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ФИЗИКАЛЫҚ, ЭКОНОМИКАЛЫҚ ЖӘНЕ ӘЛЕУМЕТТІК ГЕОГРАФИЯ

Section 1

PHYSICAL, ECONOMIC AND SOCIAL GEOGRAPHY

Раздел 1

ФИЗИЧЕСКАЯ, ЭКОНОМИЧЕСКАЯ И СОЦИАЛЬНАЯ ГЕОГРАФИЯ

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STUDYING OF THE CLIMATIC FACTORS THAT INFLUENCE ON THE GROWTH OF THE SAXAULIN THE SOUTHERN REGION

This article considers the technology of reproduction by monitoring the phytocenotic features, biomorphological and eco-biological conditions of saxaul in the southern region of Kazakhstan. As an environmental issue, the state of saxaul production in the southern regions of Kazakhstan is still not up to date. This is due to the lack of scientifically based agro technology for growing saxaul crops in the wild, the lack of forest seed base and special seeders for sowing saxaul seeds. Therefore, it is necessary to evaluate the existing cultivation technologies and reconsider the idea of saxaul as a plant that can grow in any forest conditions. The research was carried out in the laboratory conditions of the Department of Ecology and Chemistry of the Faculty of Natural Sciences. Geobotanical methods and agrotechnical research methods were used as scientific methods: control of seed planting material of black saxaul.For comparison with wild saxaul species, the expeditionary method, latent, virginal and generative development methods, control methods, and phenological research methods were used. Studies have shown that saxaul seeds can be grown in artificial and field conditions. As a result of the study, it can be predicted that the southern region has the opportunity to increase the number and scale of saxaul species. This fact provides a favorable ecological solution to the environment, that is, the problem of desertification and sand control. The seeds of the black saxaul were planted in laboratory conditions before the seedlings were ready to be transplanted into the natural area.

Key words: saxaul, desertification, salt marsh, ecological degradation, geobotanical methods, seed planting material, graysoil.

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Оңтүстік өңірдегі сексеуілдің өсуіне климаттық факторлардың әсерін зерттеу

Бұл мақалада Қазақстанның оңтүстік аймағында сексеуілдің фитоценотикалық ерекшеліктерін, биоморфологиялық және экологиялық-биологиялық жағдайларын бақылау арқылы олардың көбею технологиясы қарастырылған. Экологиялық проблема ретінде Қазақстанның оңтүстік өңірлерінде сексеуіл өндірісінің жай-күйі әлі күнге дейін өзекті емес. Бұл табиғатта Сексеуіл дақылдарын өсірудің ғылыми негізделген агротехникасының болмауына, сексеуіл тұқымдарын себуге арналған орман тұқымы базасы мен арнайы сепкіштердің болмауына байланысты. Сондықтан қолда бар өсіру технологияларын бағалау және кез-келген орман жағдайында өсуге қабілетті өсімдік ретінде сексеуіл туралы идеяны қайта қарау қажет.

Зерттеулер экология кафедрасы мен химия жаратылыстану ғылымдары факультетінің зертханалық жағдайында жүргізілді. Ғылыми әдістер ретінде геоботаникалық әдістер мен агротехникалық зерттеу әдістері қолданылды: қара сексеуілдің тұқымдық отырғызу материалын бақылау. Сексеуілдің жабайы өсетін түрлерімен салыстыру үшін экспедициялық әдіс, жасырын, виргинильді және генеративті даму әдістері, бақылау әдістері, зерттеудің фенологиялық әдістері қолданылды. Зерттеулер сексеуіл тұқымын жасанды және дала жағдайында өсіруге болатындығын көрсетті. Шағын зерттеу нәтижесінде оңтүстік өңірде сексеуіл түрлерінің саны мен ауқымын ұлғайту мүмкіндігі бар деп болжауға болады. Бұл факт қоршаған ортаға, яғни шөлейттену және құммен күресу проблемаларына қолайлы экологиялық шешім береді. Қара

сексеуіл тұқымдары табиғи ауқымға көшіруге дайын көшеттер өсірілгенге дейін зертханалық жағдайда отырғызылды.

Түйін сөздер: сексеуіл, шөлейттену, сортаң топырақ, экологиялық тозу, геоботаникалық әдістер, тұқымдық отырғызу материалы, сұр топырақ.

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Изучение влияния климатических факторов на произрастание саксаулов в южном регионе

В данной статье рассмотрена технология воспроизводства путем наблюдения за фитоценотическими особенностями, биоморфологическими и эколого-биологическими условиями саксаула в южном регионе Казахстана. Как экологическая проблема, состояние производства саксаула в южных регионах Казахстана до сих пор не актуально. Это связано с отсутствием научно обоснованной агротехники выращивания посевов саксаула в дикой природе, отсутствием лесосеменной базы и специальных сеялок для посева семян саксаула. Поэтому необходимо оценить существующие технологии возделывания и пересмотреть представление о саксауле как о растении, способном произрастать в любых лесных условиях. Исследования проводились в лабораторных условиях кафедры экологии и химии факультета естественных наук. В качестве научных методов использовались геоботанические методы и агротехнические методы исследований: контроль семенного посадочного материала черного саксаула. Для сравнения с дикорастущими видами саксаула использовались экспедиционный метод, латентный, виргинильный и генеративный методы развития, методы контроля, фенологические методы исследования. Исследования показали, что семена саксаула можно выращивать в исскуственных и полевых условиях. В результате небольшого исследования можно прогнозировать, что, южный регион имеет возможность увеличить количество и масштаб саксаульных видов. Этот факт дает благоприятное экологическое решение окружающей среды, то есть, проблемы опустынивания и борьбы с песком. Семена черного саксаула были высажены в лабораторных условиях до произростания рассад готовых к пересадке в естественный ареал.

Ключевые слова: саксаул, опустынивание, солончак, экологическая деградация, геоботанические методы, семенной посадочный материал, серозем.

Introduction

The climate of the southern region determines the high values of the influx of solar radiation on its territory. The main component of the radiation balance is the total solar radiation. As we move from north to south, there is a significant increase in the arrival of total solar radiation. The region receives the greatest amount of solar energy during the period July-September. For the most part, the maximum solar solstice occurs in the month of the summer solstice – July. This season is characterized by small gradients of radiation fluxes and the predominance of relatively thin clouds of the upper and middle tiers. The total radiation, falling on the earth's surface, is partially absorbed, and the rest, reflected, returns to the atmosphere. The reflection coefficient depends mainly on the nature of the underlying surface. In winter, in the presence of snow, it reaches 70-80%, in summer it is significantly reduced to 20-30%. The main features of atmospheric circulation are formed under the influence of the general planetary circulation, local radiation conditions, and the characteristics of the underlying surface. A very significant influence on the circulation processes of the atmosphere is exerted by the structure of its surface. Mountain ranges in the south, southeast have a certain impact on air currents on a global scale, being a natural barrier to the passage of cold air masses to the south. The influence of the mountains in the south and southeast on atmospheric fronts is obvious. Thus, fronts approaching from the north slow down their movement or become stationary. Annual rainfall varies from 230 to 340mm. The maximum also falls on the warm half of the year, when 65-80% of the annual precipitation falls. Average annual temperatures are positive (1°C). In general, the climate of the region is characterized by long hot summers, cold winters for these latitudes, large annual and daily temperature amplitudes, high air dryness, and low cloudiness.

For the warm half of the year, due to intense heat exchange between the underlying surface and the atmosphere, an intensive process of transformational drying and heating of the incoming air masses is characteristic, leading to the formation of continental local tropical air. The daily course of the wind is typically continental: calm prevails in the evening and at night, during the day the wind intensifies, reaching a maximum in the afternoon. The coldest month of the year is January with an average temperature of -5, -15°C. At the same time, even in the coldest months of winter, rare warming temperatures are possible, reaching 15-25°C on some days. The share of precipitation of the cold period is 30-54% of the annual amount. Dust storms are usually observed during the passage of cold fronts. The periods of greatest heat are associated with the development of thermal depression. A characteristic feature of the warm half-year is the high frequency of atmospheric droughts, against the background of moderately dry and dry wind-dry weather. The dry nature of the weather is determined not only by high temperatures, but also by low relative humidity, combined with a small amount of precipitation.

Winter is characterized by great instability and variability of the weather, especially in the southern part of the zone, where there are frequent changes of positive and negative temperatures. Summer is long, hot and dry, the weather is stable, it is dry and dusty, cloudless and has large daily amplitudes of air and soil temperature.

One of the biggest problems in the world today are the global warming, expansion of the ozone hole, the melting of the Arctic Ocean, the attraction of Aral water, the flight of its salt residues, and the ecology are the main problems of the global population. At the same time, it has a huge impact on the flora and fauna, climate, and environment of the biosphere. In order to preserve biodiversity, international environmental organizations are doing many work and preventive measures. In particular, the focus is on the technology of increasing forest areas, developing acreage in sandy, desert and semi-desert zones. In the desert region, efforts are being made to solve the problem by providing measures to preserve the biodiversity of the plant system. At the same time, work is underway to plant saxaul, which is resistant to hot climates, has the ability to protect against dust storms and preserve soil fertility. Not only our country, but also all over the world, including Central Africa, the United Arab Emirates, Mongolia, China, India, and Central Asia work is underway to create saxaul forests. In the desert and semi – desert region, the main thing is vegetation and saxaul trees. It accounts for more than half of the total forest fund. In order to solve this problem in the country, on behalf of the Department of Ecology, geology and natural resources, it was discussed at a methodological scientific conference and proposed to plant seedlings. The efficiency of acclimatization of this plant is a protection of the desert zone and has the ability to hold firmly, without scattering sand (Samakova, 2004:203; Melokhova, 2007:124; Lawyer, 2005:25; Toktasynov, 2018:115; Thevs, 2013:22).

Saxsaul is one of the important tree for the wilderness and desert region. The peculiarity of this plant is that it is very suitable for the ecological restoration and melioration of the desert. Since ancient times, people have used the trunks of saxaul to build settlements. People living in remote settlements use its ramification in everyday life, its energy value is close to the calorific value of coal, that is, it is characterized by thermal heat. Currently, in China this wood is categorized as small firewood. However, due to its biological features, several problems have been identified in its propagation and propagation: slow development rate, low level of artificial straight lines (<10%), and planting seedlings in non-irrigated conditions. Studies have shown that in a dry climate, sandy and stormy areas, in addition to nibbling by small jaguars, physiological stress (t> 80C) is caused by the burning of young shoots in contact with the ground (Wuherer, 2012:18; Yessimbek, 2022:486; Sukachev, 1972:28,50; Baeshov, 2000:15).

Accordingly, this stress factor is ignored by forest protection organizations. Today, as a result of research in many ecological, desert and desert regions, a new floor cultivation technology is emerging. However, these technologies can be applied in regions with relatively high water levels, desert and desert areas, sandy hills and saline soils. As a result, it was proved that the annual growth of the plant and its growth in saline desert soil could be effectively improved. These technologies have been tested in the desert regions of Xinjiang, Mongolia, as well as in the provinces of Shanghai and Gansu of China (Azenov, 2009:8; Dedkov, 1978:177).

The plane tree is a shrub plant that grows in the desert. There are many types of saxaul; three of its types are widespread in our country: white*(Haloxylon persicum)*, black saxaul (*Haloxylonaphyllum*) and zaysansaxaul (*Haloxylon ammodendron*). White plane tree grows in desert areas, on the sands, its height reaches 1.5-2.5 m, sometimes there are also large species of shrubs up to 5 m. Its

leaves are like scales, green, and the branches are used for food. This species is mainly food for camels, they feed on saxaulbushes at a height of 3 m and receive a fodder mass of up to 12 kg. In addition, sheep can eat dry leaves and bushes that have fallen to the ground. Saxaul has a high nutritional value, 100 kg of dry wood contains 4 kg of easily digestible protein and 52.0 food units.

Black saxaul is a large shrub plant, reaching a height of up to 7 m, with a strongly spreading trunk and branches. This species can form half-arid forests and spread by seed, and is common in the desert region of Central Asia. It grows well in sandy and clayey areas with high filterability, especially at a depth of 5-30 m. Occurs in areas of low energy shrubs, barren and barren areas. It is distinguished by high fodder productivity, increases the productivity of the pasture-forage mass of the adjacent territory in the form of pasture protection strips. Unlike white camels of this species, camels eat quickly and have a high forage mass (Rakhimova, 2022:287; Mathur, 2022:32; Liu, 2022:285; Shamsutdinov, 2021:19).

Zaysan ammodendron – grows in sandy and saline soil and has a branched trunk. Its branches are entwined with thin long green twigs that replace leaves, the lower part can decrease to small sizes. The flowers are small, inconspicuous, located on the neck of these scales, consisting of five pistils, five pistils and one pistil with 2-5 stigmas. The ovary contains one ovule, which develops into a seed with a spirally twisted fetus. Its wood is very hard, but brittle, not suitable for handicrafts, but excellent firewood is obtained from it. This type of sycamore grows very slowly, and regeneration after cutting takes a long time. There are other forms of saxaul marriage in Afghanistan, Iran, North Africa and Spain, but they are much less common.

The purpose of scientific work – in the course of achieving the goal, the timing of the growth of wormwood in the spring months was initially controlled according to the general control and counting method. The study of biomorphological features of seeds in the latent, virginal, generative and endogenous periods was carried out. First, the growth process of seedlings was measured by observing 15-45 rooted trees. Tree measurements were calculated based on their development and maturity in the phenological phase. The fodder mass of the saxaul product was cut agro technically and harvested.

The area of forests in the country is 30 million hectares, which 13 million hectares are considered forest. The main vegetation of this region is saxaul forests. Of the species found in our country, the white-black type occupies about 7 million. The sandy zone includes 165 million hectares of the territory of Kazakhstan with a total area of 287 million hectares. In the southern region of Kazakhstan, a large area of Almaty, Zhambyl, Turkestan, Kyzylorda, Aktobe and Mangistau regions is a desert region, and the inhabitants of this region suffer from climatic conditions. Due to the migration of sand, the sand that has moved covers the villages (Zhao, 2021:2; Singer-Avitz, 2021:105; Li, 2021:72).

Despite restrictions and bans in place since 2004, the threat to saxaul remains. In addition, in order not to restore extinct species in the future, the most radical measures should be taken today. It grows mainly in vast desert regions from the Mediterranean to Central Asia, on sand dunes, salt marshes and rocky deserts of the Gobi. In the world, 11 types of saxaul have been identified intercourse. In China, only two species, Haloxylon ammodendron and H. rersicum, are distributed over an area of about 120,000 km^2.

If we talk about special measures, then the responsibility for the sale of hemp trees should be transferred from the administrative level to criminal responsibility. If the desire for relic wood is taken at 250 MCI instead of 25 MCI, and with a few hundred extra hours of restoration work, cutting work and use should decrease. The proceeds can be used to buy seedlings and plant them in the place of the destroyed trees. It should be noted that work is in full swing to create a saxaul grove at the bottom of the dried-up Aral Lake. The plan for the next ten years is to plant about eight million seedlings in the salt desert, and by 2030 it is planned to plant 500,000 hectares of forest. In order to turn our city into a green city, we plan to plant and replant trees, as well as develop and harvest them in a short time. Because it is well known that saxaul is known as the fortress of the sandy desert. Its tree itself grows on average up to 12-15 meters in height. It comes from the greek word “galaxilon”, which means “salt tree”. This is because it protects the desert from sand and sandstorms.

The most effective climatic zones for the development of forests in the country are the southern region, such regions as Zhambyl, Almaty and Kyzylorda. It is necessary to select a product for sowing and sowing seeds, adjust the sanitary function without viruses, termites and pests (Shamsutdinov, 2020:3).

Let us focus on the general characteristic of this plant (Ubaydullayev, 2020:4): the roots are widely spread and develop well. Secondary roots penetrate deeply into the soil and spread for 10-15 meters.

The stems and leaf branches are single-branched, the base is flattened, and in the last years of life, it becomes brittle. The size of the stem is small and heavy, in this case it will sink in water. The flowers are two-lobed, small, and scaly. The leaves are divided into male and female. The male has six petals, the female has five petals. It grows and matures in the second and third months of spring and continues to bloom until mid-autumn (Burnside, 2020:1178).

The most effective climatic zones for forest development in the country are the southern region, such areas as Zhambyl, Almaty and Kyzylorda. It is necessary to select a product for sowing and sowing seeds, adjust the sanitary function without viruses, termites and pests (Batsaikhan, 2020:13).

According to the Decree of the Government of Kazakhstan dated April 29, 1999 "On the protection of saxaul forests", a great contribution was made to the development of saxaul forests. This decree prohibits poaching and the private use of wormwood; this document ordered large-scale work in the southern and southeastern regions (Purayil, 2020:5).

The life span of saxaul forests may end much earlier than expected, and then the semi-deserts, which occupy 36 percent of the entire territory of the Republic of Kazakhstan, risk turning 64 percent of the region into lifeless sands and salt marshes.

The saxaul species H. Persicum is widely distributed mainly in the provinces of Northern Xinjiang, Inner Mongolia, Gansu and Shanghai. The distribution area in Xinjiang is 73.1% of the entire country and about 14.1% in Inner Mongolia. The distribution area in the provinces of Qinghai and Gansu is relatively small, with about 7.9% and 4.9% of the species distributed. Because the tree is resistant to drought, heat, soil salinity and wind resistance, this tree has a special place in Chinese desert forestry. Plane tree planting contributes to the conservation of biodiversity in the desert plains, provides suitable habitat for about 200 species of desert animals, plays an important role in sand movement and sand consolidation, slows down desertification, maintains regional ecological balance, and plays an important role. Indispensable role in the development of the national economy and its environmental safety.

For sustainable and rational use of forests, it is necessary to know the biological, physical and geographical features of forest communities. When classifying forests, all regularities and patterns of forest development, biological features of the forest area, climatic and soil conditions, etc. should be taken into account. According to V.N. Sukachev (Bao, 2020:3) for a more complete account of the characteristics of the forest, it is necessary to use the methods of forest inventory and forest typology, and at a different level of forestry development, a certain is needed approach to typology.

Unites all classifications of saxaul forests and distinguishes three main categories: 1) ecotopic, where the focus is on environmental factors (ecotope), which in turn are divided into microclimatic and soil; 2) biocenoses, phytocenoses and zoocenoses; 3) an ecosystem that combines the foundations of the two previous classifications. Therefore, phytocenosis is a representative of all ecosystem properties of the forest.

The geobotanical concept of phytocenosis and the geobotanical approach to the classification of forests take into account such factors as a complete account of the species composition of the community involved in the exchange of matter and energy, which is an indicator of environmental conditions; establish a sinusoidal community structure; taking into account environmental factors, mechanisms of interaction of phytocenosis components. The plant association, which is the main taxonomic unit in phytocenology, is a floristic, ecological and phytocenological concept. The species Desertiarborosa saxaul belongs to the eucerophilic desert plants.

In the desert regions of southern Kazakhstan, about 40,000 hectares of black oak forests are grown annually. The main way to create forest plantations is to sow seeds. This method has a number of advantages, but also has many disadvantages. The productivity of the fields is not constant; the level of their localization depends on the weather and climatic conditions of each year. The level of land reclamation is often very low, resulting in the destruction of thousands of hectares of fields every year. White saxaul grows in the northern part of the desert, on hilly and ridged sands. In the Bakanas, plain, white saxaul grows on the tops of hills and ridges. The white saxaul formation consists of 10 communities that differ in their growth characteristics (Elmefregy, 2020:2782). The tops of the hills and ridges are characterized by shrub communities, and on the slopes of the hills, in depressions between coals and between ridges, herbaceous communities grow. Communities recommend the use of grass as a pasture in spring and autumn/winter. A mixed formation of saxaul grows in low sandy depressions and ridges of the Bakanas Triangle. On low sandy ridges (no more than 2-2.5 m), mixed alder forests are mainly common. The ridges consist of pulverized fine-grained gray mica sands, and sagebrush grows in dense silty sands underlain by clay soils.

The formation is characterized by a low degree of flight closure – 0.2-0.3 m, height – 1-2 m, as well as low productivity.

According to known information, the most common formation on the territory of Ile-Balkhash is black saxaul in the low-wave plain; in fact, black saxaul dominates in most of the entire massif. It is on this territory that forests cross the desert from southwest to northeast in the central part and reach the Karatal River. With the formation of groundwater, black saxaul spreads from 5 to 10 m in the lower parts of the area. The most common associations of this formation are black saxaul and keirey black saxaul type. Each of these communities accounts for 30% of the total area and there is a high level of preservation of the top of 0.5-0.7 cm. The height of the trees is up to 7 m, the circle of the level of return is up to 1 m, the upper part of the plant is up to 0.5-0.8 cm On clay soils grows rare and rarely growing, and on sandy soils black saxaul dominates. Therefore, the smallest in terms of productivity and area is occupied by lichen black saxaul, and these belong to this dying saxaul (Lindqvist, 1958:14).

The purpose of this scientific work aimed at solving such relevant issues is to identify and increase the types of fertile grass in the desert and deserts in the southern region in order to determine the biological and environmental nature of the Saxsaul family, biodegradable and environmental, personal significance, in pastures in the southern region. The goal was to control the phytocynotic significance of the saxaul using phytocenological significance, the use of phytomelization and the natural state of this environment, the need for the environment.

Materials and methods

Selection research methods were used as the main research methods. Works on the selection inventory of saxaul forests, on the transfer of forest seed production to a breeding basis. B. Lindqvist in Sweden introduced the concepts of “plus”, “normal” and “minus” planting; “plus”, “normal” and “minus” tree and developed a methodology for their allocation [27]. These definitions are accepted in the international practice of forest breeding. The research was carried out in the laboratory conditions of the Department of Ecology and Chemistry of the Faculty of Natural Sciences. Geobotanical methods and agrotechnical research methods were used as scientific methods: control of seed planting material of black saxaul. Geobotanical methods were used as a scientific method: monitoring of phytocene tics in the culture of saxaul types and phytocene (determination of natural conditions of saxaul), the phytoene ticques in the culture of saxaul inaccordance with the climatic conditions in the southern region. Methods of agro-technical research: to determine the stages of growth and sowing of saxaul seeds, sowing and processing of seeds. Biomorphological types of saxaul family were considered a method of latent, virginally and generative development. Research methods were used through optimal processing and depth of optimal processing and control of sowing in the development of saxaul development, plant measurement, and perfection in the phenological phase time.

Black saxaul forests for thirsty regions of Kazakhstan are a regional plant. We also consider desertested forest formations as a pasture ecosystem, as saxaul is more productive than other desert plants, only 85 tons/hectares in wooden reserves, as well as 2.5-7.5 kilometers/ hectares. In our understanding, the size of the ecosystem complies with a geobotanic understanding of the size of the plants as a taxonomic unit.

