a) up to 3 million hectares – through the reclamation of land that has been abandoned, b) up to 4–4.5 million hectares – through the new land melioration development. The realism of the option, which is based on the "new" development, is largely determined by the trends of climate change.

Agricultural land area used in RFE does not allow achieving food self-sufficiency in the region (except for potatoes, soybeans, some vegetables). The latter is maintained at an acceptable social level, mainly due to the import of products from other Russian regions (Siberia), adjacent provinces of China and other suppliers. In the strategic planning of actions to strengthen the RFE food base, along with other factors, it is necessary to take into account the options (trends) of climate change in the NEA region, namely:

– the impact of climate change will differ depending on geographic location,

– in the RFE, the agroecological significance of climatic changes will be maximum in the forest area (Prikhankaiskaya lowland, south of the Zeya-Bureya plain), where in spring and early summer aridization is likely to increase,

– in Northeast Asia, the agroecological significance of climate change will be maximum in the western part of Heilongjiang and Jilin provinces in the steppe zone, where aridization is likely to increase,

– in the structure of changes, the most agroecologically significant may be the instability of climatic parameters, rather than general trends.

The most reliable sources to date reveal that climate change will increase production risk as measured by yield variability of the main crops in Russia. In south of the Far East the evidence varies with some crops showing increased production risk and others showing reduced risk. There are strong links between risk management policies adaptation and government responses to protect farmers from climate change risks will affect their strategies. For example, support for insurance schemes and for ex post payments may reduce the incentive to diversify farm production away from more climate sensitive crops and farm practices. In this sense, these government-supported instruments can potentially crowd out appropriate adaptation strategies by farmers.

Predicted scenarios of agricultural development in a changing climate are necessary to provide strategies and decision-making tools to improve agriculture, food security and, at the same time, reduce the negative impact of agriculture on the environment [11, 17].

Conclusions and Recommendations

Natural and socio-economic potential of the Far East is significant and can be converted not only into the acceleration of its own development, but also the sustainable economic growth of the Russian Federation as a whole.

The prospects for the development of the Far Eastern region outlined by the Government of the Russian Federation will inevitably increase the technogenic impact on the natural environment, which in the context of global climate change will lead to an aggravation of existing problems in environmental management and health care, and the emergence of new environmental challenges.

To control the situation it is necessary to form a regional system of medical-geographical monitoring – tracking the state of health of various population groups and the state of climate and the environment in various systems of division (zoning) of the territory. It is important to identify in advance various forms of the impact of climate change on public health.

To develop an effective management system for the medico-geographical situation, it is necessary on the basis of scientific research to develop a model of the medical-geographical effect of various variants of climate change on the health of various population groups living in different regions of Eurasia. The formation of appropriate spatial databases is essential.

The application of the scientific and experimental base should be aimed at development of measures related to improving the quality of life of the population, as well as improving methods for predicting and preventing disaster emergencies of a natural and man-made nature in a changing climate:

1. The formation of evidence-based activities aimed at improving the quality of life of the population of the Far East, which will reduce the impact of global changes:

1.1. Development of measures to ensure the availability of comfortable housing, high-quality and safe goods and services, improving the quality of housing and public utilities.

1.2. Diversification of agricultural production, aimed at sustainable development of the industry for providing the population with high-quality food.

1.3. A comprehensive medical and geographical assessment of the state of health and development of recommendations for reducing the incidence of the population, creating conditions for a healthy lifestyle, stimulating fertility and reducing mortality, development of personalized and environmental medicine.

1.4. Development of effective measures to maintain environmental quality (pollution reduction, resource conservation, environmentally friendly energy sources, etc.).

1.5. Development of measures to ensure the preservation and development of the cultural and spiritual heritage of indigenous peoples, balancing the interests of indigenous people and labor migrants taking into account their ethnic, linguistic, cultural and religious differences, developing the education system as a factor in the socio-cultural adaptation of the population of the north-eastern territories of the Russian Federation.

2. Development of measures aimed at improving methods for predicting and preventing disaster emergencies of a natural and man-made nature in a changing climate:

2.1. Assessment of the current state of the environment and the risks of natural and man-made disasters.

2.2. Improving the methods for predicting and preventing natural and man-made emergencies resulting from natural processes (changing permafrost boundaries, seismotectonic and volcanic activity, tsunamis, etc.) and economic activity.

2.3. Improving the safety of vehicle operation and the safety of the transport of passengers and goods, ensuring transport accessibility of medical care.

2.4. Assessment and forecasting of biological safety in the RFE, implementation of breakthrough directions in the fight against respiratory and infectious diseases.