Saxaul forests of the South Balkhash region were studied using the two landfills and landscape-environmental profiles in the area of the Sary-Ishik-Atyrau region. This is a black landscape plant that makes saxaul trees for the desert, but not exceeding 0.4-0.5, it is often light forests with a clear long linear structure. Dominant black saxaul – Haloxylon Aphyllum height of 2 – 5 m, but large dimensions can reach 50-60 cm of 8 – 10 m and the thickness of the trunk. Saxaul performs asymilian and photosynthesis. Black saxaul in the classification of the form of life form of the Rounder – a phanerophyte; Serbryakova in the classification of bio morphs – Vertical geooxil, Bushkov B.A. – semi-shrub was divided into haloxerophilic. The black saxaul bond is a geliophite and reflected in lower-step plants and herpetobic animals, regardless of the transparency of the crown. The crown of saxaul generative tendents absorbs and reflects up to 30-50% of solar radiation flows, so the temperature of the open space is different, but also preserves the temperature of saxaul atmospheric moisture and accordingly. The number of parcels is not the same. Another difference in black saxaul is that seasonal branches are observed in the soil horizons, which leads to the appearance of the surface solidarity of the soil horizons, due to the large number of ashes of the plant. All of these features, we see the role of an environmentally friendly cenosis, such as other Saxsaul resorts. A number of associations,

their floristic, represents black saxaul formation and ecobiomorphcomposition also studied, with a volume of 0.25-0.5 hectares (fig.1).

Saxaul trees give seeds as they dry, which will allow the drought to plant more in Saudi Arabia. For centuries, millions of these trees have provided people with fuel and have been a mound of mounds, food and recreation in the heat of the Arabian fathers' Bedouin's desert. Saxaul roots are caught sandy and keep sandy storms.

Results and discussion

As a result of scientific research, the variety of the soil layer of the soil layer of the arid area, chemical and biomechanical composition of the diversity (tab.1).Interestingly, in different parts of the plant, different amounts of heavy metals can accumulate, which can be an environmental indicator of the environment.In this regard, this report identifies practical data on physiologically active substances in different parts of some wild plants collected in environmentally safe areas and in environmentally unfavorable areas and a number of metals. The territories of 90-100 km from the city 90-100 km were considered environmentally safe, and areas located within the city (20-30 km from the city) were considered unsafe (fig.2). The objects of study were chamomile and its various parts, comfrey root, gorse root, common yarrow.

In Table 1, it is observed that the increase in extractive substances increases increased by increased by increased by increased by the increase in extracts when switching to solvents and the maximum amount of extractive substances is obtained with water. Separate experiments showed that the explored vegetable raw materials could separate annins, sugar, inulin, C and B vitamins, water-soluble dyes, amino acids. It is noted that the amount of extractive substances in plants growing with diethyl esters, ethylacetat, isopropanol and water extractive substances in the areas where there is growing in adverse areas of the region. However, it should be noted that these differences are small, but they are exceeding the systematic error and not more than 5-6% of the determined value.Thus, the most environmentally friendly conditions for the growth of the above plants lead to an increase in the amount of physiologically active substances that are used in all solvents we use.

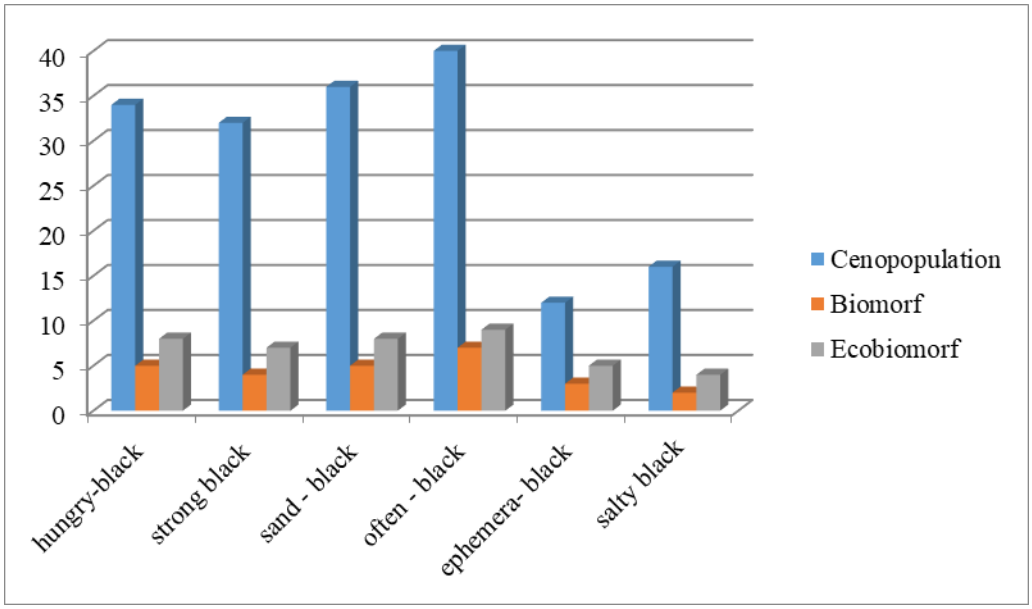

Figure 1 – Indicators of variety of black saxaul forests
of black saxaul forests of the In the shauldir-Otrar region

Table 1 – Granulometric and micro-aggregate composition of gray soil

Templates	Horizons, cm	Fraction size, mm; their size, relative to dry soil %						
		?	3-1	1-0,25	0,25-0,05	0,05-0,01	0,01-0,001	?
T – 1	0-5	1,5	2,1	0,9	20,1	32,0	6,4	13,6
	5-20	2,0	6,3	1,0	23,8	30,0	5,7	12,0
	20-30	2,3	4,8	2,1	29,6	35,2	6,1	12,4
	30-40	2,8	2,1	1,8	37,2	34,1	7,6	11,2
	40-50	3,3	3,7	1,3	28,9	29,8	6,6	10,8
T – 2	0-5	5,0	3,2	5,0	33,4	28,1	10,6	14,3
	5-20	5,6	2,6	2,9	40,6	26,9	9,1	17,2
	20-30	1,8	1,7	3,3	30,0	21,4	7,8	17,4
	30-40	1,7	1,0	1,7	22,5	21,2	7,5	17,5
	40-50	2,0	2,0	1,2	18,7	20,5	4,4	20,2
T – 3	0-5	5,7	7,2	0,4	25,4	24,0	8,5	16,3
	5-20	8,5	6,6	0,3	22,2	23,6	8,2	20,3
	20-30	7,6	5,1	0,3	15,6	20,7	7,3	5,2
	30-40	6,4	4,7	0,2	17,8	15,4	5,4	4,9
	40-50	4,2	4,0	0,2	25,8	12,1	3,3	3,8

Figure 2 – Saxaul of the southern region

Analyzing table 2, the associations of black saxaul forests can be grouped according to the prevailing existence of sub-life forms: shrub – glued and molded black saxaul forests; semi-bushy – white soil wormwood and billing black saxaul; grass – ephemeral and juicy saline black saxaul.

Table 2 – The associations of black saxaul forests

№	A group according to the prevailing existence of life forms		
1	shrub – glued	black saxaul forests	In winter, the saxaul traps snow and this helps to feed groundwater, especially in the case of low-snow winters. This tree gives life to other grasses and shrubs, providing shade and soil moisture.
2	molded		
3	white	semi-bushy forests	they play a soil-protective, sand-protecting role and are used only for spring and autumn pastures
4	black saxaul		
5	ephemeral	grass	Camels, sheep, and goats feed on young and very nutritious shoots. The saxaul is a water scout, as it always appears where groundwater is close to the surface.
6	saline black saxaul		

The variety and relatively large number of cenopophulations included in the associated associations are determined by the development of mills of ephemeras, a short development cycle in spring. Ephemeras and ephemerids in high rating and ephemerids form sinuses under saxaul cover (salt plots). In case of overhead salts, salts are rinsed from upper horizons and the location of ephemeras in the ephemeral-black saxaul association remains normal. The saxaul crown dominates the most productive in terms of wood resources and industry – saline-saxaul association, one-year salary, in unresolved land, and ephemeras. The semi-bushy forests can be considered the rarest and the rarity characterized by a relief and low projection cover in semi-shrub and low projection covers, but their frequency is very high in their consideration. The forms of life, ecobiomorphs cover all the range from different and monocarps to the bushes. Not much stable species are used for the relevant associations; they are not used for classification and enrichment of environmental conditions in the landscape.

Conclusion

It was determined that the semen of the saxaul growing in many regions of the country can cultivate. Knowing the state of the seeds of Uzbekistan and Kazakhstan, it is appropriate to organize basic arrangements equipped with specialized equipment and specialists with experience in the cultivation of landscaping materials. These seeds can be created based on self-sufficiency. Knowing the main fetus, knowing the need for annual seedlings, and in the spring it provides standard planting material. This will be much easier and more effective than the creation of small nurseries of each farm and without professional education.

Seeds should be collected from high-yielding plantations that grow from plus trees or soil and climatic conditions in areas related to areas of forest melioration.

Forestry activities provide for forest vaccinations in the first two sites, forming a dense edges and radial routes on the side of pollution for ventilation for well ventilation. Planted: karagash, poplar, willow, ash, maple, hood, currants, hoses, saxaul, intermediate, etc. Plant schemes are recommended for forest inventory for certain cultivation conditions.

Saxaul localization of desert and desert areas affects the environmental condition of the region and increases biodiversity of living organisms. Great to use nutrient grass in the Southern region in desert and deserts, gives it a positive impact on the climate, soil conditions, environmental development, allows you to protect against sandy and stormy.

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HISTORICAL-GEOGRAPHICAL ASPECTS OF SUSTAINABLE DEVELOPMENT OF SMALL TOWNS (on the example of small towns in Zhambyl region)

The problems of sustainable development of small towns were analyzed from the perspective of historical-geographical factors in this article. During the analysis, we were convinced that monoprofile towns, which are part of the group of small towns, have become the "center" of problems in the world and the country. Theoretical and conceptual analysis of the concepts, names, opinions and conclusions of scientists developed in relation to these cities associated with global industrialization was carried out. The main mechanisms of rehabilitation and support of labor resources in monoprofile towns in a crisis situation were determined on the basis of the experience of the USA, Canada, Australia, Japan, Germany and other countries. And in the conditions of our country, we considered on the example of small towns in Zhambyl region. According to it, the historical aspects of specialization of small towns were given importance, classification of common issues limiting sustainable development was compiled. Demographic problems in towns were analyzed, and the place at the strategic stage of the development of innovative city was determined on the basis of historical data and theoretical conclusions. According to the concept of sustainable development, the main areas of urban environment development were selected, and their social, economic and environmental effects were emphasized. In general, the results of the study in the article will complement research in the field of urban geography.

Key words: the problem of small and monotowns, town-building enterprises, social modernization, economic diversification, sustainable development.

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Шағын қалалардың тұрақты дамуының тарихи-географиялық аспектілері (Жамбыл облысының шағын қалалары мысалында)

Бұл мақалада шағын қалалардың тұрақты даму мәселелері тарихи-географиялық факторлар тұрғысынан талданды. Талдау барысында, шағын қалалар тобына жататын монобейінді қалалар, әлемде және елімізде мәселелер «орталығына» айналғанына көз жеткіздік. Әлемдік индустрияландырумен байланысты бұл қалаларға қатысты қалыптасқан түсініктерге, атауларға, ғалымдардың пікірлері мен тұжырымдарына теориялық-тұжырымдамалық талдау жасалды. АҚШ, Канада, Аустралия, Жапония, Германия және т.б. елдердің тәжірибесі негізінде, дағдарыс жағдайындағы монобейінді қалаларда еңбек ресурстарын оңалтудың және қолдаудың негізгі тетіктері анықталды. Ал, еліміз жағдайында Жамбыл облысының шағын қалалары мысалында қарастырдық. Ол бойынша, шағын қалалардың мамандануының тарихи аспектілеріне мән беріліп, тұрақты дамуын шектейтін ортақ мәселелердің классификациясы жасалды. Тарихи деректер мен теориялық тұжырымдар негізінде, қалалардағы демографиялық мәселелер талданып, инновациялық қала дамуының стратегиялық кезеңіндегі орны анықталды. Тұрақты даму тұжырымдамасы бойынша, қалалық ортаны дамытудың негізгі салалары таңдалып, олардың әлеуметтік, экономикалық және экологиялық әсерлеріне мән берілді. Жалпы, мақаладағы зерттеу нәтижелері қалалар географиясы бағытындағы зерттеулерді толықтыратын болады.

Түйін сөздер: шағын және моноқалалар мәселесі, қала құраушы кәсіпорындар, әлеуметтік жаңғырту, экономиканы әртараптандыру, тұрақты даму.

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Историко-географические аспекты устойчивого развития моногородов (на примере моногородов Жамбылской области)

В данной статье были проанализированы проблемы устойчивого развития малых городов с точки зрения историко-географических факторов. В ходе анализа мы убедились, что монопрофильные города, относящиеся к группе малых городов, стали «центром» проблем в мире и стране. Проведен теоретико-концептуальный анализ сложившихся представлений, названий, мнений и выводов ученых относительно этих городов, связанных с мировой индустриализацией. На основе опыта стран: США, Канады, Австралии, Японии, Германии и др. были определены основные механизмы реабилитации и поддержки трудовых ресурсов в монопрофильных городах в условиях кризиса. А в условиях нашей страны мы рассматривали на примере малых городов Жамбылской области. По нему была разработана классификация общих проблем, ограничивающих устойчивое развитие, с упором на исторические аспекты специализации малых городов. На основе исторических данных и теоретических выводов проанализированы демографические проблемы городов и определено место инновационного городского развития на стратегическом этапе. Согласно концепции устойчивого развития, были выбраны основные области развития городской среды, уделяя особое внимание их социальному, экономическому и экологическому влиянию. В целом результаты исследования в статье будут дополнять исследования по географии городов.

Ключевые слова: проблемы малых и моногородов, градообразующие предприятия, социальная модернизация, диверсификация экономики, устойчивое развитие.

Introduction

The problem of small towns development is distinguished by its relevance in the history of the geography of cities. This is especially related to monotowns, which the economy is based on the dominant development of one industry, belonging to the group of small towns. In these cities, people's livelihood, social-economic development depended on the activities of the city-building enterprise (Nurlanova, 2012: 156), (Kaimuldinova, 2015: 456).

Such small towns are called *"monotowns"* (The program for the development of monotowns for 2012-2020. URL: http://adilet.zan.kz/kaz/docs/P1200000683) in the country and in the vast majority of CIS countries, they are widely recognized as *"one industry town"* or *"single-industry town"* (Elizabeth, 2021) in the world experience. And accumulated problems in small towns of the countries was the basis for forming the names *"boomtowns"* (Carson, 2013: 31), *"resource towns"* (Stelter, 2006), *"company towns"* (Julie, 2006) in the USA, Canada, Australia, Germany and other countries. That is, although the names are different, the formation of these cities corresponds to the industrial period, and the city's activity (specialization) was closely connected with the development of resources.

The difference between these towns (monotowns) in comparison with other towns with other multifunctional economy depends more on changes in the external environment, changes in government goals, the state of economic sectors, conjuncture in the foreign market, the volatility of demand for goods, monitoring of payment terms, etc. For example, a long period of economic decline served as the basis for some monospecialized towns to become "abandoned" or "ghost" town. Such small settlements can be found in all countries of the world. In international practice, these towns are known as "ghost towns" (https://en.wikipedia.org/wiki/List_of_ghost_towns_by_country). In history, such a state of cities, in addition to an economic recession, was influenced by natural and man-made disasters, genocide and political factors.

Development issues of small towns take an important place in world practice, research of scientists and scientific-research organizations. The regularities of the geography of the city are explained from a special point of view in the scientific works of the well-known American scientist Edward Glazer. In his monograph, which quickly spread to many countries of the world, he described cities as an environment that makes humanity happy (Glazer, 2015: 394).

Glazer discovered the phenomenon of the *"resource curse"* in relation to small towns with heterogeneous economy. According to the explanation of the scientist, the successful development of only one industry hinders the diversification of industry, which can be called the

"curse of resources". Such "cursed" cities include Detroit, which was called the "automobile capital of the United States" at the time and Pittsburgh, a coal city (Glazer, 2009). In the USA, the problem of small towns (company towns) has existed for 130 years. The problem of small towns based on the activities of monopolistic companies became acute in the 70s of the previous century. Areas that experienced a sudden decline in industrial production were named the "Rust Belt" in the United States. Measures were taken from economic restructuring to reduction of cities during the reconstruction of small towns in this country (Shlomo, 2010).

The problems of small towns have become known in the Canadian experience as "resource cities" or "new cities". These settlements differed from other cities in that they were small and isolated. Dependence on the same branch of industry often leads to instability in the development of the city's economy, and this instability persists. For example, the Great Depression that began in the United States in 1929 affected small Canadian towns for 10 years. This economic "chronic disease", which lasted until 1939 caused a 40% drop in GDP (Kenneth, 1991: 634). Canadian scientists have been conducting research in this field since the 1970s. The new community, economic diversification, development of the service industry and cluster development policies are considered effective in the development of small cities. Even in this country, program for the development of villages and small towns has been accepted (David, 2005: 88). The structure of the economic development of small communities in Canada and the theoretical views of scientists are systematized in this program.

The experience of Germany in the reconstruction of mono-industrial towns is of considerable interest in history. It should be noted that Germany has organizational efforts in the development and analysis of comprehensive programs for the modernization of monoprofile towns, and also deals with large consulting firms with a reputation in government bodies and financial centers.

One such major entity is Albert Speer & Partner GmbH. One of these projects is an analysis of the development processes of resource-industrial cities in the Ruhr valley of the famous coal region of Germany, aimed at "green" development (Bülow, 2013: 19). The company's projects were carried out together with German scientists geographers and mainly focused on the works of landscape planning (Bystrova, 2014: 9).

As a comprehensive solution to the problem of mono towns in the UK in order to ensure new homes, increase labor mobility of the population, attention is paid to the formation and activation of transport infrastructure connecting jobs in cities and surrounding areas, the gradual long-term modernization of city-forming enterprises, the stimulation of the creators of new types of economic services, etc.

As a comprehensive solution to the problem of mono towns in Great Britain in order to ensure new houses, increase labor mobility of the population, attention is paid to the formation and activation of transport infrastructure connecting with workplaces in cities and surrounding areas, the gradual long-term modernization of city-building enterprises, encouraging creators of new types of economic services, etc. (Lyubovny, 2009: 100).

Japan is characterized by a high level of social responsibility and cooperation between city-building enterprises and municipal authorities. The solution to the problem of mono towns in the crisis situation in Australia is based on the diversification of the city's economy and the deployment of labor in other territories.

In the Czech Republic, in solving the problem of diversification, priority is given to the effective use of the tourist potential and the competitive renewal of the city-building enterprise. In Poland, the policy of developing small towns is aimed at increasing public literacy and developing human capital. In this regard, projects on development of transport infrastructure, alternative sources of energy, development of information society, improvement of environment and education were implemented. In general, most countries of the European Union solved the problem of monoprofile small towns in crisis situations by restructuring "old" enterprises and forming a new development model (Beysenova, 2016: 10).

The objectives of sustainable development of cities are defined within the framework of the Sustainable Development Goal 11 called "Make cities and human settlements inclusive, safe, resilient and sustainable".

Researches on sustainable development of cities have been been conducted in various directions in recent years. Issues of socio-spatial inequality in cities, social inequality in ensuring urban stability (Cody, 2018: 26), (Sara, 2019: 793), management of sustainable development of cities, analysis of the main development problems (Serge, 2017: 107), (Stina, 2019: 217), (Ramin, 2009: 5), adaptation of sustainable development goals to individual city

conditions (Sandra, 2019: 4), issues of urbanization in environmentally vulnerable areas (Stephen, 2022: 460), study of the practice of deindustrialization of cities (Seth, 2020: 283) are important within the framework of our research topic. In this regard, analyzing the foreign experiences of sustainable development of small cities, in the condition of the regions of the country, starting from the history of the formation of cities, consideration of the current situation is the basis for assessing the possibilities of their post-industrial sustainable development. Because the development of the city is the basis for the development of the country. We will consider this on the example of small towns of the Zhambyl region.

Materials and methods

The initial research materials are based on theoretical and conceptual works of foreign and domestic scientists and research organisations dealing with the problem of sustainable development of small towns. The analysis of established ideas and concepts, strategic documents and programmes concerning small towns with a unified economy was carried out. When analysing the data related to the history, population of small towns in the Zhambyl region, historical data, statistical data since 1970 were used. The official information provided by the A.G. Vishnevsky Institute of Demography (IDEM), National Statistical Office of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and the Department of Statistics of the Zhambyl Oblast were summarised and systematised. When analysing the prospects for sustainable innovative development of cities, we were guided by the conclusions of experts, the classification of famous urban scientists. In addition, on the basis of the common methods of geography, a review of theoretical works, a comparative analysis of foreign and domestic experience, processing of spatial data of the studied settlements, classification of information on settlements, assessment of dynamic changes, system analysis of results were carried out.

Results and discussion

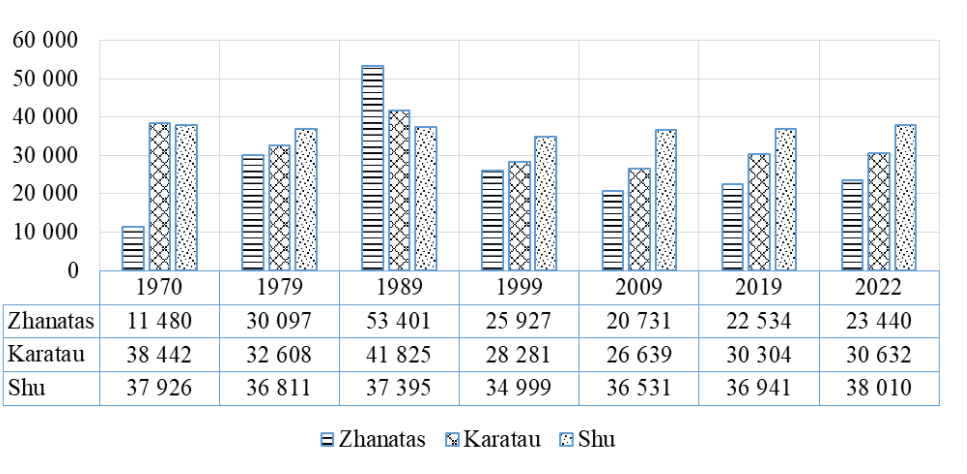
Cities are an important part of the entire territorial system of the society, the basis of the country and national economy. At present, cities around the world are being characterized as drivers of sustainable economic growth. Science and education, financial exchanges, innovative achievements, competitive human resources are concentrated in cities (Aliaskarov, 2017: 243). However, it is known that there are periods when the "playground" for cities changes radically. This is especially typical for cities with a single-industry (mono-profile) economy, which are part of the group of small towns.