2.5. Studies of the dynamics of living systems, development of measures to improve the system of state environmental monitoring.

2.6. Development of new types of technologies in the field of environmental management, eliminating the possibility of destruction and degradation of the natural environment, including from destructive fires.

2.7. Development of measures for the rehabilitation of territories and water areas affected by natural disasters and man-caused environmental impacts.

BIBLIOGRAPHY

1. Baklanov P.Ya. The Far Eastern region of Russia: Problems and preconditions of sustainable development. Vladivostok: Dalnauka. 2001. P. 1–144. (In Russian).

2. Baklanov P.Ya., Moshkov A.V., Romanov M.T. Pacific Russia: Main Factors and Directions of Long-Term Development // Problems of Geography. 2016. Vol. 141. P. 595–618. (In Russian).

3. Baklanov P.Ya., Romanov M.T., Moshkov A.V., Stepanko N.G., Lozovskaya S.A., Tkachenko G.G., Kornienko O.S., Churzina A.A., Pogorelov A.R. On National Security and the Social – Economic, Ecological Position in the Far Eastern Region // Journal of Advance Research in Dynamical & Control Systems. 2018. Vol. 10, 02 – Special Issue. P. 1187–1195. (In Russian).

4. Bartalev S.A., Stytsenko F.V., Egorov V.A. et al. Satellite-based assessment of Russian forests fire mortality // Lesovedenie. 2015. N 2. P. 83–94. (In Russian).

5. Bogatov V.V., Besprozvannykh V.V., Prozorova L.A. Harmful Parasitoses on the Russian Southern Far East under Climatic and Demographic Changes // Doklady Biological Sciences. 2019. Vol. 487. P. 108–111. DOI: 10.1134/S0012496619040033.

6. Bogatov V.V., Fedorovskiy A.S. Freshwater ecosystems of the southern region of the Russian far east are undergoing extreme environmental change // Knowledge and Management of Aquatic Ecosystems. 2016. Vol. 417, (34), P. 1–10. DOI: 10.1051/kmae/2016021.

7. Bogatov V.V., Fedorovskiy A.S. Basics of River Hydrology and Hydrobiology. Vladivostok: Dalnauka. 2017. P. 1–384. (In Russian).

8. Bogatov V.V., Prozorova L.A., Chernova E.N., Lysenko E.V., Ngo Q., Tran T., Hoang S. Bioaccumulation of Heavy Metals in Soft Tissues of Bivalve Mollusks from Natural Lakes in Eastern Sikhote Alin (Russia) and the Mekong Delta (Vietnam) // Doklady Earth Sciences. 2019. Vol. 484. Pt 1. P. 76–78. DOI: 10.1134/S1028334X19010094

9. Bogatov V., Sirotsky S., Yuriev D. The ecosystem of the Amur River. In: Ecosystems of the world. Vol. 22. River and stream ecosystems / ed. by C.E. Cushing, K.W. Cummins, G.W. Minshall // Amsterdam-Lausanne-New York-Oxford-Shannon-Tokyo: Elsevier. 1995. P. 601–613.

10. Bolotin E.I., Fedorova S.Yu. Spatial-temporal organization of the infectious morbidity of the population of the south of the Russian Far East. Vladivostok: Dalnauka, 2008. P. 1–223. (In Russian).

11. Chaika A.K., Klykov A.G. Priority directions in the development of agro-industrial complex in the Far East of Russia // Vestnik of the Far East Branch of the Russian Academy of Sciences. 2016. N 2 (186). P. 24–30. (In Russian).

12. Dudarev A.A., Gorbanev S.A., Fridman K.B. Partnership of the Northwest Public Health Research Center in the international projects in the field of Arctic environmental health // Gigiena i Sanitaria (Hygiene and Sanitation, Russian journal). 2017. N 96 (7). P. 601–606. (In Russian). DOI: http://dx.doi.org/ 10.18821/0016-9900-2017-96-7-601-606.

13. Egorova A.I., Davydova V.Ya. Analysis of the mental state of specialists working in the Arctic // Russian Journal of Education and Psychology. 2018. Vol. 9, N 10. P. 20–36. (In Russian).

14. Forestry complex of the Russian Far East: an analytical review / ed. A.S. Sheingauz // Vladivostok; Khabarovsk: FEB RAS, 2005. P. 1–160. (In Russian).

15. Izerina E.V., Lozovskaya S.A. Morbidism in pollinosis of the population of Vladivostok // Geosystems of North-East Asia: the peculiarities of their spatialtemporal structures, zoning of land and waters. Collection of Scientific Articles // Vladivostok: PGI FEB RAS, 2019. P. 386–388. (In Russian).