The country's inclination to the market economy at the end of the 20th century, the influence of the global financial and economic crisis that began in the 2008's, served as the basis for widespread recognition of the concept of "monotown" which belongs to the category of small towns in Kazakhstan. Fluctuations in the cost of oil on the world market, decrease in demand for non-ferrous metals – put on the agenda a "new" issue for Kazakhstan, which the economy depends on the export of mineral resources. This is the problem of the development of small and monotowns. The economy of these cities, built on the basis of production and processing of natural resources in our country, went into sharp decline due to various factors (decrease in demand for natural resources, financial and economic, etc.). As a result, the vast majority of about 60 small towns in the country have become depressed regions. Among them there are towns of Zhambyl region (Zhanatas and Karatau – mono cities; Shu – a small city). Due to political and economic factors, common problems characteristic of cities have accumulated. This hindered the sustainable development of towns (Table 1).

The most actual common problem of small towns of Zhambyl region is related to the demographic situation. Well-known urban scientist G.P. Lappo mentions 3 factors that improve the demographic situation of the city's population: a) natural population growth; b) mechanical growth (due to migration); c) joining suburban rural settlements to the territory of the city (Lappo, 1997: 479). But judging by the dynamics of the population, starting from the period of the historical formation of cities until now, we do not observe natural growth. For Zhanatas and Karatau, we see a positive indicator of natural growth before 1989, and the period of the "great decline" from 1989 to 2009, when the population decreased by almost 2 times. In recent decades, we have seen the stabilization of the situation according to the strategic decisions accepted by the state (The program for the development of monotowns for 2012-2020. URL: http://adilet.zan.kz/kaz/docs/P1200000683) (Figure 1).

Table 1 – Classification of common problems limiting sustainable development of small towns in Zhambyl region

The name of the town	Time of establishment of the town	Field of specialization	Common problems specific to towns
Zhanatas town	25 June, 1969	Mining industry and manufacturing industry	*Social issues:* - population migration from small towns to large settlements; negative balance of demographic growth; unemployment of the economically active population; low quality of human resources; level of deterioration of social infrastructures, etc. *Economic issues:* - low level of economic diversification; low infrastructure provision (roads, communication networks, energy supply, heat supply, etc.); technological backwardness of city-building enterprises, etc. *Ecological problems:* - anthropogenic erosion of terrain of the earth, degradation of landscapes; non-timely cleaning of household waste; the size of waste storage facilities of manufacturing enterprises; the emission of pollutants by many small boilers working on solid fuel; non-compliance of residual dumps with environmental standards, etc.
Karatau town	1963		
Shu town	1960		



	1970	1979	1989	1999	2009	2019	2022
Zhanatas	11 480	30 097	53 401	25 927	20 731	22 534	23 440
Karatau	38 442	32 608	41 825	28 281	26 639	30 304	30 632
Shu	37 926	36 811	37 395	34 999	36 531	36 941	38 010

Figure 1 – Change in the population of small towns in Zhambyl region (1970-2022)
(Demoscope Weekly 1970, 1979, 1989, 1999), (Smailova, 2011: 94),
(Statistical collection Taraz. URL: https://www.stat.gov.kz/)

This reveals that the specialization of the town of Shu was more "resistant" to external factors (reduced demand for raw materials, political-economic) than the previous two and specialized in modern innovative direction. In general, population can influence technological innovations in cities and improve the economic development of cities (Alonso, 2018: 5), (Castells, 2014: 345), (Bettencourt, 2011: 52), (Zheng, 2020: 465). However, excessive population growth can lead to environmental pollution, excessive consumption of resources, traffic congestion (Fan, 2019: 150), (Salomons, 2012: 7), (Wen, Y. 2020), etc. aggravation of social situation.

World-class urban scientists, while discussing the future of the city, attach high importance to innovation. Even the concept of "innovative city" has been formed in the geography of cities. Peter Hall introduced this concept: "this is a city of a new social form, socially and economically changed due to innovations, resulting from the integration of many innovations. The development of these cities depends on the role of science and technology, including the dominance of independent innovations and the priority of innovative culture, that is, a city based on the systematic development of technology, education, people's intelligence and culture"- summarizes his thought (Peter, 1998: 22).

Peter Hall's opinion is confirmed by Chinese urban scientist Ch. Fang. It summarizes the innovative formation and development of cities into 4 stages: 1) *the initial stage*, during which the driving force of city development depends on natural resources; 2) *middle period*, where the development of the city depends on capital activity; 3) *the later period*, innovations will have leading importance in the development of the city. 4) *the last stage*, human intelligence and mental ability create dominance (Fang, 2014: 1098) (Figure 2).

The mentioned 4 stages of urbanization in Fang's works can be evaluated as gradual or strategic development achievements. That is, with the onset of the next stage, the driving force for the development of society also changes. At the same time, if we look at the system presented by Fang, from the Kazakhstani point of view, it can be understood that the current situation of monotowns in Kazakhstan, including Zhanatas and Karatau, passes between the resource and capital management. The inclusion of these towns in the program "Development of Monotowns 2020" and the allocation of large amounts of money from the state seem to indicate that the period of resource leadership is "weakening" and "stepping" into the period of capital leadership.

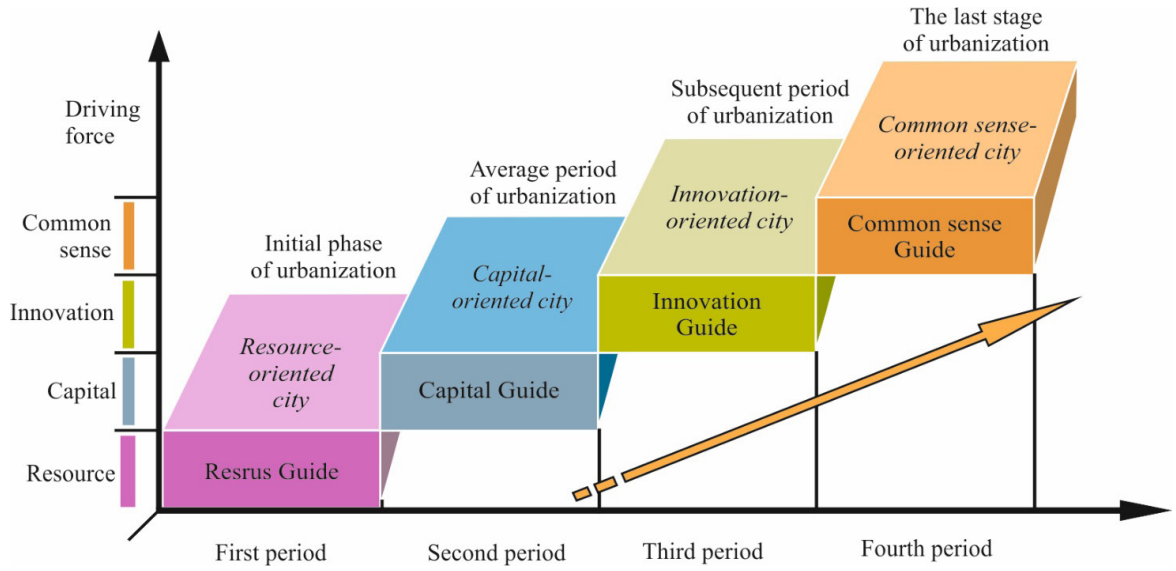


Figure 2 – Strategic stages of innovative city development

Therefore, speaking about the future development of towns and regions, it is necessary to pay special attention to the concept of Sustainable Development (http://sirse.info/wp-content/uploads/2016/02/indicators_for_sustainable_cities_IR12_en.pdf). Sustainable development of regions, including towns, depends on social, economic and environmental factors (Figure 3). If the harmonious development of the 3 spheres (society, economy, environment) forming the basis of the city ensures the stability of the city, the achievements of mental potential will become the basis of innovative development.

The following can be mentioned as the effects of the interdependence of above mentioned main principles in the urban environment:

- *social influence*, the development of human capital – serves as the main driving force of social innovation. That is an improvement in the quality of education, health care, the formation of highly qualified labour force, a developed political and institutional environment will be the basis for the development of social society.

- *economic impact*, cities move to science-intensive effective economic specialization and geo-economic competition for the international division of labor increases. This circumstance will serve as the basis for the growth of competition in the global creativity indexof cities.

– *environmental impact,* a modern innovative city, first of all, should become a "green" city. That is, it must meet environmental requirements, become a comfortable environment for living without waste, in accordance with ecological requirements. This will ensure the viability of the city.

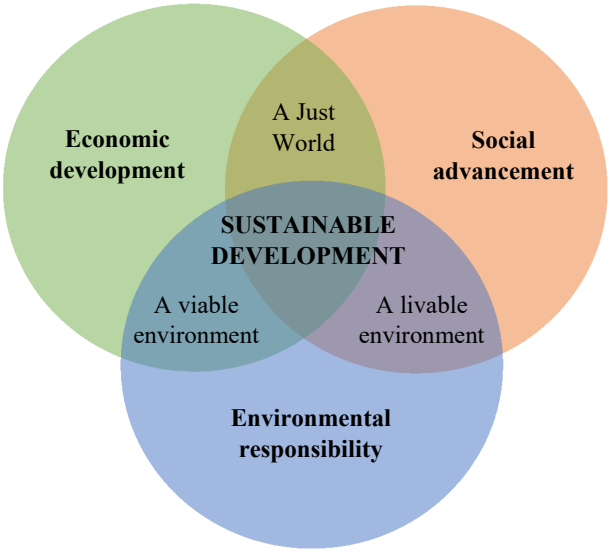


Figure 3 – Basic principles of sustainable development of the urban environment

Conclusion

The following conclusions can be drawn from the results of scientific analysis regarding the sustainable development of small and monotowns:

– The economic success of Zhanatas and Karatau is mainly based on the existence of abundant reserves of raw materials in the territory, its production and processing. Efficient use of natural resource potential is characterized only in the direction of raw material production.

At the moment, this process continues. For instance, the activities of city-forming enterprises in Karatau and Zhanatas (Kazphosphate LLP, EuroChem company, Talas Investment Company, etc.) are still based on a single specialization, that is, the mining industry. As a result, the environmental situation in these territories is aggravated. Over time, there is an increase in the area of terricons, anthropogenic changes in the terrain, the spread of water from open mines into the urban areas without treatment, and gross violations of environmental standards by companies.

This one-sided specialization is described as a limiting factor for the development of other areas. That is why it is necessary to get rid of dependence on raw materials and consider ways of effective use of natural resources. For example, the natural state of the territory where the cities are located allows the development of alternative energy sources. In addition to meeting the city's energy demand, this situation provides opportunities for efficient use of "future" energy.

In addition, for the ecological improvement of cities, it is necessary to create a natural and ecological frame consisting of basic and indirect elements. These solutions not only create a microclimate for local residents of the city, but also perform the function of sanitary protection. And, the spatial advantages of the town of Shu must be effectively used for export-import exchanges between macro-regions;

- Special attention should be paid to the best experiences of foreign countries, including the experience of Germany. Today, Germany is the only country that develops monoprofile towns as a center for innovative products. It becomes an example for the world by creating a multifunctional economy from a monofunctional economy. Here, diversification of the economy, the development of entrepreneurship, the formation of a favorable investment climate, the creation of a society based on science were considered as a solution to the monotown issue (Gurkov, 2016a). Of course, mutual relations between the authorities of the local municipality and business representatives can also be mentioned here. That is, quick and convenient solutions, local preferential taxes, minimums in the bureaucracy, support by the leadership for scientific developments were described as the "secret" of successful achievements. Chemical-pharmaceutical products (Leverkusen), production of wind generators (Magdeburg), software (Waldorf),

production of ordinary and premium class cars (Wolfsburg, Ingolstadt, Emden, Rüsselsheim), chemical technologies (Ludwigshafen), tailoring of branded clothes (Metzingen), meeting the needs of the global media industry (Gütersloh) – paved the way for the global success of small towns in Germany (Gurkov, 2016b). These achievements reveal that the concept of "monotown" is "obsolete" in Germany. That is, when considering the sustainable development of cities with a single economy, it is necessary to take as a basis the best models in world practice.

- as known from history, instability in the world market, relapse of the crisis situation – this requires the creation of scenarios of post-industrial development for cities. It should be based on the principles of sustainable development. *First*, to ensure economic growth while maintaining the environmental equilibrium; *second*, the balance of the economic and social spheres taken in the human dimension; *third,* to ensure the harmony of the urban community and future generations, not only in the present situation, but also taking into account the future.

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THE MAIN DEMOGRAPHIC PROBLEMS OF CITIES IN THE LOWER REACHES OF THE KURA RIVER IN AZERBAIJAN

Geo-demographic conditions and regulation of the development of an urban settlement in the lower reaches of the Kura River is a certain part of the sustainable socio-economic policy pursued in the Republic of Azerbaijan. There was a need to study the demographic conditions of cities for a more efficient territorial organization of production and population in the region. The article analyzes the formation and development of an urban settlement in the lower reaches of the Kura River, the dynamics of the level of urbanization in administrative districts. The creation and development of industrial zones in the lower reaches of the Kura River, the opening of new work places created conditions for the concentration of the population in cities along with regional centers, which in turn gave impetus to the development of cities. It was determined that more than 38% of the population, most of the industrial and socio- economic potential of the region are concentrated in 7 cities (Mingachevir, Yevlakh, Zardab, Sabirabad, Salyan, Shirvan, Neftchala). In 2021, the share of industry in the total volume of production in the main areas in the region increased to 25%. In the course of the research, the variability of the dynamics of the population of the cities for 1989-2021 was studied. As a result of the research, it was determined that the factor that played the most important role in the growth of the urban population in the cities of the region was natural growth. Thus, it was determined that 81.5% of the increase in the urban population of the region in the years under study was due to natural growth, and the rest – due to giving the settlement status to villages. The largest natural growth was noted in the cities of Sabirabad (165.12%) and Zardab (153.84%), where the main occupation is agriculture, and the smallest natural growth was in Mingachevir, the largest industrial city of the region (129.52%). As a result, appropriate recommendations were given to resolve the problems of the demographic development of cities located in the lower reaches of the Kura River.

Key words: population, urbanization, industry, natural growth, settling, employment.

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Әзірбайжандағы Кура өзенінің төменгі ағысындағы қалалардың негізгі демографиялық мәселелері

Геодемографиялық жағдайларды реттеу және Құра өзенінің төменгі ағысында қалалық елді мекенді дамыту Әзірбайжан Республикасында жүргізіліп жатқан тұрақты әлеуметтік-экономикалық саясаттың белгілі бір бөлігі болып табылады. Өңірдегі өндіріс пен халық санын тиімдірек аумақтық ұйымдастыру үшін қалалардың демографиялық жағдайын зерттеу қажеттілігі туындады. Мақалада Кура өзенінің төменгі ағысындағы қалалық елді мекеннің қалыптасуы мен дамуы, әкімшілік аудандардағы урбанизация деңгейінің динамикасы талданады. Кура өзенің төменгі ағысында индустриалды аймақтардың құрылуы мен дамуы, жаңа жұмыс орындарының ашылуы халықтың облыс орталықтарымен қатар қалаларға шоғырлануына жағдай туғызды, бұл өз кезегінде қалалардың дамуына серпін берді. Облыс халқының 38%-дан астамы, өндірістік және әлеуметтік-экономикалық әлеуетінің басым бөлігі 7 қалада (Мингачевир, Евлах, Зардаб, Сабирабад, Салян, Ширван, Нефтчала) шоғырланғандығы анықталды. 2021 жылы облыста негізгі бағыттар бойынша өндірістің жалпы көлеміндегі өнеркәсіп үлесі 25 пайызға дейін өсті. Зерттеу 1989-2021 жылдардағы қала халқының динамикасының өзгермелілігін зерттеді. Зерттеу нәтижесінде зерттелетін қалалардағы қала халқының өсуіне ең маңызды рөл атқарған фактор табиғи өсім екені анықталды. Мәселен, зерттеліп отырған жылдардағы облыстағы қала халқының өсімінің 81,5 пайызы табиғи өсім есебінен, қалғаны ауылдарға ауыл мәртебесін беру есебінен екені анықталды. Ең көп табиғи өсім негізгі кәсібі ауыл шаруашылығы болып табылатын Сабирабад (165,12%) және Зардаб (153,84%) қалаларында, ал ең аз табиғи өсім облыстың ірі

өнеркәсіптік қаласы Мингачевирде (129,52%) байқалды. Қорытындысында Құра өзенінің төменгі ағысында орналасқан қалалардың демографиялық даму мәселелерін шешу бойынша тиісті ұсыныстар берілді.

Түйін сөздер: халық, урбанизация, өнеркәсіп, табиғи өсім, қоныс аудару, жұмыспен қамту.

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Основные демографические проблемы городов в низовьях реки Кура в Азербайджане

Регулирование геодемографических условий и развитие городского поселения в низовьях реки Куры является определенной частью устойчивой социально-экономической политики, проводимой в Азербайджанской Республике. Возникла необходимость изучения демографических условий городов для более эффективной территориальной организации производства и населения в регионе. В статье анализируются становление и развитие городского поселения в низовьях реки Куры, динамика уровня урбанизации в административных районах. Создание и развитие промышленных зон в низовьях Куры, открытие новых рабочих мест создали условия для концентрации населения в городах наряду с районными центрами, что в свою очередь дало толчок развитию городов. Определено, что более 38 % населения, большая часть промышленного и социально-экономического потенциала области сосредоточены в 7 городах (Мингячевир, Евлах, Зардаб, Сабирабад, Сальян, Ширван, Нефтчала). В 2021 году доля промышленности в общем объеме производства по основным направлениям в регионе увеличилась до 25%. В ходе исследования изучалась изменчивость динамики численности населения городов за 1989-2021 годы. В результате исследования было определено, что фактором, сыгравшим важнейшую роль в росте городского населения в изучаемых городах, был естественный прирост. Таким образом, было определено, что 81,5 % прироста городского населения области в изучаемые годы произошло за счет естественного прироста, а остальная часть – за счет придания посёлочного статуса селам. Наибольший естественный прирост отмечен в городах Сабирабад (165,12 %) и Зардаб (153,84 %), где основным занятием является сельское хозяйство, а наименьший естественный прирост – в Мингячевире, крупнейшем промышленном городе области (129,52 %). В итоге были даны соответствующие рекомендации по урегулированию проблем демографического развития городов, расположенных в низовьях реки Кура.

Ключевые слова: население, урбанизация, промышленность, естественный прирост, расселение, занятость.

Introduction

The strengthening of integration trends between countries, the expansion of globalization processes, the strengthening of the role of social and environmental factors in economic development, the implementation of state policy in the field of demography require the solution of new tasks that have no analogues in the international community and in the regions. The twentieth century was marked by the growth of the world's population, the dynamics of socio-economic indicators, climate change, a decrease in biodiversity and a violation of the ecological system in the history of mankind. The history of the development of society has proved that the processes taking place in the economy and society are inextricably linked with environmental and socio-demographic problems. It is the definition of these relations and the creation of a socio-economic concept on their basis that is currently one of the most urgent problems. In this direction, scientists from different countries conducted multidisciplinary research (Brennan et all., 2005; Leetmaa et all., 2015; Nagiev and Efendiev, 2016; Meili and Mayer, 2017; Andersen and Nørgaard, 2018; Yelin and Pashin, 2019; Simagin et all., 2019; Ocejo et all., 2020; Semeko, 2021; Grossmann & Mallach, 2021; Wagner and Growe, 2021).

Quantitative and qualitative indicators related to the population and its structure are the main elements of national power, and, of course, issues such as protecting the gene pool of the Azerbaijani people, migration and demography are very important from the point of view of national security. In this regard, the development of the social sphere and human capital is one of the main priorities of the "Concept of Sustainable Development" (Demographic

development concept of the Republic of Azerbaijan, 1999: 2-3).

As a result of the socio-economic reforms successfully implemented in the Republic of Azerbaijan over the past 20 years, especially over the past 10 years, the demographic situation and average annual population growth in the country have improved, life expectancy has been extended and a positive migration balance has been achieved. In recent years, the population of Azerbaijan has increased rapidly and has exceeded 10 million people. In the past period, the growth rate of the rural population was higher than that of the urban population (Population of Azerbaijan, 2017:47-51).

Socio-economic reforms carried out in the Republic of Azerbaijan since 2003, sustainable macroeconomic stability, strengthening the system of social protection of the population, reducing poverty and improving the living standards of the population also had a positive impact on demographic development. During this period, as a result of the measures taken to improve the health of the population, there was a decrease in mortality, especially infant mortality, an increase in life expectancy, a decrease in the migration flow from the country, and there is a gradual transition to a positive balance of migration.

Demographic policy as part of the general social policy is currently of particular importance in the Republic of Azerbaijan. In this regard, in order to achieve the development of demographic processes in accordance with the socio-economic strategy of the country and improve the demographic situation, in 1999 the "Concept of the demographic development of the Republic of Azerbaijan" was adopted, on the basis of this, by the Decree of the President of the Republic of Azerbaijan dated November 11, 2004, " State Program in the field of demography and development of population resettlement" was approved (Demographic development concept of the Republic of Azerbaijan, 1999:3).

Although Mingachevir, Shirvan, Yevlakh and other cities of the region played a progressive role in the development of the country's economy, their positions in the development of urbanization were weak. For this reason, the region lagged far behind the national level in the development of natural growth in the period 1999-2022. To solve the problems that arise in the demographic development of urban areas, it is very necessary to conduct scientific analyzes and, based on their results, analyzes at the state level (Regions of Azerbaijan, 2018:521-527).

Materials and methods

The cities of Mingachevir, Yevlakh, Zardab, Sabirabad, Salyan, Shirvan and Neftchala located in the lower reaches of the Kura River in Azerbaijan, were taken as the object of the study, indicators of the demographic and socio-economic situation of these cities for 1989-2022 were collected and analyzed (Demographic indicators of Azerbaijan, 2018: 325-337; Population of Azerbaijan, 2017: 45-68; Regions of Azerbaijan, 2018:53; Statistical indicators of the regions, 2021:3-7).

The theoretical basis of the study is the methodological approaches used in scientific research by Hajizade (1965), Mekhraliyev (1988:128-131), Efendiyev (2015:93), Mamedov and Eyyubov (2016:382-387) and others working in the field of demographic research and economic geography. In the analysis of urban settling, historical, cartographic, mathematical-statistical, systematic analysis, comparison and other research methods were used.

Results and discussion

The emergence of cities and the expansion of their territory, the gradual increase in their population, the integration of rural settlements into the urban environment, the increasing role of cities in society, the formation of an urban settlement environment with its own way of life, the population of plants and animals suitable for the urban environment, the transformation of natural landscapes into cultural in conditions of ecological stress and the decline of nature comes from the content of urbanization.

The creation of cities located in the lower reaches of the Kura River, the development of urbanization and bringing to a modern state have come a long historical way. The modern structure of the economy in the regions of Azerbaijan, the creation of new settlements and the formation of a network of cities on their basis began in the 30s of the 20th century. In the process of industrialization, from this time on, along with large cities, cities located in the lower reaches of the Kura River and some industrial centers were created. The transformation of the cities of Mingachevir, Shirvan, Yevlakh and dozens of small settlements into cities created conditions for the creation and development of industrial areas in the regions and the concentration of the population in these settlements. These centers contributed to the gathering of the rural population in the cities along with the district centers, the urban population

increased rapidly. The development of these cities is based on the use of natural economic, social, scientific and technical opportunities. To increase the population in these cities, it is important to organize socio-cultural services, provide jobs, and use the recreational potential (Badalov, 2018: 214-217).

The dynamics of urban development and the size of the urban population have changed significantly over the years of independence. Population growth is the result of quantitative and qualitative changes in the population under the influence of social, economic and biological processes. An analysis of the dynamics of the urban population shows that their number in cities is constantly increasing. Despite this, some cities are sparsely populated. Due to a weak economic and social base, they cannot fully support the demographic potential on the ground. For a long time, the rural population in Azerbaijan was the main source of population growth in the country. The population rapidly increased due to the predominance of a large rural population and the high demand for labor for agricultural work (Eminov, 2005:137).

An analysis of the research data shows that as a result of the high natural increase that took place in the 60-70s of the twentieth century, conditions were created both for the rapid growth of the share of the urban population and for the formation of urbanization centers with an advantageous geographical position. For example, cities located in the lower reaches of the Kur River are formed on the basis of demographic, geopolitical and natural potential.

The main goal in urban planning is the adaptation of people to the urban environment by taking into account its geographical features. Of great importance is the improvement of the lifestyle of the population, which is a geographical feature of urbanization, the use of an appropriate economic and geographical position in intra-city passenger traffic, and free behavior in natural conditions. Effective, purposeful use of natural conditions, especially land plots, when placing residential apartments, public buildings, industrial enterprises and consumer services in urban planning projects, in the development of cities, gives the environment sustainability, beauty and a unique look. The development of the cities of Mingachevir and Shirvan, located in the lower reaches of the Kura River, is associated with the creation in the post-war period of hydro and thermal power plants, the oil industry and, on their basis, industries of national importance.

The cities located below the Kura River, which are part of the Aran economic and geographical region, have developed industrial regions. The main part of the industrial potential is concentrated in the cities of Shirvan, Salyan and Neftchala, located in the east, and Mingachevir and Yevlakh in the northwest. Oil and gas extraction, electric power industry, chemistry, production of building materials are developed and specialized industries in this region. Oil and gas are produced around the city of Shirvan, in the Salyan and Neftchala regions. State District Power Station operates in the cities of Mingachevir and Shirvan, and a Hydroelectric Power Station operates in Mingachevir. Mingachevir is an important energy base of the country. This economic region provides 60% of the electricity produced in the country (Efendiyev and Demirgayayev, 1995:93-97).

Chemical industry enterprises operate in the cities of Mingachevir, Salyan and Neftchala. There is a plastics plant in Salyan, and an iodine-bromine plant in Neftchala. The primary processing of cotton grown in the economic region is carried out at ginneries. This area provides the bulk of light industry products. In addition, there are enterprises for the production of cotton fabrics (Mingachevir), primary processing of wool (Yevlakh), carpet weaving (Hajigabul). However, serious problems arose in their activities. Therefore, the role of light industry is still low, it is important to restore its former role. Although the food industry has a sufficient raw material base, they are little used, and the network of processing industries is weak. There are many opportunities for creating enterprises in the field of fruit and vegetable and fish canning, processing of meat, milk and other livestock products. Agriculture in the studied areas is based only on irrigation. Cotton growing, dry subtropical fruit growing, and horticulture are specialized branches of agriculture. Cereals, grapes, potatoes, sugar beets, sunflowers, fodder crops are also planted (Efendiyev and Gasimova, 2013: 116-121). There are enough natural opportunities for the development of animal husbandry, with the help of which cattle and sheep are kept.

The Mingachevir agglomeration includes Mingachevir, the city of Yevlakh, the village of Khaldan along the left and right banks of the Kur River. The Mingachevir agglomeration, covering an area of 1370 km^2, is home to 106 000 people, with 761 people per 1 km^2 (Table 1).

Table 1 – Change in demographic indicators of cities in the lower reaches of the Kura River, for the period 1989-2022 (Population of Azerbaijan, 2017; Demographic indicators of Azerbaijan, 2018)

No	Names of cities	Area, thous. sq.km	Population, thousand people				Population density in 2022 (1 sq. km, people)	Growth during 1989-2022,%
			1989	1999	2009	2022		
1	Mingashevir	0,14	82,3	94,0	96,3	106,6	761	129,5
2	Yevlakh	1,47	92,1	108,2	117,8	131,0	89	142,24
3	Zardab	0,86	39.0	46,1	52,9	60,0	70	153,84
4	Sabirabad	1,47	110,1	139,9	151,7	181,8	124	165,12
5	Shirvan	0,07	59,8	65,5	77,1	88,2	1260	147,49
6	Neftchala	1,45	60,1	71,5	79,5	89,6	62	149,08
7	Salyan	1,60	93,2	112,0	121,9	141,6	89	151,93

According to the statistics of 2022, the population of the city of Mingachevir was 100.6 thousand people, which is 1% of the country's population. Compared with the all-Union census of 1989, the population of Mingachevir increased by 21 thousand people. The average population density of the city of Mingachevir is 719 people per 1 km^2, which is 7 times higher than the average population density in the republic (104 people per 1 km^2). Although Mingachevir, Shirvan, Yevlakh and other cities of the region play a progressive role in the development of the country's economy, their role in the development of urbanization was weak. For this reason, during 1999-2017. this region lagged behind the national level (Eminov 2005). During 2004-2013 the balance of migration in these cities as a whole is negative.

Dynamics of population growth in cities located in the lower reaches of the Kura River, for the period 1989-2022 presented on the graph (Figure) (Population of Azerbaijan, 2017; Demographic indicators of Azerbaijan, 2018).

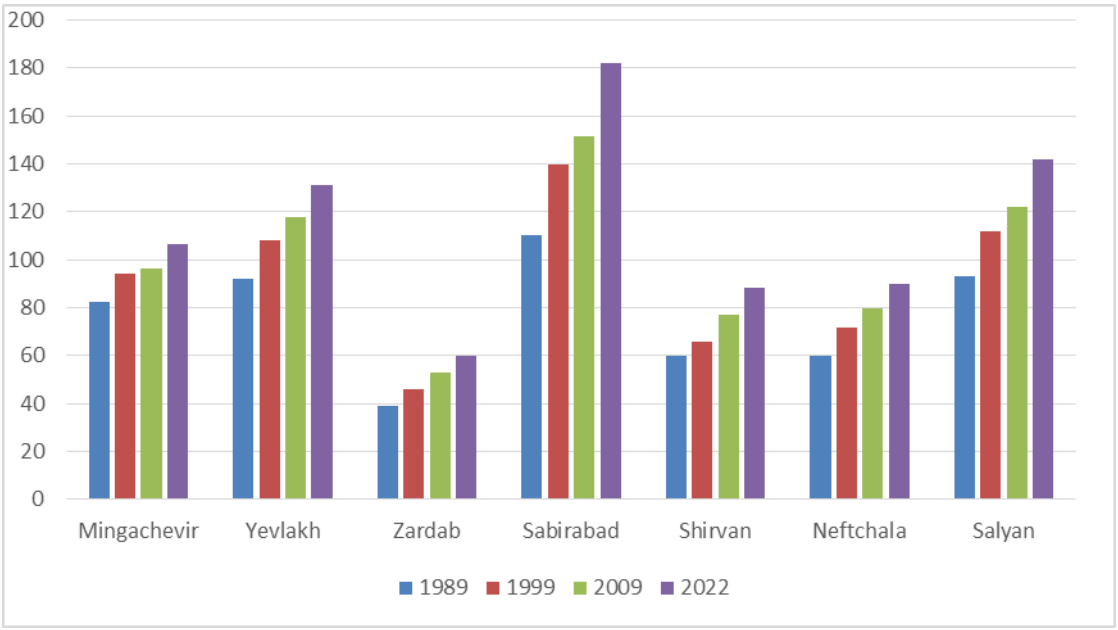

Figure – Dynamics of population growth in cities located in the lower reaches of the Kur River, for the period 1989-2022

As can be seen from the diagram, there is a gradual increase in the number and density of the population of the studied cities. Over the past 13 years, the largest natural increase occurred in the cities of Sabirabad and Salyan, and over 33 years, the largest population growth occurred in the cities of Sabirabad (165.12%) and Zardab (153.84%). It should be noted that since the number of industrial enterprises in these cities is small, the population is mainly engaged in agriculture.

The main goal of the state policy in the field of demography is to ensure the quantitative and qualitative growth of the population in accordance with the long-term development strategy of the country by eliminating negative trends in demographic processes (Badalov, 2017:34-39). One of the most important factors influencing the growth and decline of the country's population and changes in its structure is the health of people and their mortality (Badalov, 2019:41-48). The process of population reproduction is characterized by the excess of the number of births over the number of deaths by 2.5-3 times. The dynamics of the population determines its difference in natural growth, fertility and mortality.

The table below shows the change in 6-year (2015-2021) demographic indicators of cities located below the Kura River. It can be noted that as a result of the research, we see a decrease in the natural growth of cities located in the lower reaches of the Kura River in the period 2015-2021. So, in 2021, a sharp decline in natural population growth is observed in the cities of Mingachevir (-8.5%) and Neftchala (-7.3%), this is significantly lower than the national average (12.8% per 1,000 people).

The 2019 global pandemic also affected the population growth dynamics of cities in the lower reaches of the Kura River. During the Covid-19 pandemic, a significant economic effect was expressed in the morbidity and mortality of people (especially the working-age population), a decrease in the birth rate and, as a result, natural population growth, speed, life expectancy and other demographic parameters (Efendiyev and Demirgayayev, 1995:118).

The pandemic has had an extremely negative impact on the region's economy, including a decline in population. Statistical indicators that the number of deaths in 2019-2020 higher than in 2015 are reflected in the Table 2. If the natural increase in the city of Mingachevir in 2015 was 992 people, then in 2021 this figure was 126 people. We see that not only in the city of Mingachevir, but also in all cities located below the Kura River, the natural increase in 2021 is low.

One of the most important factors influencing natural population growth is marriages and divorce rates. As can be seen from Table 2, except for the city of Salyan, in all other 6 cities, a decrease in marriage rate and an increase in the number of divorces were recorded. If we look at the number of children who died before the age of 1, we can see that the number of child deaths has increased in Mingachevir, the main industrial city among the cities below the Kura River.

As you know, improving the socio-economic indicators of the regions leads to an improvement in the demographic situation. In this regard, the table reflecting the employment rates of the population of the cities of the lower reaches of the Kura River is of great importance. As can be seen from Table 3, over the past 7 years, the work carried out to improve the employment situation of the population living in these cities is not satisfactory, since the number of new jobs opened in all cities has sharply decreased. The worst situation is in the cities of Yevlakh and Sabirabad, the situation is relatively satisfactory in the cities of Shirvan and Mingachevir. The process of industrialization is most noticeable in the cities of Mingachevir, Shirvan and Yevlakh (Table 3).

The number of operating industrial enterprises in the city of Mingachevir in 2015 was 45, and in 2021 this figure decreased to 36. If we consider income from industrial products, the total value of production in 2015 was 266,653.8 manats (156,855.18 USD), and in 2021 – 359 348.8 manats (211,381.65 USD). In the field of agriculture for 6 years of 2015, the area of grain and leguminous plantations decreased by 72 hectares, the area of vineyards and melon crops increased. The economically active population in 2015 amounted to 57.7 thousand people, and in 2021 it increased to 61.2 thousand people. If in 2015 the number of new jobs in Mingachevir was 996, then in 2021 it decreased to 283.

There is an increase in the number of operating industrial enterprises in the city of Yevlakh (+9). In the field of agriculture in the territory of the city of Yevlakh, 10,190 hectares of grain and leguminous crops were sown in 2015, in 2021 – 12,131 hectares, an increase in sown areas is observed (table 4). The development of cotton growing influenced the growth dynamics in the Yevlakh region, in 2015 958 hectares of cotton were sown, and in 2021 this figure was 2328 hectares, which affected the employment of the population. The number of employed people in 2015 amounted to 60.6 thousand people, in 2021 – 64.6 thousand people.

Table 2 – Demographic indicators of cities in the lower reaches of the Kura River (Statistical indicators of the regions, 2021)

Cities / Population	Mingachevir		Zardab		Yevlakh		Sabirabad		Shirvan		Salyan		Neftchala	
	2015	2021	2015	2021	2015	2021	2015	2021	2015	2021	2015	2021	2015	2021
Population (thousand people)	102,4	106,6	57,1	60,0	125,7	131,0	170,3	181,8	84,0	88,2	133,5	141,6	85,5	89,6
Natural growth people	992	126	608	308	1116	407	2809	1501	980	190	1848	789	932	323
Fertility	1586	1066	954	689	1929	1564	3762	2625	1501	865	2613	1786	1427	984
Mortality	594	940	346	381	813	1157	953	1124	521	675	765	997	495	661
The number of children who died before the age of 1 year. people	17	21	10	8	18	12	37	14	16	7	31	15	12	8
Number of marriages	809	560	370	351	769	626	1341	1025	620	505	134	201	673	484
Number of divorces	229	247	45	78	146	243	97	197	124	182	1061	898	86	144
In % per thousand population														
Natural increase	9,7	1,2	10,7	5,1	8,9	3,2	16,7	8,3	11,8	2,1	13,9	5,5	10,9	3,6
Fertility	15,5	10,0	16,8	11,5	15,4	12,0	22,3	14,5	18,0	9,8	19,7	12,6	16,7	11,0
Mortality	5,8	8,8	6,1	6,4	6,5	8,8	5,6	6,2	6,2	7,7	5,8	7,1	5,8	7,4
For every 1000 population														
Marriages	7,9	5,3	6,5	5,9	6,1	4,8	7,9	5,7	7,4	5,7	8,0	6,4	7,9	5,4
Divorces	2,2	2,3	0,8	1,3	1,2	1,9	0,6	1,1	1,5	2,1	1,0	1,4	1,0	1,6

Table 3 – Employment rates of the population of the cities of the lower reaches of the Kura River (Statistical indicators of the regions, 2021)

No	Cities	Number of newly opened jobs		Number of industrial enterprises operating	
		2015	2022	2015	2022
1	Mingachevir	996	283	45	36
2	Yevlakh	1110	70	15	24
3	Zardab	435	31	5	7
4	Sabirabad	1133	29	10	16
5	Salyan	579	69	27	21
6	Shirvan	1115	437	37	30
7	Neftchala	1179	201	15	16

According to the number of industrial enterprises operating in the city of Zardab (7), it can be said that the population of this city is mainly employed in agricultural fields. In 2015, 153 hectares of cotton were sown in the nearby areas of the city of Zardab, and in 2021 this figure was 3,070 hectares. The number of employed people increased from 27.5 thousand people in 2015 to 29.3 thousand people in 2021. The number of new jobs opened was 435 in 2015 and decreased to 31 in 2021.

The number of industrial enterprises operating in the city of Sabirabad increased slightly by 6 units and became 16 in 2021. In 2015, in the field of agriculture, we see that agricultural activity in the surrounding areas of the city of Sabirabad is predominant, and the areas of arable land and perennial crops are expanding. The number of people employed in the labor market in 2015 amounted to 76.5 thousand people, in 2021 – 82.2 thousand people. The number of new open jobs was 1133 in 2015, and in 2021 this result has dropped sharply to 29.

We see that the number of industrial enterprises operating in the city of Salyan has decreased by 6 units. It is noted that cotton fields among agricultural crops have expanded dramatically (from 406 hectares to 6134 hectares), the number of new jobs was 579 in 2015, but in 2021 this figure decreased to 69. The number of people employed in the labor market in 2015 was 62,000 people, and in 2021 – 66,300 people, it is clear that this population is employed in agriculture. The number of new jobs was 27 in 2015 and 21 in 2021.

In 2015, the number of industrial enterprises operating in the city of Shirvan was 37, and in 2021 it decreased to 30. In general, it can be seen that the city of Shirvan differs from other cities located in the lower reaches of the Kura River in that its population works more in industrial enterprises than in agriculture, livestock breeding is also developed here. If in 2015 the number of new jobs was 115, then in 2021 this figure was 437. The number of people employed in the labor market in 2015 amounted to 42.2 thousand people, in 2021 – 44.4 thousand people.

In 2015, 15 enterprises operated in the city of Neftchala, and in 6 years only 1 new enterprise was opened. The population of this city works mainly in agricultural sectors, the cotton growing industry is developing, the area of which increased from 221 ha to 6949 ha. In 2015, 42,000 people worked in the labor market, in 2021 – 44,600 people. If in 2015 the number of new jobs was 1179, then in 2021 it dropped sharply to 201. At the same time, we note that Mingachevir and Shirvan are the most urbanized cities among the cities of the lower reaches of the Kura River.

Table 4 – Development indicators of agriculture in the downstream areas of the Kura River (Statistical indicators of the regions, 2021)

Cities	Mingachevir		Yevlakh		Zardab		Sabirabad		Salyan		Shirvan		Neftchala	
Agricultural indicators	**2015**	**2021**	**2015**	**2021**	**2015**	**2021**	**2015**	**2021**	**2015**	**2021**	**2015**	**2021**	**2015**	**2021**
agricultural plants														
arable land, ha														
Cereals and legumes	125	53	10190	12131	16884	19427	23528	26081	20111	17173	1	1	43778	40491
including winter and spring wheat	95	-	4469	6680	10365	13007	11907	14860	5692	5708			4620	5980
Cotton	-	100	958	2328	153	3070	1633	9260	406	6134			221	6949
Sugar beet	7	6	-	-	-	-	-	-	-	-			-	-
sunflower	19	16	295	489	-	1	10	15	-	12			114	147
Potato	-	-	232	134	116	210	1327	1393	421	411	5	5	122	142
Vegetables	78	102	530	503	152	205	3295	3438	1304	1501	60	61	140	85
melon plants	125	53	276	188	229	209	4146	3974	1120	932	1	3	588	602
Gardens and orchards	95	-	780	996	471	496	1631	2192	715	832	21	33	7	134
Vineyards	-	100	330	223			1	80	1187	1126	20	22	43778	40491
Number of animals, birds and bee colonies:														
Number of cattle, heads	2504	2314	68310	2314	54428	54862	116932	123263	62820	62751	2820	2565	42428	43528
Livestock of cows and buffaloes, heads	1404	1109	27834	1109	22828	22919	58199	61874	33351	33331	1340	984	21062	22452
Sheep and goats, head	4708	4440	181710	4440	112971	114818	211414	233040	186567	185993	15635	8750	132983	148662
birds, head	8397	7552	395430	7552	188782	195526	848992	1481417	659927	677733	175510	345203	910620	697249
Bee colonies, pieces	122	160	-	160	633	2147	100	2039	-	1456	-	-	-	99

Conclusion

The dynamics of the demographic situation of the 7 most populated cities (Mingachevir, Yevlakh, Zardab, Sabirabad, Salyan, Shirvan, Neftchala) located in the lower reaches of the Kura River has been studied. The database for analysis was taken from the 1989-2021 census data and statistical demographic indicators by years.

It was determined that, compared with previous years, there was an increase in the area, population and density of administrative-territorial units of cities located in the lower reaches of the Kura River. The most natural increase was observed in the cities of Sabirabad (165.12%) and Zardab (153.84%). The fact that the natural increase in the population of these cities is higher than in other cities can be explained by the fact that they are mainly engaged in various branches of agriculture (grain growing, horticulture, viticulture, cotton growing). Thus, a relatively low natural increase is observed in cities, the population of which is mainly employed in industrial sectors. (for example, Mingachevir (129.52%).

We believe that in order to regulate the problems of demographic development in the cities in the lower reaches of the Kura River, it is necessary to carry out continuous measures in the areas of employment, social protection, medicine and other areas, open new industrial parks in the cities of Mingachevir and Shirvan, expand urban areas in accordance with the new urban infrastructure, create new industrial areas in Yevlakh, Zardab, Sabirabad, Salyan, Neftchala, develop tourism, agriculture, country farms, processing industry.

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SOIL FERTILITY ASSESSMENT OF AGRICULTURAL LAND IN THE ALMATY REGION USING GIS TECHNOLOGIES

Being a strategically important and irreplaceable economic resource, today, agricultural land is the main source of raw materials for the agro-industrial complex. These features impose certain obligations on the state and land users to preserve the basic value of this category of land – its fertility. Taking into account the fact that Almaty region occupies an important place in the agricultural sector of the country, the effective use of agricultural land in providing food to the population of the territory remains an urgent problem.

Reducing the utilization of agricultural land may lead to the creation of negative processes and will contribute to the decrease of fertility in the future, excluding farmland from intensive farm turnover. In the article, there are assessed the state of soils of agricultural land in the Almaty region based on the global system of digital mapping of soils using GIS technology, and the issues of improving the rational use of agricultural land in the region are considered. Specifically, maps of the degree of soil density, the content of organic carbon in the soil, the acidity, and characteristics of the distribution of chernozem in this area were developed using GIS technologies and based on data from a digital relief model, as a result of which the lands of the district of the region are classified into three groups and the dynamics of the specific gravity of the lands are presented.

Key words: soil fertility, GIS, Almaty region, agricultural land, soil assessment.

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ГАЖ технологияларын пайдалана отырып, Алматы облысындағы ауыл шаруашылығы алқаптарының топырақ құнарлылығын бағалау

Стратегиялық маңызды және таптырмас экономикалық ресурс бола отырып, бүгінде ауыл шаруашылығы алқаптары агроөнеркәсіптік кешен үшін шикізаттың негізгі көзі болып табылады. Бұл ерекшеліктер мемлекет пен жер пайдаланушыларға жердің осы санатының негізгі құндылығы – оның құнарлылығын сақтау бойынша белгілі бір міндеттемелер жүктейді. Алматы облысының еліміздің ауыл шаруашылығы саласындағы маңызды орын алатынын ескерсек, аумақтағы халықты азық-түлікпен қамтамасыз етуде ауыл шаруашылығы мақсатындағы жерлерінің құнарлығын сақтап тиімді пайдалану әрқашанда өзекті мәселе болып қала бермек.