16. Kharuk V.I., Ponomarev E.I. Fires and burns of the Siberian taiga // Science First Hand. 2020. N 2 (87). P. 56–71. (In Russian).

17. Klykov A.G., Kim I.V., Potenko T.A. Food security and the role of agricultural science in sustainable agricultural development in the Far East // Vestnik of the Far East Branch of the Russian Academy of Sciences. 2018. N 3 (199). P. 5–11. (In Russian).

18. Kosolapov A.B., Lozovskaya S.A., Izergina E.V., Tsitsiashvili G.Sh., Veremchuk L.V., Vitkina T.I., Mineeva E.E., Sidletskaya K.A., Golohvast K.S. Methodological approaches to assessing the health of the population of the regions of the Russian Far East // Health. Medical Ecology. 2019. Nauka. N 3 (79). P. 14–22. DOI: 10.5281/zenodo.3559636. (In Russian).

19. Legendre M., Bartoli J., Shmakova L., Jeudy S. et al. Thirty-thousand year old distant relative of giant icosahedral DNA viruses with a pandoravirus morphology // Proc. Natl. Acad. Sci. U.S.A. 2014. Vol. 111 (11). P. 4274–4279.

20. Lozovskaya S.A., Kosolapov A.B., Pogorelov A.R. The Health of the Population of the Regions of the Eastern Arctic of Russia. // Scientific Research of the SCO Countries: Synergy and Integration. Beijing. 2019. P. 70–77. (In Russian).

21. Lozovskaya S.A., Tsitsiashvili G.Sh., Stepanko N.G., Bolotin E.I., Izergina E.V., Pogorelov A.R. Factor temporary forecast of socially significant morbidity in Primorsky Krai // Regional Problems. 2018. Vol. 21, N 3 (1). 2008. P. 17–21. DOI: 10.31433 / 1605-220X-2018-21-3 (1)-17-21.

22. Lozovskaya S.A., Pogorelov A.R., Tsitsiashvili G.Sh., Radchenkova T.V., Izergina E.V., Veremchuk, L.V., Mineeva E.E., Vitkina T.I. , Gvozdenko T.A., Sidletskaya K.A., Golokhvast K.S. Regional special features of the formation of respiratory diseases in the conditions of the south of the Russian Far East (Primorsky Territory) // Health. Medical Ecology. Nauka. 2018. N 3. P. 77–84. DOI: 10.5281/zenodo.1488042. (In Russian).

23. Noskov A.K., Vishnyakov V.A., Chesnokova M.V. Current issues of anti-epidemic readiness of a Russian Federation region for emergency situations associated with infectious diseases dangerous for humans. Report 1. Concepts, terms, definitions // Irkutsk Antiplague Research Institute of Siberia and Far East. Bulletin VSNTS SB RAMS. 2013. N 2 (90), pt 2. P. 202–205. (In Russian).

24. Report on Climate Features on the Territory of the Russian Federation in 2019 // Moscow: Roshydromet. 2020. P. 1–97. (In Russian).

25. Semiletov I.P., Shakhova N.E., SergienkoV.I., Lobkovsky L.I. et al. Permafrost degradation and imbalance in the carbon cycle in the seas of the Eastern Arctic (Greenhouse gas flows, extreme ascidification, georiski) // Comprehensive Research of the Natural Environment of the Arctic and Antarctic. Abstracts of the international scientific conference. St. Petersburg: Arctic and Antarctic Research Institute. 2020. P. 81–84.

26. Shakhova N., Semiletov I., Salyuk A., Yusupov V., Kosmach D., Gustafsson O. Extensive methane venting to the atmosphere from sediments of the East Siberian Arctic Shelf // Science. 2010. Vol. 327, N 5970. P. 1246–1250.

27. Solonin Yu.G., Bojko E.R. Medical and Physiological Problems of the Arctic // Syktyvkar: Institute of Physiology, Komi Scientific Center, Ural Branch of the Russian Academy of Sciences. 2017. P. 3–40. (In Russian).

28. Stepanko N.A., Lozovskaya S.A. Ecological aspect of the tourism development in the Chukotka Autonomous Region // Arctic: History and Modernity: Works of the Annual International Scientific Conference. St. Petersburg: Politich-Press. 2019. P. 181–193. (In Russian).

29. Stepanko N.G., Stepanko A.A., Tkachenko G.G. Possible environmental consequences of the economic development of the Northern territories of the Russian Far East // Arctic: ecology and economy. 2017. N 4 (29). P. 26–36. DOI: 10.25283 / 2223-4594-2018-1-26-36. (In Russian).