Ауылшаруашылық жерлерін пайдалануды азайту теріс процестерге әкелуі мүмкін және болашақта құнарлылықтың төмендеуіне, ауылшаруашылық жерлерін қарқынды ауылшаруашылық айналымынан шығаруға ықпал етеді. Мақалада ГАЖ технологиясын пайдалана отырып, топырақты цифрлық картаға түсірудің жаһандық жүйесі негізінде Алматы облысының ауыл шаруашылығы алқаптары топырағының жай-күйіне баға берілді, сондай-ақ өңірдегі ауыл шаруашылығы алқаптарын ұтымды пайдалануды жақсарту мәселелері қаралды. Атап айтқанда, топырақ тығыздығының дәрежесі, топырақтағы органикалық көміртектің мөлшері, қышқылдығы және осы аумақтағы қара топырақтың таралу сипаттамалары карталары ГАЖ технологияларын қолдана отырып және цифрлық рельеф моделінің деректері негізінде әзірленді, нәтижесінде облыс ауданының жерлері үш топқа жіктеліп, жердің үлес салмағының динамикасы ұсынылды.

Түйін сөздер: топырақ құнарлығы, ГАЖ, Алматы облысы, ауылшаруашылық алқаптары, топырақты бағалау.

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Оценка плодородия почв сельскохозяйственных угодий в Алматинской области с использованием ГИС технологий

Являясь стратегически важным и незаменимым экономическим ресурсом, сегодня сельскохозяйственные угодья являются основным источником сырья для агропромышленного комплекса. Эти особенности налагают определенные обязательства на государство и землепользователей по сохранению основной ценности этой категории земель – ее плодородия. Учитывая, что Алматинская область занимает важное место в сфере сельского хозяйства страны, сохранение и эффективное использование плодородия земель сельскохозяйственного назначения в обеспечении продовольствием населения на территории всегда остается актуальным вопросом.

Сокращение использования сельскохозяйственных угодий может привести к возникновению негативных процессов и будет способствовать снижению плодородия в будущем, исключению сельхозугодий из интенсивного сельскохозяйственного оборота. В статье дана оценка состояния почв сельскохозяйственных угодий Алматинской области на основе глобальной системы цифрового картографирования почв с использованием ГИС технологии, а также рассмотрены вопросы улучшения рационального использования сельскохозяйственных угодий в регионе. В частности, карты степени плотности почвы, содержания органического углерода в почве, кислотности и характеристик распределения чернозема на данной территории были разработаны с использованием ГИС технологий и на основе данных цифровой модели рельефа, в результате, которого земли района области классифицированы на три группы и представлена динамика удельного веса земель.

Ключевые слова: плодородие почвы, ГИС, Алматинская область, сельскохозяйственные угодья, оценка почвы.

Introduction

Agriculture is one of the main sectors of the economy of Kazakhstan, providing food and economic security as well as the labor potential of the country, particularly in rural areas and has historically been the backbone of Kazakhstan's economy (Tokbergenova, Kiyassova, and Kairova 2018). According to official data from the National Bank of the Republic of Kazakhstan, in January 2019, the gross output of agricultural products increased by 3.5% and amounted to 3.6 trillion tenge, of which the production of livestock products increased by 2.8% (National Bank of the Republic of Kazakhstan 2019).

During the period of agricultural enterprise reform from 1991 to 2005, the area of agricultural land in the country decreased by 136.2 million hectares. However, from 2005 to 2015, the area of agricultural land increased annually by 18.6 million hectares. The most valuable land for agricultural purposes (97.4% of arable land) is agricultural land, which includes 91.1% of irrigated land, 56.2% of perennials, 51.7% of fallow land, and 42.4% of hayfields, of which 33.6% is land that has been improved and 52.0% estuary irrigation (Tokbergenova, Kiyassova, and Kairova 2018).

However, despite the positive dynamics of gross agricultural output, the volume of production, in general, lags behind the growth rate of consumption and income, maintaining labor productivity and product competitiveness at a low level does not allow for increased production, which leads to a high share of imports in domestic consumption. Moreover, with the accession of Kazakhstan to the World Trade Organisation, the conditions for rising competition in international markets have enhanced.

Digital innovations fundamentally shift this outdated sector, as seen by the observations of developing countries such as the USA, Canada and Australia. Diverse data sources, such as modern geoinformation systems and the Internet of Things, contribute to a high produce without soil degradation and with efficient use of resources. Today, industrial Internet elements allow farmers to create automated farms with remote control. While maintaining quality, a well-developed logistics system and e-Commerce will enable even small farms to reduce the cost of delivering agricultural products to the final consumer. This is an essential factor in preserving and expanding the production of environmentally friendly products, both from the perspective of safeguarding the nation's health and of realizing its export potential (The state program "Digital Kazakhstan").

Today, the share of agricultural producers of the Republic of Kazakhstan using digital technologies in agriculture is insignificant, which limits the reduction in productivity and costs. In addition, agricultural land is not used for its intended purpose or is used inefficiently, and this is hampered by the low density of a large territory, the population and the lack of the necessary infrastructure for monitoring the condition and use of land, analysis and forecasting in the short and long term. For this reason, the economic assessment of agricultural land is relevant. The use of modern information approaches in the land assessment will improve the quality of work and is a powerful tool for decision-making and management of government decisions. The results of the joint use of GIS technologies and economic assessment methods will help to obtain timely and accurate information about changes in agricultural production, and changes in the level of land fertility by type and degree of degradation.

Special mention should be made of the FAO framework guidelines on agricultural land use, agroecological zoning and land assessment, as well as the long-term work on the creation and development of an international database and GIS. In the context of the accelerated growth of informatization and globalization of agricultural production, the global trend towards increasing economic unification, technological unification and functional refinement of information and analytical support for agroecological assessment of lands at various territorial levels is reflected. Spatio-temporal change in land use and quality has contributed to the development of the concept of agroecological land assessment: its algorithms, regulatory framework and assessment technology are constantly being improved, as its tasks and capabilities are specified from the local to the regional, district and economic levels (Kiryushina V.I. and Ivanov A.L. 2005). Land assessment studies require a large amount of spatial data easily and efficiently processed by geographic information systems (GIS). Therefore, many researchers use GIS to assess land as a process that allows combining many attributes and different criteria involved in decision-making (Davidson, Theocharopoulos, and Bloksma 1994; Malczewski 2006). Land assessment can be considered as a multi-element decision analysis (MCDA) process (Joerin etc. 2001) which together with GIS can become a powerful approach to land assessment (Aldababseh, etc. 2018).

Local, regional, national, and worldwide uses of GIS technologies for agriculture have increased significantly during the past three decades. Typically, these applications entail the use of GIS in conjunction with partner technologies like as remote sensing, GPS, and data analytics to get an in-depth understanding of a certain farm or region and to provide intervention or corrective actions for crops and/or soils (Ghosh, Kumpatla 2022).

GIS methods play an indispensable role in spatial analysis, and multi-criteria decision analysis (MCDA) provides a rich set of tools for structuring decision-making problems as well as evaluating and prioritizing alternative solutions (Davidson, Theocharopoulos, and Bloksma 1994).

Over the past decade, the agrarian sector of the economy in the Almaty region has been reformed based on a developed legislative framework that encourages the growth of market relations by incorporating international experience. Consequently, a land market was established, crop production expanded, and the number of livestock in animal husbandry grew. The examination of the state of the agricultural industry revealed, however, that the extremely low level of introduction into production of modern technologies for processing agricultural products and scientifically proven agricultural technologies is the primary reason for this industry's low profitability. Obviously, this decreases the competitiveness of domestic products on domestic and international markets.

Against the backdrop of the region's major achievements, the problem of contradictions between the actual agricultural production sector and scientific research is currently manifesting itself. The yearly fluctuation of the agricultural products market and the increasing demands for its competitiveness necessitate the introduction of new research into the agricultural science of the region's agricultural production.

Materials and methods

The work of prominent domestic such as Tazabekov T., Gnezdilov L., and Lyubchak M., and international researchers in the field of qualitative and economic evaluation of land serves as the conceptual and methodological foundation for this study. In the process of determining the level and trends of agricultural land use, improving and assessing their quality, the following methods were used: empirical methods (observation, comparison), as well as economic and statistical methods (statistical grouping, tabular and graphical methods) and cartographic methods using the ArcGIS PRO 2.4 software.

ArcGIS is a collection of software products used to develop a geographic information system. It is utilized for the creation, management, integration, analysis, visualization, and presentation of spatial data. ArcGIS software products enable the use of GIS in all areas where functionality and business logic are required, including desktop, server, client, web-based, and mobile applications.

When evaluating the agricultural lands of the Almaty region and mapping all the data about the region, it will be very beneficial to use the desktop GIS included in the ArcGIS PRO 2.4 software package. This is due to the fact that ArcGIS PRO is an application comprised of ArcView, ArcEditor, and ArcInfo that provides a group of programs with suitable functions, general operating principles, and a unified interface, as well as functions that allow to work several times faster and more efficiently than the ArcMap application.

The information basis of the study is reports and consolidated reports of the Ministry of Agriculture of the Republic of Kazakhstan, recommendations of research organizations, and statistics of the Department of Land Relations of the Almaty region.

Almaty region is in the southeast of the Republic of Kazakhstan. In the East, the region borders the People's Republic of China, and in the South with the Republic of Kyrgyzstan (Chui and Issyk-Kul regions). The region has a rather complex geographical characteristic and a very diverse terrain. According to official data from the Department of land relations, as of the first quarter of 2020, the region's land resources amounted to 22 million 357 thousand hectares, 8 million 632 thousand hectares of agricultural land, including arable land – 1 million 056 thousand hectares, irrigated arable land – 480 thousand hectares, perennial plantations – 29 thousand hectares, deposits – 120 thousand hectares, hayfields – 458 thousand hectares, pastures – 13 million 744 thousand hectares, gardens and homesteads – 5356 hectares (Website of Akimat of Almaty region n.d.).

Results and Discussion

The qualitative state of soils in large areas in the Republic is complicated by the presence of signs that negatively affect their fertility. According to the Republic of Kazakhstan's 2020 annual consolidated analytical report on the state and use of lands, to take into account the quality of agricultural land, the following reclamation groups have been adopted, uniting soils with the general orientation and nature of reclamation measures:

I – uncomplicated by negative signs; II- highly rubbled; III– salted; IV – saline; V– washed away; VI – deflated; VII – subject to water and wind erosion together; VIII – waterlogged; IX – swampy; X – others (Bimendina G.A. et al. n.d.).

Agricultural lands of the Almaty region are classified in the second category according to the state of soil quality. The gravel group includes areas with weak soil, undeveloped, thickets of rocks, and others. The total area of the Republic is 43.1 million hectares or 20.0% of agricultural land, in the Almaty region – 2.7 million hectares.

Let's evaluate the current state of the soil in the Almaty region based on the database of soil networks obtained as a result of joint work of the Food and agriculture organization of the United Nations and the Kazakh Research Institute of soil science and Agrochemistry.

The Soil network (Soil Grids) is a global digital soil mapping system that uses modern machine learning methods to map the spatial distribution of soil properties across the globe. Soil grid forecasting models are constructed from the database of the world soil information service and several ecological covariates under the control of more than 230,000 soil profiles (Pikovskaya O. 2017).

The level of soil density in the region. The soil density is the most important characteristic that reflects the conditions under which plants grow and develop. All soil regimes depend on soil density: air exchange, water permeability, water capacity, heat capacity, microbiological, and redox processes. In addition, it affects the technological properties, and quality of soil treatment, which affects the volume and quality of products.

The main causes of soil compaction are:

- high degree of plowing;
- application of intensive tillage;
- failure to observe crop rotation during crop rotation;
- Insufficient amount of organic fertilizers applied to the soil (Pikovskaya O. 2017).

A map of the degree of soil compaction in the region is shown in Figure 1.

As can be seen from the map, even at depths of 2 m and 0.05 m, the soil density in the mountainous and foothill areas of the region is significantly lower than in the plains. The territories with the highest degree of soil compaction include the lands of the northern part of Raiymbek, Uyghur, Zhambyl, Sarkand, Koksu, and Karatal districts. The soil density of these territories is approximately 1.8 g / cm^3.

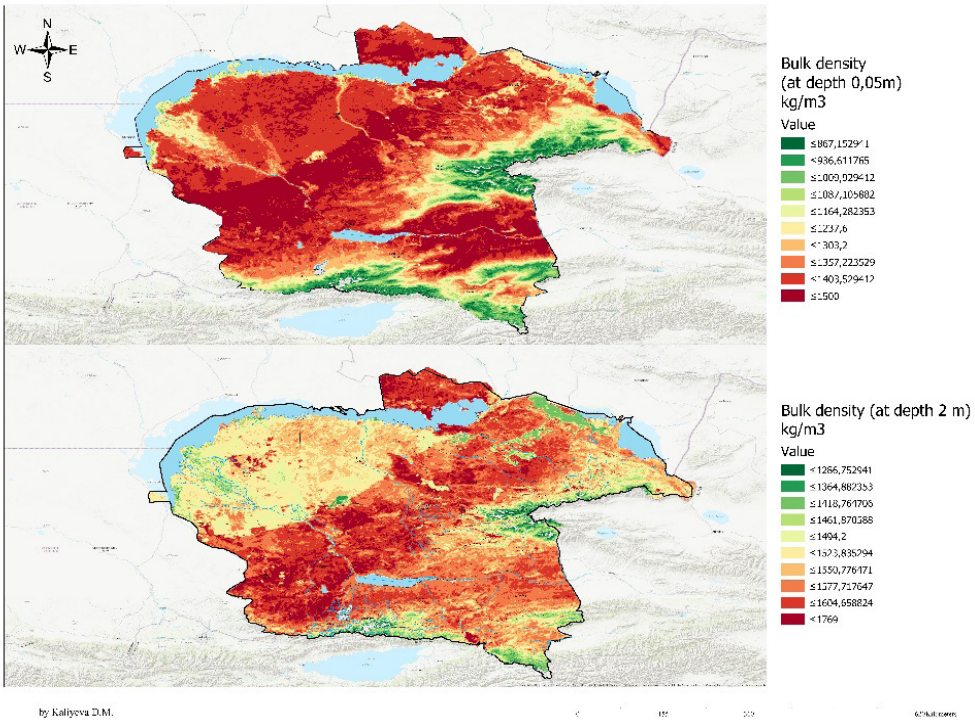

Figure 1 – The density map of the soils of the Almaty region (at a depth of 0.05 m and 2 m)

During soil compaction, the following occurs:

- increasing the actual weight of the soil;
- reduction of General and especially non-capillary porosity;
- slows down the growth of the root system-reduces the total mass of roots and prevents root penetration into the soil and subsoil;
- reducing the supply of moisture to plants;
- deterioration of the physical properties of water: water capacity, level of irrigation water absorption, reduced water permeability;
- deterioration of aeration and biological processes;
- increase in surface flows and thin ground runoff;
- deterioration of soil nutrition;
- processes such as reduced productivity and quality of agricultural products (Pikovskaya, 2017). High-density soils include loamy, swampy soils. In addition, this type of soil is poorly permeable to water and does not form a well-developed capillary system, resulting in plant roots having difficulty obtaining the moisture necessary for their life. However, when collecting water, loamy soils do not direct it to the lower layers but accumulate in the breeding zone of plants, which leads to disruption and destruction of the root system. The weight of clay in the soil of the region (Fig. 2) is from 15 to 39% of the global soil network (Boekel 1963).

It is known that depending on the mechanical components of the soil are divided into clay, sand-clay and sand. The mass fraction of sand in the soil of the region ranges from 29 to 70 percent. In the above figure, clay soils are distributed mainly in the South-Western, Central and North-Western regions of the region, soils with a 50-70% share of sand are distributed on the lands of Balkhash, Zhambyl, Kerbulak, Enbekshikazakh, Rayimbek districts (Fig. 3).

Organic carbon in soil (carbon in soil organic matter) is critical for soil health, fertility, and ecosystem maintenance, including food production, which places great importance on its conservation and restoration for sustainable development.

High-carbon soils are highly productive and allow the filtering and purifying of water. Poor land-use results in increased soil density, as well as loss of organic matter in the soil/loss of carbon and greenhouse gas emissions (FAO 2020).

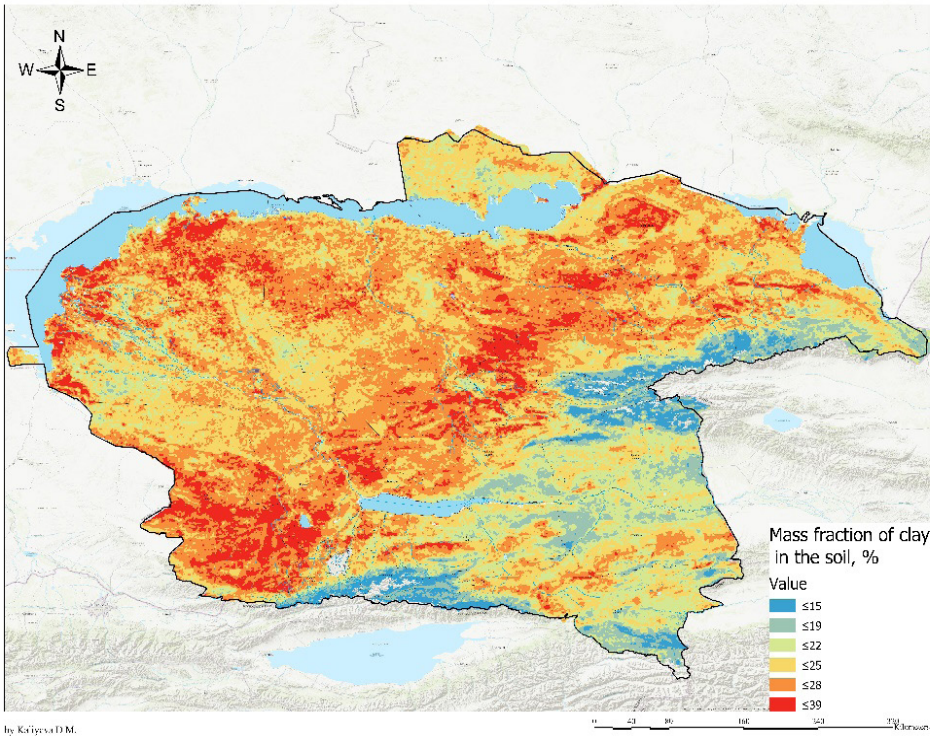

Figure 2 – Mass fraction of clay in the soil of the region, %

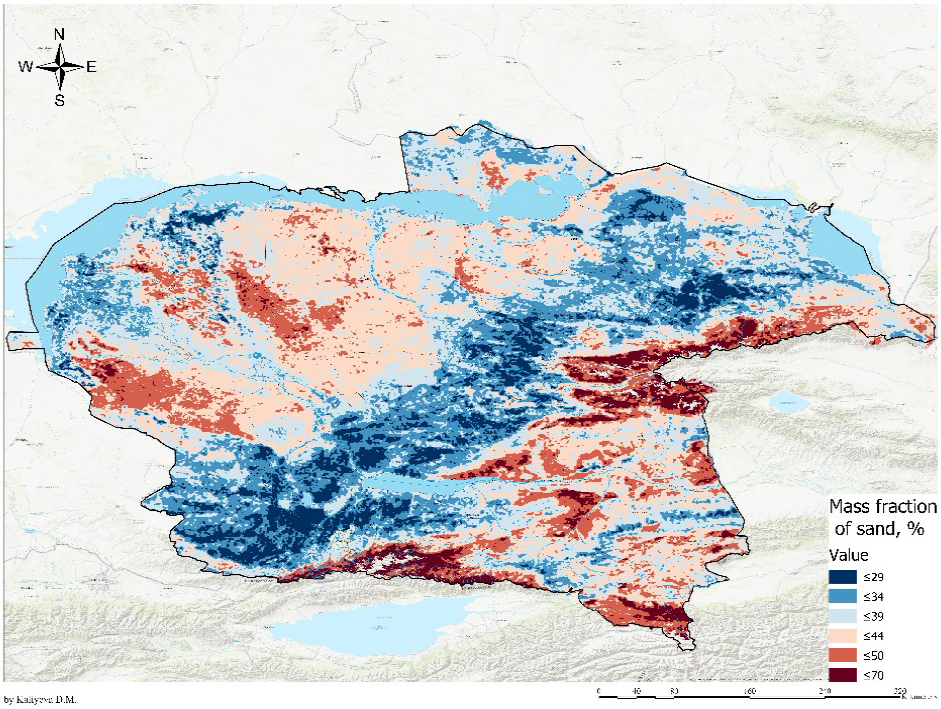

Figure 3 – Mass fraction of sand in the soil of the region, %

Below is a map of organic carbon in the region's soil (Fig. 4). As indicated above, the amount of compacted soil is small in mountainous and foothill areas, where, on the contrary, the organic carbon content is high in river and mountain soils.

Today, the main indicator of effective use of arable land is closely related to the annual yield of crops grown in the regions. Crops grown in the region are distributed unevenly, that is, not all 17 districts have the same types of crops, which, in turn, depends on the natural and climatic characteristics of the region, as well as on the physical and chemical properties of the soil. Among the chemical properties of the soil acidity plays a significant role. For example, let's talk about the features of sugar beet sowing.

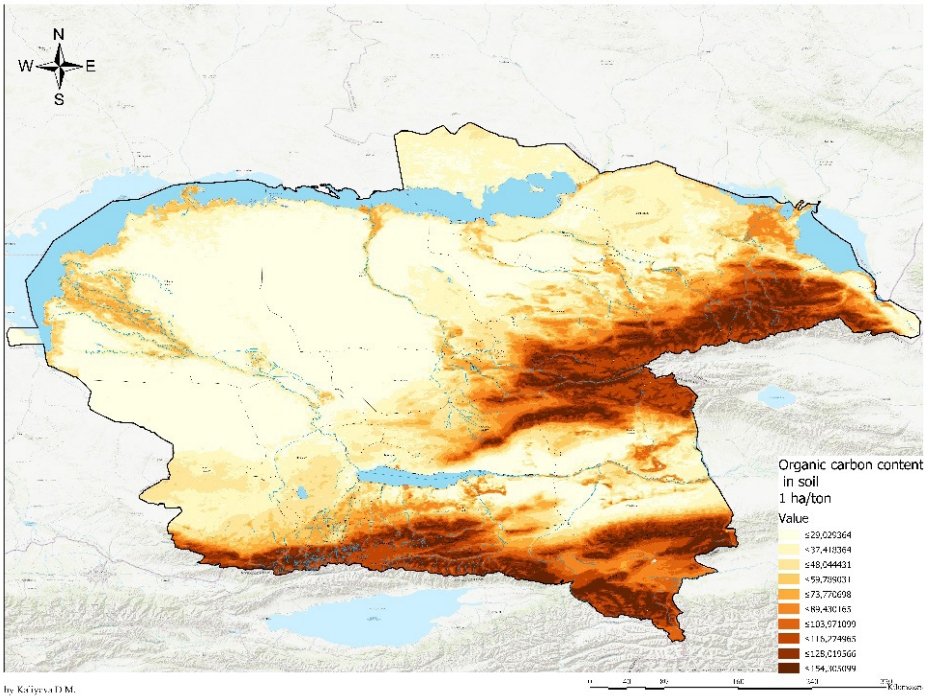

Figure 4 – Map of organic carbon content in the soil, ha/ton

Nowadays, more than 440 thousand tons of products are sold in the Almaty region alone. However, according to official data, currently, products collected from all over the country can not meet even half of the total demand. This factor forces buyers to buy raw materials from abroad, which puts us at the top of the world's list of major importers of sugar beet. The list of requirements for sugar beet indicates that the soil acidity should be 6-7 (Velyamov et al. 2020). In addition, even though the crop is resistant to salty soil, it grows well on weak, drainage, aerated ground soils with a large mass of nutrients, – representatives of Kazakhstan industrial chemistry and a company specializing in the sale of products for the agricultural sector note. Therefore, for the yield to be high, it is necessary to pay special attention to the acidity of the soil (Fig. 5).

If the pH value is less than 6, it will be acidic soil and in alkaline soils – the pH will be more than 7.0. As noted above, the most effective indicator for sugar beet is the middle of these two values. A significant deviation in both directions leads to a decrease in productivity, mainly to the death of plants. Acidic soil contributes to rotting and damage to the core and nutrition disorders. Alkaline soil disrupts the absorption of many minerals and reduces the formation of chlorophyll. Plants form weak roots, and leaves often turn yellowish (Dedov A.V., Nesmeyanova M.A., and Khryukin N.N. 2018).

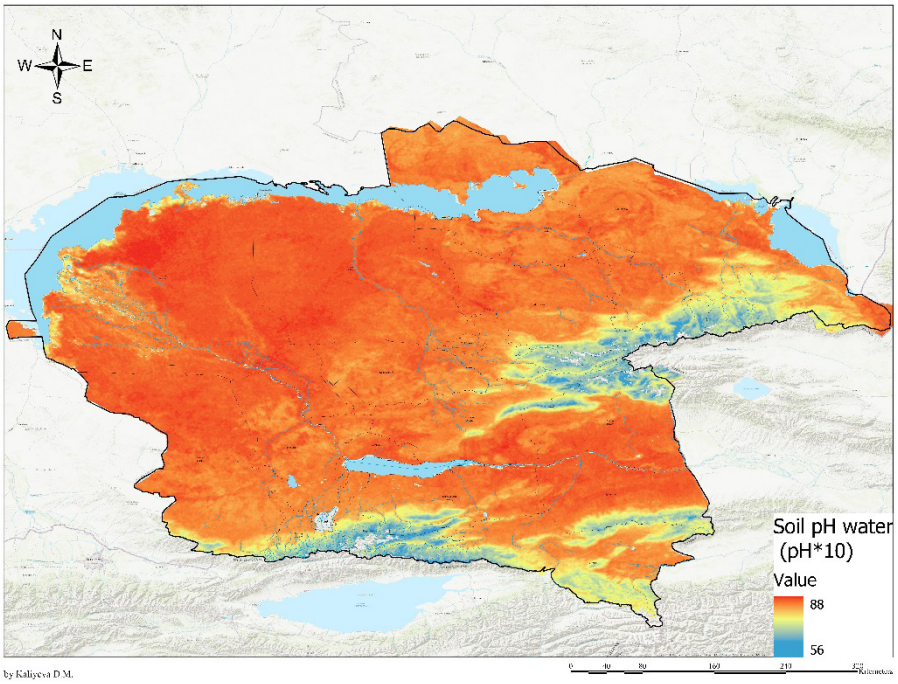

Figure 5 – Map of soil acidity

In the Almaty region, there are a few districts that grow beets Eskeldi, Koksu, Karatal, Aksu, and Sarkand. In this regard, it should be noted that in this map of soil acidity indicators of land in this area are ambiguous. So, in the map given above, the soil acidity of the Koksu district at a depth of 2 m is 7.6, and in the Aksu, Sarkand and Karatal districts, a significant area shows an acidity of 7.6 to 8.7. It can be noted, that the Eskeldi district has an inherent acidity of 5.6-6.4 indicators.

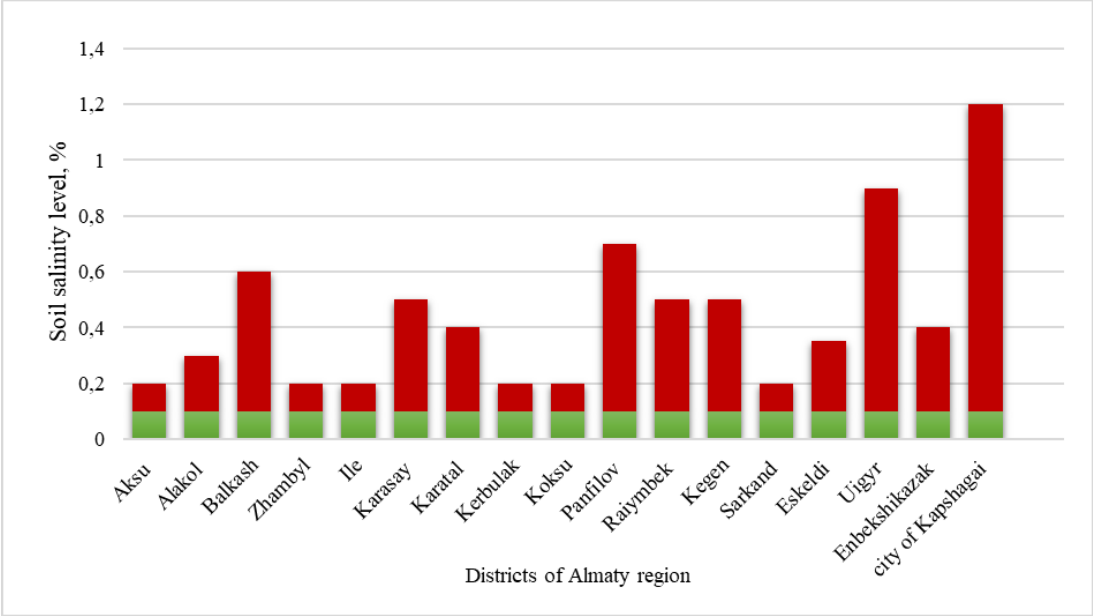

Figure 6 – The level of salinity of soils in the districts of the Almaty region, %

In the statistical data provided by the Department of land relations of the Almaty region, the level of soil salinity by the district is different for each district (Fig. 6). In particular, the level of salinity (0.1%) is observed in the lowest areas in the farmlands of Aksu, Ile, Zhambyl, Kerbulak, Koksu and Sarkand districts, the highest in Kapchagai (1.1%), Uigyr – about 0.8%, Panfilov – 0.6% and Balkash district (0.5%) (Report of the mayor of Almaty region for 2019, 2020).

Special attention should be paid to calcium as an element that affects the ratio of H+ and OH-ions, which regulates the acidity of the total soil solution-pH. One aspect of the ecological relationship between soil and plants depends on the amount of calcium in it. In addition, the role of calcium in the formation of the earth's crust and the life of biological organisms allows us to consider it one of the most important elements in nature. Humus compounds enriched with calcium ions have a black color, which well withstands the sun's rays, which contributes to increasing the heat capacity of the soil and also favorably affects the growth and distribution of heat-loving plants in them (Rahman et al. 2018). In the Almaty region, the area of calcian chernozems is not very large. As the area of these soils, we can distinguish the lands of the Raiymbek district, the riverbanks of the Balkhash district and a significant part of the lands of the Kerbulak, Aksu, and Alakol districts (Fig. 7).

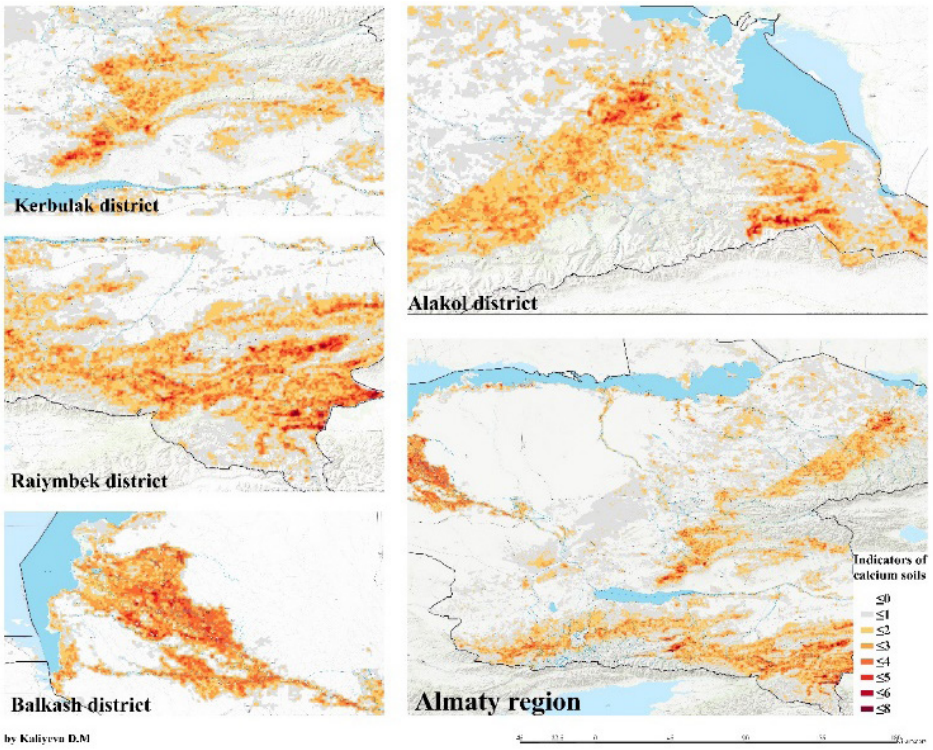

Figure 7 – Map of the area of calcium chernozems in the region

Based on the conducted research, the agricultural lands of the districts were classified and considered into 3 groups depending on the level of soil quality degradation:

- complicated – 40-60 %;
- satisfactorily – 20-40 %;
- sustainable – 0-20%.

The main indicators of the state of land resources and priority areas of land degradation in the districts of the Almaty region are shown in table 1 and figure 8. As a result of this classification, Aksu, Balkhash, Kerbulak, Koksu, Eskeldi, Zhambyl, Sarkand, Ile and Talgar districts were classified as group I (complicated).

As can be seen from the above graph, about 50% of the farmland of each district that is part of group 1 is more susceptible to severe degradation. The main areas of land quality degradation are shown in table 1 below.

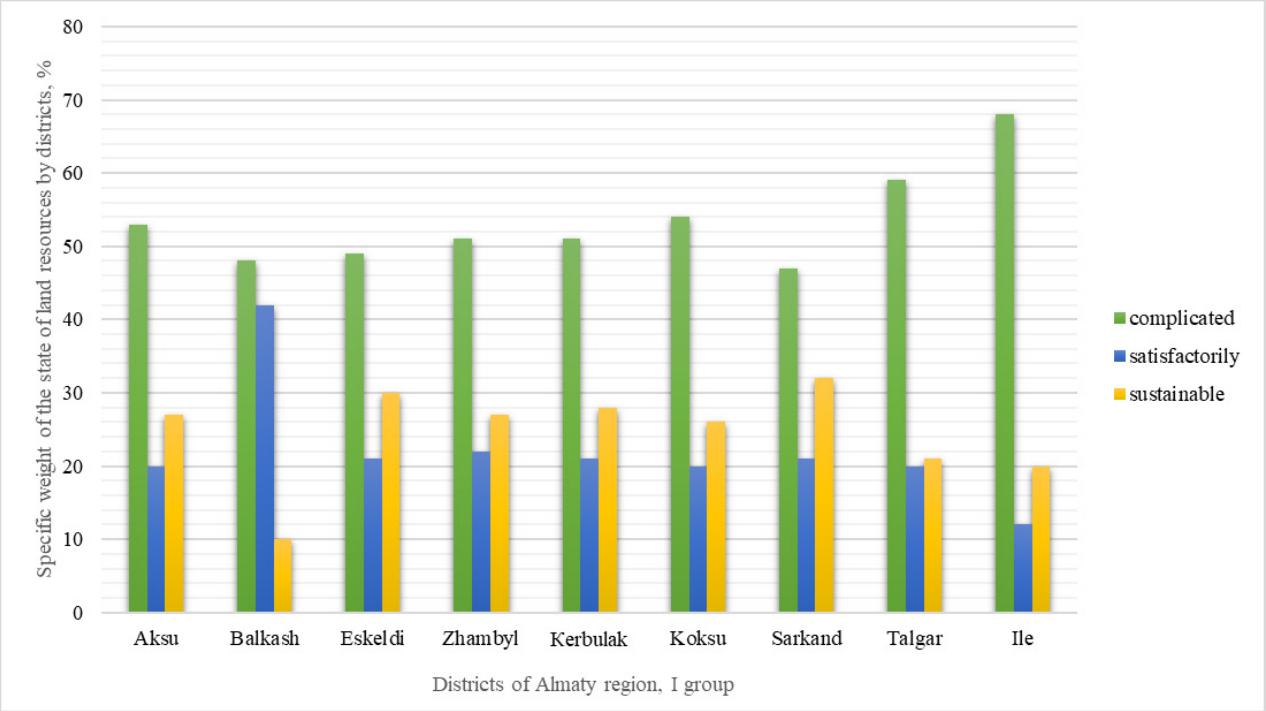

Figure 8 – The specific weight of the state of land resources by districts, % (group I)

Table 1 – Indicators of the state of regional district's land resources, the group I

Name of district	The main directions of agricultural land quality deterioration
Aksu	the degradation of grasslands, soil erosion (wind, water)
Balkhash	pasture degradation, soil erosion, weeding of saxaul forests.
Eskeldi	soil erosion, pasture degradation, felling of trees
Zhambyl	pasture degradation, soil degradation, soil erosion
Kerbulak	pasture degradation, soil erosion
Koksu	pasture degradation, soil degradation, soil erosion
Sarkand	pasture degradation, soil erosion
Talgar	soil erosion, pasture degradation
Ile	soil erosion, pasture degradation

The second group (satisfactorily) includes Alakol, Karasay, Enbekshikazak and Karatal districts. The main areas of deterioration of agricultural land and the share of the total land situation are shown in table 2 and figure 9 below.

The third group (with the sustainable state of land resources) includes relatively Panfilov, Raiymbek (Kegen), and Uyghur districts of the region located in mountainous areas (table 3, Fig. 10).

Table 2 – Indicators of the state of regional district's land resources, group II

Name of district	The main directions of agricultural land quality deterioration
Alakol	soil erosion, pasture degradation
Enbekshikazak	pasture degradation, felling of trees
Karasay	soil erosion, pasture degradation, felling of trees
Karatal	soil erosion, pasture degradation, felling of trees

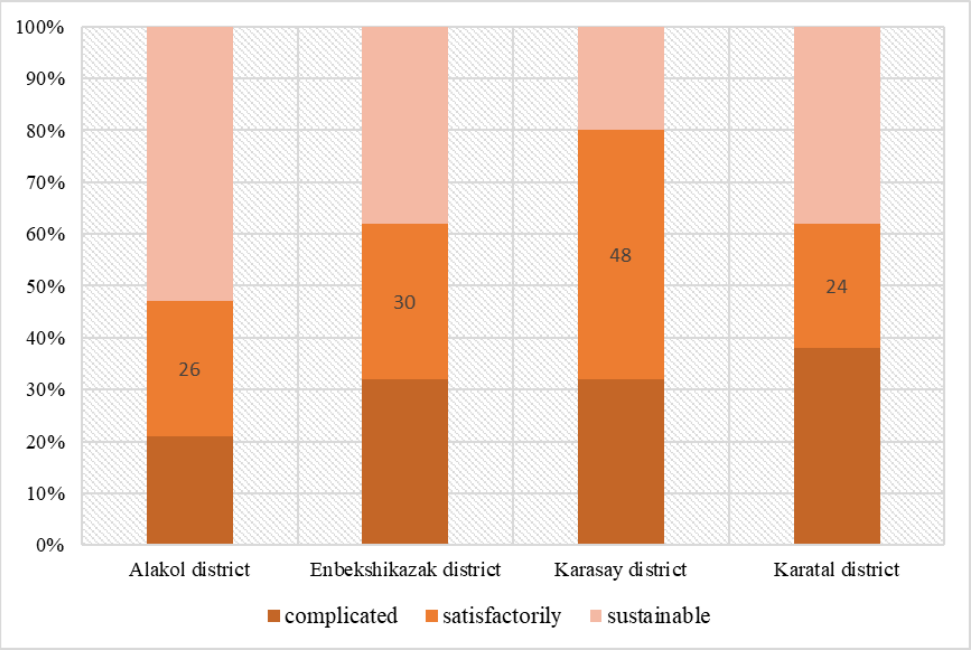

Figure 9 – Specific weight of the state of land resources by districts, group II, %

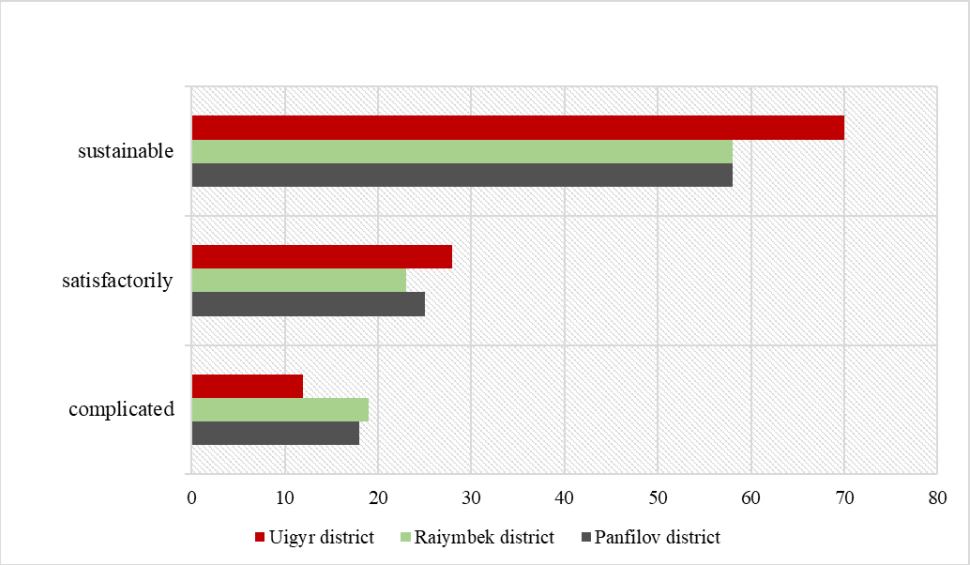

Figure 10 – Specific weight of the state of land resources by districts, group III, %

Table 3 – Indicators of the state of regional district's land resources, group III

Name of district	The main directions of agricultural land quality deterioration
Panfilov	pasture degradation, soil degradation soil erosion
Raiymbek	pasture degradation, soil erosion
Uigyr	soil erosion

According to research, the fertility of arable land is reduced because farmers in the districts of the Almaty region do not pay attention to the importance of increasing soil fertility. Land degradation damages the agriculture of the districts. The damage caused by the withdrawal of arable land from agricultural turnover is reflected in 3 directions.

→ Damage to agriculture: the quality of crops is deteriorating; there Will be additional costs associated with the development of new land due to missed production. As a result, the area of arable land will be reduced, and the tendency of soil to the environmental crisis will increase.

→ Environmental and economic damage to the social environment – as a result of land degradation, the local natural balance is disrupted, the number and type of diseases in the population increases, and life expectancy decreases (Molzhigitova D.K. 2014).

→ Environmental and economic damage-additional costs to increase the fertility of low-yielding land.

In the Almaty region, the soil of land withdrawn from agricultural turnover is classified into 4 main groups: grey; light brown; black; red-brown. There are 4 reasons for the withdrawal of arable land from agricultural turnover:

- unused vacant land;
- land allocated for other industries;
- contaminated land;
- various eroded lands.

According to the official data of 2019, the area of land that was withdrawn from circulation in the region was 120,552 ha, for some districts it looks as follows (Fig. 11): Aksu – 16820 ha; Alakol – 3345 ha; Eskeldi – 2652 ha; Zhambyl – 9496 ha; Kerbulak – 11848 ha; Koksu – 11991 ha; Karasay – 7242 ha; Karatal – 1403 ha; Panfilov – 1348 ha; Raiymbek – 13301 ha; Kegen – 1566 ha; Sarkand – 6515 ha; Talgar – 1142 ha; Uigyr – 1063 ha; Ile – 12447 ha; cities of Kapchagay – 18306 ha and Tekeli – 89 ha ('The Report of the Akim of Almaty Region to the Population on February 19, 2020' n.d.).

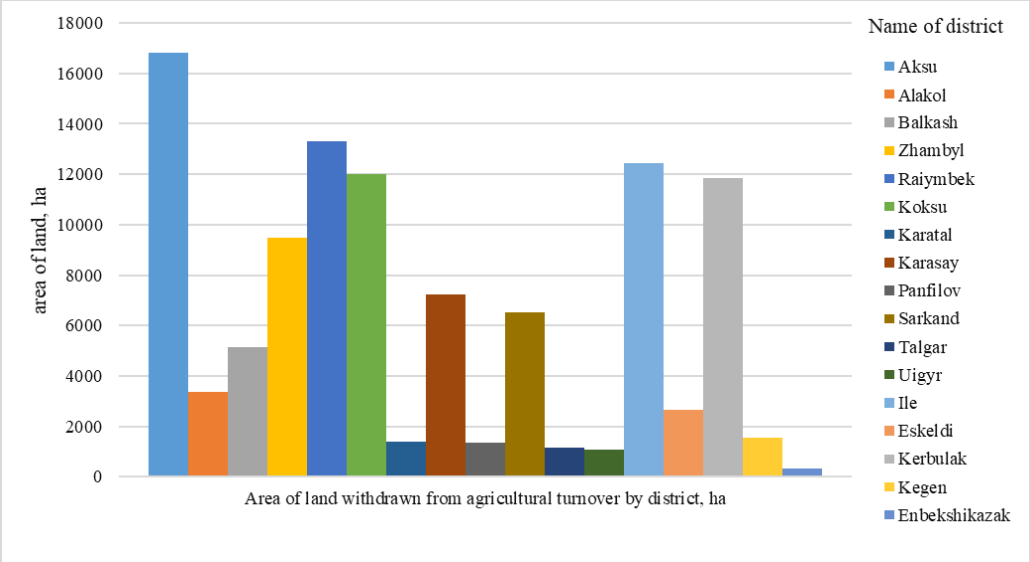

Figure 11 – The area of land withdrawn from circulation in districts, ha

Today, the introduction of land is one of the priorities and strategic tasks of agricultural production in the region. In turn, untimely and incorrect land development is one of the factors that lead to deterioration of the quality of agricultural land in General, a sharp decrease in soil fertility. The prevention of such cases is, of course, part of the functions of special state bodies. The state, as the owner, independently exercises state control and protection of land use. State control is a previously structured and well-developed institution for regulating land relations. At the same time, state control, being an integral activity of the state administration, is aimed at achieving the goals of management, and solving the tasks facing the state (Saimova S.A. 2020).

At present, state control over land is the most effective measure. However, in some parts of the country, the requirements for the correct and efficient use of land specified in the law are now completely ignored. This, in turn, leads to the opinion that state control is not carried out to a significant extent, while it is not carried out in all conditions of land use and the controlling authorities do not fully cover the totality of land relations. At the same time, it can be assumed that a system of public land control was introduced to achieve high results in the effective use and protection of land, as well as to prevent and mitigate legally harmful effects of land. Public control is characterized by the prevention of violations in the sphere of executive power through the use of measures of public influence. Public control, like state control, is based on a legal basis. The advantage of this proposal is that the State responds quickly, which in turn guarantees minimal damage to land users (Saimova S.A. 2020).

The high percentage of unused land, the negative dynamics of the main acreage of crops, and the growth of shrubs and ponds on the land indicate the need for measures to improve the quality of land resources and involve highly productive agricultural land in the turnover. When solving problems of land use in agricultural production, it is necessary to take into account natural and climatic, soil, spatial conditions and economic feasibility, labor resources and other factors (Iovlev, Goldina, and Zorkov, 2020).

The introduction of unused land plots into agricultural circulation will increase the area of agricultural land. An increase in the area of the developed land will increase crop productivity, which has a positive impact on the provision of food to the population. The introduction of large areas of land into agricultural circulation will not only ensure employment of the population of the region but also increase investment interest in the region and contribute to increasing the incomes of the population. Thus, the full use of arable land will have a positive impact not only in the field of agriculture but also in other sectors of the national economy (Zhelyaskov A., Denisova N., and Seturidze D. 2014).

Conclusion

Today, the main condition for the sustainable development of the agro-industrial complex is the preservation, cultivation and effective use of land. Therefore, improving soil fertility of agricultural land, without loss and effective use of land, is a prerequisite for management decisions. Geographic information systems, as the basis for combining various data and information based on a spatial component, are the main element for making administrative decisions. Effective management of infrastructure, natural resources, the environment and territories, as shown by world experience, is based only on the ability to integrate GIS. In general, the introduction of GIS in the practice of assessing agricultural land, and soil fertility will increase the quality of storage of information on the state of soil fertility and accessibility to consumers, the use of which will improve the validity of management decisions both in a particular farm and by representatives of executive authorities at all levels. It is necessary to intensify research in the following main areas:

- development of theoretical foundations and methodologies for enhancing soil fertility in intensive agricultural systems;
- improvement and implementation of integrated methodologies for grouping agricultural soils;
- implementation of innovative remote sensing and GIS technologies in agriculture;
- development of effective methods for desalinization of saline soils and restoration of their eroded, highly compacted, degraded, and technologically contaminated soils;
- the development of new systems for the use of mineral fertilizers on a variety of crops, taking into consideration the use of new forms of organic fertilizers, organomineral compositions, and local mineral raw materials;

- to enrich the soil with organic matter, preserve and increase its fertility, it is necessary to apply recommended agricultural techniques and, annually for three to four years, apply high rates of organic fertilizers in the range of 20 to 40 tons per hectare, along with reduced rates of mineral fertilizers;

- in order to monitor the state of soil fertility, it is necessary to monitor plowed lands based on their humus and fundamental nutrient composition.

Along with the indication of traditional rules, it is necessary to take into account the totality of controlled agrochemical, agrophysical, and biological indicators of soil fertility for a more comprehensive assessment and expansion, as well as the need to improve the efficiency of the use of fertilizers and other elements in agricultural systems; the development of rational (scientific) methods of soil fertility evaluation.

Acknowledgments

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2-бөлім

ГЕОДЕЗИЯ ЖӘНЕ КАРТОГРАФИЯ

Section 2

GEODESY AND CARTOGRAPHY

Раздел 2

ГЕОДЕЗИЯ И КАРТОГРАФИЯ

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ОПТИМИЗАЦИЯ МЕТОДОВ ГЕОДЕЗИЧЕСКОГО ОБЕСПЕЧЕНИЯ СТРОИТЕЛЬСТВА АВТОМОБИЛЬНЫХ ДОРОГ В УСЛОВИЯХ СЕВЕРНОГО КАЗАХСТАНА

В статье исследован метод измерения ровности покрытий автомобильных дорог, который основывается на оценке продольного микропрофиля покрытия, то есть массива вертикальных отклонений от горизонтальной поверхности покрытия. В отличие от предыдущих методов, которые измеряли среднее значение поперечного неравномерного профиля покрытия, этот метод позволяет получить более детальную информацию о поверхности дороги.

Для измерения продольного микропрофиля покрытия используется специальное оборудование, которое может фиксировать вертикальные отклонения покрытия с высокой точностью и разрешением. Расстояние между фиксируемыми ординатами может быть выбрано в зависимости от требуемой точности измерения и особенностей покрытия дороги.

Полученный массив ординат можно анализировать с помощью различных методов обработки данных, например, для определения степени ровности покрытия, выявления причин неровностей и планирования работ по их устранению. Такой подход позволяет более точно определить качество покрытия и принимать меры по его улучшению.

Метод измерения ровности покрытий автомобильных дорог Северного Казахстана, результаты которого представлены в статье, принципиально отличается от предшествующих прежде всего тем, что в его основу положен новый подход, который заключается в том, что результатом измерения является продольный микропрофиль в виде массива ординат (амплитуд).

Работа содержит описание метода и его преимущества перед предыдущими методами измерения ровности покрытия, а также анализ результатов и возможных практических применений.

Таким образом, данная работа имеет большое значение для транспортной инфраструктуры и может быть использована для повышения безопасности и комфортности движения на дорогах.

Ключевые слова: автодорога, измерения ровности покрытия автодороги, метод амплитуд.

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Optimization of methods of geodetic support for the construction of highways in the conditions of Northern Kazakhstan

The article investigates a method for measuring the evenness of road pavements, which is based on an assessment of the longitudinal microprofile of the pavement, that is, an array of vertical deviations from the horizontal surface of the pavement. Unlike previous methods, which measured the average value of the transverse uneven pavement profile, this method allows you to get more detailed information about the road surface.

To measure the longitudinal microprofile of the coating, special equipment is used that can record the vertical deviations of the coating with high accuracy and resolution. The distance between the fixed ordinates can be selected depending on the required measurement accuracy and the characteristics of the road surface.

The resulting array of ordinates can be analyzed using various data processing methods, for example, to determine the degree of evenness of the coating, identify the causes of irregularities and plan work to eliminate them. This approach allows you to more accurately determine the quality of the coating and take measures to improve it.

The method of measuring the evenness of road surfaces in Northern Kazakhstan, the results of which are presented in the article, is fundamentally different from the previous ones, primarily in that it is based on a new approach, which lies in the fact that the result of the measurement is a longitudinal microprofile in the form of an array of ordinates (amplitudes).

The work contains a description of the method and its advantages over previous methods for measuring the evenness of the coating, as well as an analysis of the results and possible practical applications.

Thus, this work is of great importance for the transport infrastructure and can be used to improve the safety and comfort of traffic on the roads.

Key words: road, road surface evenness measurements, amplitude method.

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Солтүстік Қазақстан жағдайында жол салу үшін геодезиялық қамтамасыз етудің әдістерін оңтайландыру

Мақалада жабынның бойлық микропрофилін, яғни жабынның көлденең бетінен тік ауытқулар массивін бағалауға негізделген жол төсемдерінің тегістігін өлшеу әдісі зерттеледі. Көлденең тегіс емес жабын профилінің орташа мәнін өлшейтін алдыңғы әдістерден айырмашылығы, бұл әдіс жол төсемі туралы толығырақ ақпарат алуға мүмкіндік береді.

Қаптаманың бойлық микропрофилін өлшеу үшін жабынның тік ауытқуларын жоғары дәлдікпен және рұқсатпен жаза алатын арнайы жабдық қолданылады. Бекітілген ординаталардың арасындағы қашықтықты талап етілетін өлшем дәлдігіне және жол төсемінің сипаттамаларына байланысты таңдауға болады.

Алынған ордината массивін әртүрлі деректерді өңдеу әдістерін қолдану арқылы талдауға болады, мысалы, жабынның біркелкі болу дәрежесін анықтау, бұзушылықтардың себептерін анықтау және оларды жою бойынша жұмыстарды жоспарлау. Бұл тәсіл жабынның сапасын дәлірек анықтауға және оны жақсарту шараларын қабылдауға мүмкіндік береді.

Нәтижелері мақалада келтірілген Солтүстік Қазақстандағы жол жамылғыларының тегістігін өлшеу әдісі бұрынғылардан түбегейлі ерекшеленеді, ең алдымен оның жаңа көзқарасқа негізделгендігімен ерекшеленеді, ол нәтижені анықтауда жатыр. өлшеудің ординаталар (амплитудалар) массиві түріндегі бойлық микропрофиль болып табылады.

Жұмыста әдістің сипаттамасы және оның жабынның біркелкілігін өлшеудің алдыңғы әдістеріне қарағанда артықшылықтары, сондай-ақ нәтижелерді талдау және мүмкін практикалық қолдану бар.

Осылайша, бұл жұмыс көлік инфрақұрылымы үшін үлкен маңызға ие және жолдардағы қозғалыс қауіпсіздігі мен жайлылығын арттыру үшін пайдаланылуы мүмкін.

Түйін сөздер: жол, жол бетінің тегістігін өлшеу, амплитудалық әдіс.

Введение

Для обеспечения геодезического сопровождения проектирования, строительства и дальнейшего наблюдения за осадками в процессе эксплуатации автомобильных дорог существует множество подходов в использовании рекомендуемых технологий и современных приборов. Вопрос выбора определяется необходимостью соблюдать требуемую точность.

Строительство сложных автомагистральных развязок и обеспечения качества на современном этапе их развития является наиболее актуальным процессом в практике инженерно-геодезических работ, постоянно требующим качественного решения задач, связанных с контролем геометрических параметров сложных инженерных сооружений линейного типа, которыми и являются автомобильные комплексы.

Материалы и методы исследования

В текущий момент времени в арсенале геодезических технологий сопровождения строительства имеется множество современных технологий, основанных на цифровизации и

искусственном интеллекте так или иначе интегрированных с данными дистанционного зондирования. Важным этапом нужно считать процесс обработки и получение качественной информации для пользователя, выполняющего требования инструктивной документации. Актуальным трендом можно считать исполнительные съемки с использованием геодезического класса мобильных систем воздушного и наземного лазерного сканирования, позволяющие получать детальные 3D модели объектов с географической привязкой, выполняющих расчет траектории движения системы в реальном времени. Сканирование автомобильных дорог может быть использовано на любом действующем жизненном цикле трассы от топографических съемок, создания профилей при изысканиях, выноса в натуру, ремонта, до создания цифровых информационных моделей дорожного покрытия, анализа и корректировки уклонов и создания паспорта автодороги.

В учебной литературе, изданной до 2016 г. (Клюшин, 2014:496; Маслов, 2013:598), указывается что при строительстве автомобильных дорог проложение нивелирных ходов осуществлять технических нивелированием. В настоящее время при строительстве автомобильных дорог широко применяются электронные тахеометры и цифровые нивелиры, опыт их использования и исследования представлены в работах (Zou, 2017:254; Nestorovic, 2014:32; Shults, 2016:359; Takalo, 2006:5).

Процесс оптимизации существующих подходов в использовании рекомендуемых технологий и современных приборов при проектировании и строительстве находит свое место во внедрении BIM-технологий на весь жизненный цикл объекта, начиная с процесса инженерных изысканий.

Использование BIM-технологий предусматривает решение задачи интеграции результатов инженерных изысканий в среду информационного моделирования, которая предусматривает не только накопление, но и обработку огромного массива информации.

Действующие и существующие нормативные документы по геодезическому сопровождению строительства с использованием цифровых информационных технологий указывают на использование методик, содержащихся в руководствах по эксплуатации современного геодезических приборов и оборудования, но в них не указаны требования к обеспечению точности инженерно-топографических работ, направленных непосредственно на проектирование, реконструкцию и строительство автомобильных дорог (Пантусо, 2019:5).

Без надежных, точных и оперативных измерений и качественной научно обоснованной их обработки невозможны исследования в области геодезического обеспечения строительства.

Оптимизация заключается в обоснованном выборе методов и технологий геодезического сопровождения проектирования и строительства автомобильной дороги применительно к конкретным физико-географическим условиям местности. Обоснование выбора опирается на выполнение необходимой точности проведения геодезических работ, что возможно с применением информационного моделирования при использовании BIM-технологий в строительстве автомобильных дорог. Одной из задач которого проектируется выполнение анализа и оптимизации последовательности выполнения работ, проверки выполнимости технологических решений с обеспечением качества; контроля выполненных физических объемов строительных работ с возможностью визуализации выполнения проектных решений; что способствует также оптимизации численности персонала на строительной площадке. Создание и использование BIM – модели способствует проведению геодезического контроля на всех этапах строительных работ, а также обеспечивает проведение мониторинговых работ по охране труда, выполнения экологических требований и промышленной безопасности на всех участках строительства. (Von Olshausen, 2021: 179)

На качество укладки асфальтобетонного покрытия дорог активно влияют промежуточные этапы всего технологического процесса.

Качество будущей магистрали, в не меньшей степени зависит от соблюдения правил на этапе укладки и укатывания асфальта, чем от выбора смеси и приготовления её в точном соответствии с инструкцией. Если технологией пренебречь, то дорога не прослужит долго. (Ralbovsky, 2020: 11787)

При эксплуатации автомобильных дорог, а также при разработке новых проектов и проектов реконструкции автомобильных дорог, необходимо выявлять участки, не соответствующие

требованиям обеспечения безопасности движения, и предусматривать мероприятия по ее повышению (Шакиева, 2015:215).

Одним из важнейших транспортно-эксплуатационных показателей автомобильных дорог является ровность дорожного покрытия.

В настоящее время в странах – членах Таможенного союза наиболее широко применяют методы контроля ровности покрытий автомобильных дорог, основанные на следующих подходах:

1-й подход – измерение рейкой длиной три метра с клиновым промерником, предусматривающее измерение величины просвета под рейкой;

2-й подход – измерение нивелиром и нивелирной рейкой, предусматривающее вычисление модуля разности вертикальных отметок (ординат) поверхности с шагом 5, 10 и 20 м; (используется в наших исследованиях);

3-й подход – измерение с применением автомобильной установки ПКРС-2 или другими приборами, показания которых приведены к показаниям ПКРС, предусматривающее определение интенсивности (уровня) вертикальных колебаний прицепного прибора относительно подрессоренного кузова, выражаемое в виде суммарного перемещения неподрессоренной массы относительно подрессоренной на 1 км дороги (см/км).

Продольная ровность дорожного покрытия является одним из важнейших параметров, которые влияют на комфорт и безопасность движения на автомобильной дороге. Она характеризуется неровностями покрытия в продольном направлении и измеряется величиной поперечного наклона дороги на определенном участке.

Для измерения продольной ровности дорожного покрытия наиболее точным методом является метод амплитуд, который основан на использовании специальных измерительных приборов – профилометров. Профилометры позволяют измерять высоту профиля дорожного покрытия и определять амплитуду неровностей в продольном направлении.

Однако, для более простых случаев можно использовать и другие методы измерения продольной ровности дорожного покрытия, такие как средства геометрического нивелирования. Эти методы основаны на использовании специального оборудования, которое позволяет определять уровень дороги в продольном направлении.

Таким образом, для более точного измерения продольной ровности дорожного покрытия наиболее эффективно использовать метод амплитуд с помощью профилометров, но для простых случаев можно применять и более простые методы, такие как средства геометрического нивелирования (Русяева, 2016:56).

Метод измерения ровности покрытий автомобильных дорог, результаты которого представлены в статье, принципиально отличается от предшествующих прежде всего тем, что в его основу положен новый подход, который заключается в том, что результатом измерения является продольный микропрофиль в виде массива ординат (амплитуд). При этом расстояние между фиксируемыми ординатами может составлять несколько сантиметров, а точность их измерения – доли миллиметров в зависимости от особенностей применяемого оборудования.

По высотам, полученным из результатов исполнительных съемок протяженностью пять километров, после реконструкции автомобильной дороги республиканского значения "Астана-Петропавловск" транзитного коридора "Боровое-Кокшетау-Петропавловск-граница РФ", выполнен анализ ровности дорожного покрытия на основе результатов вертикальных отметок по микропрофилю левой, правой кромкам и оси покрытия. Измерения проводились последовательно с установкой рейки на все метки.

Расчет определения точности высотного положения покрытия выполнен по разностям вертикальных отметок на прямолинейных участках с шагом 20 метров и на характерных точках покрытия автомобильной дороги. Для выполнения математической обработки, в количественном отношении по каждой полосе, было получено 269 определений разностей вертикальных отметок, по которым в соответствии с [ГОСТ 33101-2014] вычислены модули разностей, определяемые как отклонение ординаты микропрофиля от прямой линии согласно формулы 1:

$$\delta h_i = \left| \frac{h_{i-1} - h_{i+1}}{2} - h_i \right| \qquad (1)$$

где h_i, h_{i-1}, h_{i+1}, ордината точки массива, ординаты последующей и предыдущих точек массива.

Для математической обработки, разности использовались без модуля и из них были сформированы три вариационных ряда отклонений по левой, правой кромкам и оси поверхности дороги, разность ординат внутри интервалов определялась по формуле Стерджесса:

$$h = \frac{R}{1 + 3{,}32 \lg N}, \qquad (2)$$

где R – разность ординат между максимальным и минимальным значениями; N – количество ординат.

Количество интервалов в каждом ряду, составленном по левой (правой) кромкам и оси определялось как отношение разности ординат между максимальным и минимальным значениями к разность ординат внутри интервалов.

Для всех трех рядов значения получены практически одинаковые $h=4$ *мм*, в каждом ряду получилось одинаковое количество интервалов равное 9, это позволяет сделать вывод о несимметричности распределения ординат относительно нулевого значения.

Характеристикой количества появлений ординат в интервале служит частотность, определяемая как отношение числа ординат в интервале (частота) обозначим его буквой n, к объёму всего ряда обозначим его за $N=269$, вычислим частоту по формуле 3:

$$W_i = n_i / N. \qquad (3)$$

Выполнив предварительное распределение отклонений ординат по интервалам, наблюдаем что их частота внутри рядов практически одинакова, поэтому рассмотрим статистическую обработку на примере ряда отклонений ординат, выполненного по левой кромке. Следует отметить, что ординаты равные нулевому значению получены в объеме 150 штук из 269 штук всего ряда, это говорит о том, что поверхность исследуемого покрытия довольно ровная. Следует отметить, что восьмой интервал от -20 мм до -16 мм не содержит ни одного отклонения ординат, а девятый интервал от 12 мм до 16 мм содержит также одно отклонение ординат, поэтому для дальнейшей обработки целесообразнее вместо девяти интервалов, обработать только семь, увеличив количество отклонений ординат (частоту) в крайнем положительном интервале.

Количество интервалов, их границы (a и b) и соответствующие им частоты, приведены в таблице 1, и составляют статистическое распределение, Частотой интервала характеризуется сумма частот отклонений ординат, попавших в интервал, при этом сумма всех частот равна количеству значений рассматриваемого ряда.

Характеристикой статистической оценки, является математическое ожидание (МО), при данном виде оценки эта величина заменяется средним арифметическим хначением $\bar{x}$, вокруг которого сконцентрированы отклонения ординат отметок, для дальнейшей математической обработки будем использовать середины интервалов, которые обозначим $x_1, x_2, x_3, \ldots, x_n$. Количественное выражение среднего арифмитического значения отклонения ординат выражается формулой (4):

$$\bar{x} = \frac{\sum_{i=1}^{N} n_i x_i}{N}, \qquad (4)$$

Величина среднего арифметического значения позволяет определить значение средней квадратической ошибки измерения ординат отметок, в теории вероятностей ее значение приближается к значению стандарта (σ), значение которой можно вычислить по формуле (5):

$$m = \sqrt{\frac{\sum_{i=1}^{k} n_i \left(x_i - \bar{x}\right)^2}{N - 1}}. \qquad (5)$$

Для дальнейшей статистической обработки вычислим значение M характеризующее величину средней квадратической ошибки среднего арифметического значения исследуемого ряда и величину надежности оценки m_m по формулам (6):

$$M = \frac{m}{\sqrt{N}}; \qquad (6)$$

где:

$$m_m = \frac{m}{\sqrt{2(N-1)}}.$$

Рассмотренная по формулам (3)–(6) оценка точности является точечной и характеризуется одним числом, расчеты по указанным формулам приведены под табл.1 (слева). Мы же в своем исследовании рассматриваем вариационный ряд отклонений ординат ограниченный максимальным и минимальным их значением. В этом случае разумнее было бы применить интервальные оценки, определяемые двумя характеристиками точности и надежности оценок.

Большинство геодезических работ оцениваются доверительной вероятностью $P = 0{,}95$ и уровнем значимости (точностью оценки) $q = 0{,}05$. Составим «доверительный интервал» для математического ожидания (МО) и стандарта (σ), с учетом доверительной вероятности и точности оценки, доверительные интервалы и точечная оценка приведены под таблицей 1. Для математического ожидания *MO* и стандарта σ в пределах исследуемого ряда доверительные интервалы определяются неравенствами:

$$\bar{x} - t \cdot M < MO < \bar{x} + t \cdot M,$$
$$m(1-g) < \sigma < m(1+g), \qquad (7)$$

где t – нормируемый множитель, зависящий от доверительной вероятности p и количества отклонений ординат N; g – коэффициент с применением распределения χ^2 (критерия К. Пирсона), зависящий от объема исследуемого ряда отклонений ординат и вероятности, может быть определен из выражения. Показатели определяются из таблиц, позволяющих оценивать статистические ряды. Доверительные интервалы приведены под табл.1 (справа).

Приведенные неравенства для построения доверительных интервалов, применимы при количестве отклонений ординат больше пятидесяти определений. При выполнении исследования используется ограниченное количество определений, поэтому для построения доверительных интервалов применяется распределение Стьюдента.

Для наглядного представления исследуемого ряда отклонении ординат, приведем кривые практического (строящаяся по частостям W_i и соответствующим им серединам интервалов x_i) и теоретического (строящаяся серединам интервалов x_i и значениям вероятностей $P(x_i)$ им соответствующим) их распределений, рисунок 1.

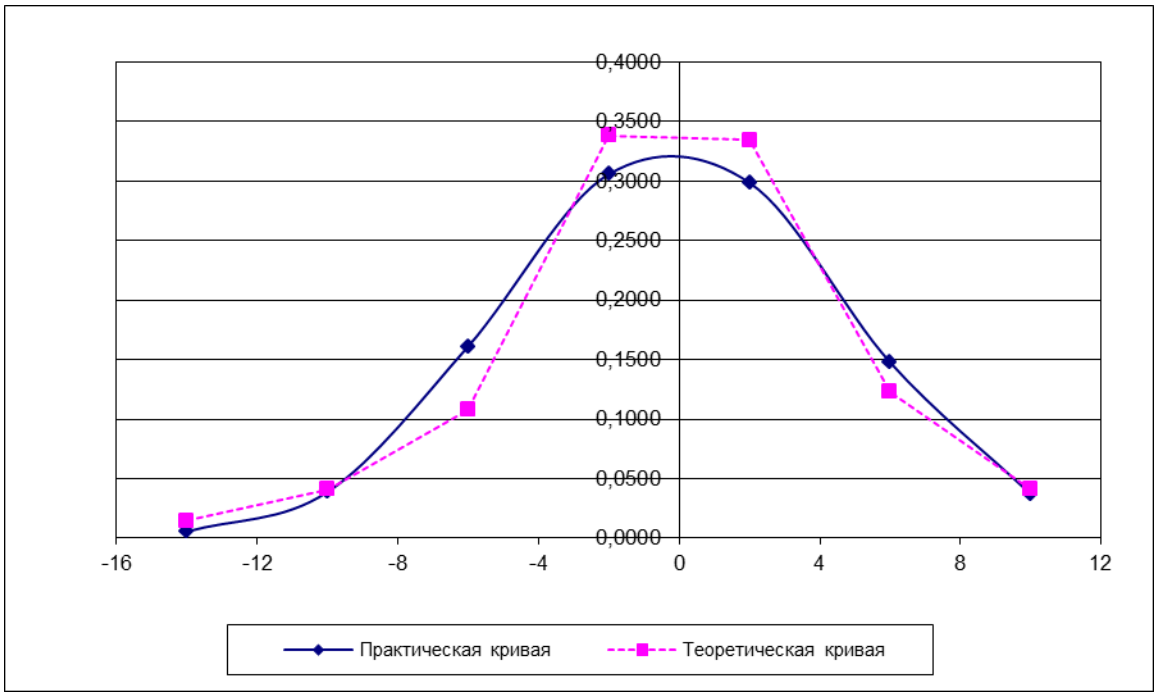

Рисунок 1 – Теоретическая и практическая кривые распределения отклонений ординат

Исследуя ряд отклонений ординат, примем нулевую гипотезу о нормальном распределении отклонений ординат, при этом вероятности $P(x_i)$ определяются согласно формулы Лапласа, все необходимые расчеты приведены в табл.1:

$$\Phi(t) = \frac{1}{\sqrt{2\pi}} \int_0^t e^{-t^2/2} \cdot dt, \qquad (8)$$

где $t = (a - \bar{x})/m$ или $t = (b - \bar{x})/m$ зависит от границ интервалов отклонений ординат *a* и *b*.

Таблица 1 – Статистическая обработка распределения отклонений ординат поверхности автомобильной дороги

Интервалы, мм		Частота n_i	Относ. частоста w_i	Середина интерв. x_i,мм	nx_i, *мм*	$(x_i - \bar{x})$, *мм*	$n_i(x_i - \bar{x})$, *мм*	$n_i(x_i - \bar{x})^2$, *мм*	$t_1 = \frac{a-\bar{x}}{m}$	$t_2 = \frac{b-\bar{x}}{m}$	$\frac{1}{2}\Phi(t_1)$	$\frac{1}{2}\Phi(t_2)$	$P(x_i)$
a	b												
-16	-12	4	0,015	-14	-56	-13,87	-55,49	769,91	-3,37	-2,52	-0,4997	-0,4941	0,0056
-12	-8	11	0,041	-10	-110	-9,87	-108,61	1072,37	-2,52	-1,67	-0,4941	-0,4552	0,0389
-8	-4	29	0,108	-6	-174	-5,87	-170,33	1000,48	-1,67	-0,82	-0,4552	-0,2939	0,1613
-4	0	91	0,338	-2	-182	-1,87	-170,50	319,45	-0,82	0,03	-0,2939	0,0120	0,3059
0	4	90	0,335	2	180	2,13	191,38	406,94	0,03	0,88	0,0120	0,3106	0,2986
4	8	33	0,123	6	198	6,13	202,17	1238,58	0,88	1,73	0,3106	0,4582	0,1476
8	12	11	0,041	10	110	10,13	111,39	1127,98	1,73	2,58	0,4582	0,4951	0,0369
Сумма		269	1,0		-34			5935,70					0,9948

Доверительный интервал для " MO"

$$\bar{x} = -34/\sqrt{269} = -0,1\ мм \quad \bar{x} - t_q \cdot M < MO < \bar{x} + t_q \cdot M, \text{ где } t_q(N = 269;\ P = 0,95) = 1,96$$

$$M = 4,7/\sqrt{269} = 0,3\ мм \quad -0,1 - 1,96 \cdot 1,0 < MO < -0,1 + 1,96 \cdot 0,3 \Rightarrow -0,7 мм < a < 0,5 мм$$

$$m = \sqrt{5935,7/269} = 4,7\ мм$$

Доверительный интервал для "σ":

$$m_m = 4,7/\sqrt{2 \cdot (269 - 1)} = 0,2\ мм$$

$$m \cdot (1 - g) < \sigma < m \cdot (1 + g), \text{ где } g(N = 269, P = 0,95) = 0,089$$

$$4,7 \cdot (1 - 0,089) < \sigma < 4,7 \cdot (1 + 0,089) \Rightarrow 4,3\ мм < \sigma < 5,1\ мм$$

Отечественными и зарубежными исследователями неоднократно доказывалось, что подобные отклонения ординат полученные в процессе строительства сооружений подчиняются нормальному закону их распределения и носят закономерный характер, гипотезу о подчинении исследуемого ряда нормальному закону возможно проверить используя критерий сходимости Пирсона (χ^2 хи-квадрат). Следует отметить тот факт, что предложенный критерий отличающейся высокой чувствительностью к гипотезе о нормальном распределении отклонений ординат, вычисления приведены в таблице 2, конечная формула определения сходимости имеет вид (9), вычисления связанные с применением критерия Пирсона приведены в табл.2:

$$\chi^2_{набл} = \sum_{i-1}^{к} (n_i - NP(x_i))^2 / NP(x_i), \qquad (9)$$

где *n* – частоты; $NP(x_i)$ – теоретические частоты; *к* – число интервалов отклонений ординат; $P(x_i)$ – вероятность попадания x_i в интервал отклонений ординат.

Таблица 2 – Вычисление критерия Пирсона χ^2 для оценки сходимости исследуемого ряда отклонений ординат с нормальным распределением

Интервалы, мм		Частота n_i	Вероятность $P(x_i)$	Теорет.частота $NP(x_i)$	$n_i - NP(x_i)$	$[n_i - NP(x_i)]^2$	$\frac{[n_i - NP(x_i)]^2}{NP(x_i)}$
a	*b*						
-16	-12	4	0,0056	1,506	2,494	6,218	4,13
-12	-8	11	0,0389	10,464	0,536	0,287	0,03
-8	-4	29	0,1613	43,390	-14,390	207,063	4,77
-4	0	91	0,3059	82,287	8,713	75,915	0,92
0	4	90	0,2986	80,323	9,677	93,637	1,17
4	8	33	0,1476	39,704	-6,704	44,949	1,13
8	12	11	0,0369	9,926	1,074	1,153	0,12
Сумма		269					$\chi^2_{выч} = 12,26$
При семи интервалах число степеней свободы $k = 3$. $\chi^2(0,05;4) = 9,5$							
Таким образом, $12,26 > 9,5$. Нулевая гипотеза отвергается.							

Из результатов проверки подчинения, исследуемых данных нулевой гипотезе видно возникающих случайных ошибках в измерениях, они подразделяются на ошибки первого уровня, если гипотеза правдоподобна и второго уровня, если она неправдоподобна. Для устранения в опытных данных ошибок первого рода выбирается существенно малый уровень значимости, в этом случае ошибки первого уровня возможны в пределах 5% из 100% определений, и предельную величину *2m* по абсолютной величине будут превышать значения с вероятностью *P= 0,05. В исследуемом ряду отклонений ординат, при обозначенных условиях,* вычисленный показатель критерия Пирсона К., оказался больше критического определенного по уровню значимости $\chi^2_{набл} > \chi^2_{кр}$, для рассматриваемого ряда данные показатели составляют 12,26 > 9,5 критическое значение показателя критерия К. Пирсона определено из статистических таблиц, по принятому уровню значимости *q=0,05* и числу степеней свободы равному 4 (количество интервалов без обязательных параметров нормального распределения), поэтому для дальнейшей проверки статистического распределения нами применим критерий Ястремского Б.С., вычисления по этому критерию приведены в табл.3, который является менее чувствительным к проверяемой гипотезе о нормальном распределении отклонений ординат, и определяется формулой (10):

$$J = Q - k/\sqrt{2k + 4\Theta}, \qquad (10)$$

где k – количество интервалов определений ординат.

Таблица 3 – Вычисление критерия Б.С. Ястремского для оценки сходимости исследуемого ряда отклонений ординат с нормальным распределением

Интервалы, мм		Частота n_i	Вероятность $P(x_i)$	Теорет.частота $NP(x_i)$	$n_i - NP(x_i)$	$[n_i - NP(x_i)]^2$	$1 - P(x_i)$	$NP(x_i)[1 - P(x_i)]$	Q
a	*b*								
-16	-12	4	0,0056	1,506	2,494	6,218	0,994	1,498	4,15
-12	-8	11	0,0389	10,464	0,536	0,287	0,961	10,057	0,03
-8	-4	29	0,1613	43,390	-14,390	207,063	0,839	36,391	5,69
-4	0	91	0,3059	82,287	8,713	75,915	0,694	57,115	1,33
0	4	90	0,2986	80,323	9,677	93,637	0,701	56,339	1,66
4	8	33	0,1476	39,704	-6,704	44,949	0,852	33,844	1,33
8	12	11	0,0369	9,926	1,074	1,153	0,963	9,560	0,12
Сумма		269							Q =14,31
При семи интервалах $S = 7$, $\Theta = 0,6$, $J = \frac{(Q - S)}{\sqrt{(2S - 4\theta)}} = 1,63$									
Так как $1,63 < 3$, то нулевая гипотеза подтверждается.									

Коэффициент, $\Theta = 0,6$ при k<20,а величина Q определяется из формулы:

$$Q = \frac{[n_i - NP(x_i)]^2}{NP(x_i) \cdot [1 - P(x_i)]}. \quad (11)$$

Вычисления, выполненные по формулам (9-10) представлены в таблице 3, ниже приведено сравнение нулевой гипотезой о нормальном распределении, она принимается при J<3, для рассматриваемого ряда *1,63*<3, гипотеза о подчинении ряда нормальному распределения подтверждается критерием Б.С. Ястремского.

Результаты и обсуждение

В результате анализа, по выполненным исследованиям с применением статистического анализа определения ординат отклонений вертикальных отметок поверхности автомобильной дороги, установлено, что отклонения ординат носят закономерный характер распределения, подтверждена статистическая однородность с применением критериев согласия К. Пирсона и Б.С. Ястремского, вычислены статистические характеристики точности выполнения измерений.

По результатам измерений ровности покрытия автодороги методом амплитуд, средствами геометрического нивелирования была выполнена оценка их точности, вычислена средняя квадратическая погрешность, которая позволяет сделать следующие **выводы:**

определение ровности дорожного покрытия средствами геометрического нивелирования является корректным методом;

покрытие дороги на исследуемом участке находится в удовлетворительном состоянии.

Кроме того, выполнена систематизация существующего уровня практического применения теории вероятностного метода исследований в области геодезического обеспечения ровности дорожного покрытия. Наряду со всеми приведенными в статье современными технологическими средствами, используемыми для определения ровности, самым оптимальным является метод амплитуд, он доказательно обеспечивает требования указанные в [ГОСТ 33101-2014], так как точность является одним из показателей качества любого строительства.

Заключение

Автомобильная дорога относиться к сложным техническим объектам, характеризуется особенной историей своего развития и сильной технологической наследственностью. Чтобы улучшить ее состояние в нашей стране, необходимо опираться на современные методы строительства дорог и учитывать существующие технологии наших регионов и территорий. Только при таком подходе, автомобильные дороги будут удовлетворять всем возрастающим потребностям общества, выдерживать постоянно увеличивающийся рост автотранспортных средств, нарастающую интенсивность движения и возрастающие нагрузки.

Исходя из описания в статье, можно сделать следующие выводы:

Метод измерения ровности покрытий автомобильных дорог, основанный на оценке продольного микропрофиля покрытия, позволяет получить более детальную информацию о поверхности дороги и более точно определить степень ее ровности, чем предыдущие методы измерения.

Для измерения продольного микропрофиля покрытия используется специальное оборудование, которое может фиксировать вертикальные отклонения покрытия с высокой точностью и разрешением.

Полученный массив ординат может быть анализирован с помощью различных методов обработки данных, что позволяет определить степень ровности покрытия, выявить причины неровностей и спланировать работы по их устранению.

Метод измерения ровности покрытий автомобильных дорог, описанный в статье, имеет высокую ценность для транспортной инфраструктуры и может быть использован для проек-тирования и строительства новых дорог, реконструкции и модернизации существующих дорожных покрытий, контроля качества дорожных работ и обслуживания дорожной инфраструктуры.

В целом, метод измерения ровности покрытий автомобильных дорог, основанный на оценке продольного микропрофиля покрытия, может быть полезным инструментом для повышения безопасности и комфортности движения на дорогах, что является особенно важным для обеспечения эффективного функционирования транспортной системы.

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GEOINFORMATION MODELING OF THE ESIL RIVER FLOOD ZONE BASED ON REMOTE SENSING DATA

The article presents the technique for geoinformation modeling of a site of a river valley with an insufficient amount of hydrological data. The technique will make it possible to carry out a forecast of hydrological phenomena in order to prevent the flooding of adjacent territories by flood waters. The study is based on the use of Earth remote sensing (RS) data and the use of geoinformation technologies (GIS). The sequence of the work is briefly described. The study was carried out on the example of a site of the valley of the Yesil (Ishim) river, located near Petropavlovsk (North Kazakhstan region, Republic of Kazakhstan). On the basis of remote sensing data and GIS technologies, a digital relief model of the studied section of the river valley was developed. The initial data were SRTM (Shuttle Radar Topography Mission) images. The modeling of the scenario of possible flooding of adjacent territories by flood waters has been carried out. Modeling and mapping of flooding carried out for the flood peak. Modeling and construction of a flood map were carried out for the flood peak. An approach is proposed that makes it possible to perform a more accurate assessment of the boundaries of flooding without the procedure for calculating the hydrological characteristics of the river during the flood period and the absence of hydrometric observation data. Recommendations are given for the prevention of flood events, measures to protect adjacent lands from possible flooding. The obtained cartographic materials can be useful for planning and carrying out measures to prevent emergency situations related to floods on the river, reduce the risk of flooding of adjacent areas, and territorial design.

Key words: mapping, modeling, GIS, remote sensing data, digital terrain model, river valley, flooding.

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Қашықтықтан зондтау деректері негізінде Есіл өзенінің су басу аймағын геоақпараттық модельдеу

Мақалада гидрологиялық мәліметтер жеткіліксіз болған кезде өзен аңғары учаскесін геоақпараттық үлгілеу әдістемесі келтірілген. Әдістеме іргелес аумақтарды тасқын сулармен су басудың алдын алу мақсатында гидрологиялық құбылыстардың болжамын жүзеге асыруға мүмкіндік береді. Зерттеу Жерді қашықтықтан зондтау (ЖҚЗ) деректерін қолдануға және Геоақпараттық технологияларды (ГАЖ) пайдалануға негізделген. Жасалған жұмыстың реттілігі қысқаша баяндалған. Зерттеу Петропавл қаласы маңындағы (Солтүстік Қазақстан облысы, Қазақстан Республикасы) Есіл өзені аңғары учаскесінің мысалында жүргізілді. ЖҚЗ материалдары мен ГАЖ-технологиялар негізінде өзен аңғарының зерттелетін учаскесінің жер бедерінің сандық үлгісі әзірленді. Бастапқы деректер ретінде SRTM (Shuttle Radar Topography Mission) суреттері алынды. Іргелес аумақтарды тасқын сулармен су басу мүмкіндігінің сценарийін үлгілеу орындалды. Жоғары деңгей кезіндегі су тасқыны картасын үлгілеу және құрастыру жүргізілді. Су тасқыны кезеңіндегі өзеннің гидрологиялық сипаттамаларын есептеу процедурасын жасамастан және гидрометриялық бақылаулар деректерінің болмауына қарамастан су басу шекараларын дәлірек бағалауға мүмкіндік беретін тәсіл ұсынылды. Су тасқыны құбылыстарының алдын алу бойынша ұсыныстар, іргелес аймақтарды ықтимал су тасқынынан қорғау шаралары ұсынылды.

Алынған картографиялық материалдар өзендегі су тасқыны құбылыстарымен байланысты төтенше жағдайлардың алдын алу, іргелес аймақтардың су басу қаупін азайту, аумақтық жобалау бойынша іс-шараларды жоспарлау және жүргізу үшін пайдалы болуы мүмкін.

Түйін сөздер: картаға түсіру, үлгілеу, ГАЖ, қашықтықтан зондтау деректері, жер бедері сандық үлгісі, өзен аңғары, су тасқыны.

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Геоинформационное моделирование зоны затопления реки Есиль на основе данных дистанционного зондирования

В статье приведена методика геоинформационного моделирования участка речной долины при недостаточном количестве гидрологических данных. Методика позволит осуществить прогноз гидрологических явлений с целью предупреждения затопления прилегающих территорий паводковыми водами. Исследование базируется на применении данных дистанционного зондирования Земли (ДЗЗ) и использовании геоинформационных технологий (ГИС). Кратко изложена последовательность проведенной работы. Исследование осуществлялось на примере участка долины р. Есиль (Ишим), расположенного вблизи г. Петропавловска (Северо-Казахстанская область, Республика Казахстан). На основе материалов ДЗЗ и ГИС-технологий разработана цифровая модель рельефа исследуемого участка долины реки. Исходными данными послужили снимки SRTM (Shuttle Radar Topography Mission). Выполнено моделирование сценария возможного затопления прилегающих территорий паводковыми водами. Моделирование и построение карты затопления проведены для пика паводка. Предложен подход, позволяющий выполнить более точную оценку границ затопления без процедуры расчетов гидрологических характеристик реки в паводковый период и отсутствии данных гидрометрических наблюдений. Даны рекомендации по предупреждению паводковых явлений, меры защиты прилегающих земель от возможного подтопления. Полученные картографические материалы могут быть полезны для планирования и проведения мероприятий по предупреждению чрезвычайных ситуаций, связанных с паводковыми явлениями на реке, снижению риска затопления прилегающих участков, территориального проектирования.

Ключевые слова: картографирование, моделирование, ГИС, данные дистанционного зондирования, цифровая модель рельефа, долина реки, затопление.

Introduction

The Yesil (Ishim) River is the main water artery of the North Kazakhstan Region and a basic source of water resources for household needs, industrial production, agriculture, tourism and recreation. Its source is located in the Niyaz mountains, in the upper part the river flows through a narrow valley in the northwestern and western direction, below the city of Nur-Sultan, the valley expands to the southwest, further to the north (in front of town Derzhavinsk) and northeast (Petropavlovsk). The Yesil River is fed by snow. Its freezing begins in the beginner of November, opening of the river is in April and May. The maximum level of water rise during the spring flood occurs in May and June. During this period the river overflows up to 15 km in its low part. Average consumption near Petropavlovsk in 1975-2019 is 60.0 m³/s, the largest one is 2420 m³/s in 2017. The main tributaries are Koluton, Zhabay, Akkanburluk (right). About 80% of its annual runoff is formed in the spring due to snowmelt. The Vyacheslavskoye and Sergeevskoye reservoirs are located on the river. (Geografija Severo-Kazahstanskoj oblasti, 2016:35-38; URL1:2022)

Intensive melting of the snow cover in spring often causes floods on the river, flooding the territories adjacent to the valley. Flooding processes in the form of floods cause significant social and economic damage. During such emergencies, damage and destruction of residential and industrial buildings and constructions, infrastructure facilities, flooding of agricultural land, leading to the death of crops take place. So, there is a threat to domestic animals, and most importantly, the health and life of the population living near the river.

According to the Department of Emergency Situations for North Kazakhstan Region (URL 3:2022), the area subject to flood events in the region is 43,991.95 ha (2020). To prevent emergen-

cies there is a system of gauging stations designed to monitor the hydrological, hydrochemical characteristics and parameters of the river. Due to the specifics of the device and the nature of the relief in the flat areas, the density of observations of the parameters of rivers is much less than in mountainous areas. In total, within the North Kazakhstan region on the river Yesil operates 19 gauging stations, 5 of which were opened in 2020 to improve the quality of forecasting.

However, for a more detailed study, assessment and accurate forecasting of flood events, their number is insufficient. The available materials do not allow to accurately and quickly determining the areas of possible flooding. This makes it difficult to timely carry out the relevant work to prevent floods, and reduces their effectiveness.

The relevance of the study is connected with a significant economic development and population of the river Yesil valley and adjacent territories. There are many settlements here, including regional center – town Petropavlovsk, agricultural land, important engineering and construction facilities, elements of road transport infrastructure.

Nowadays, the development of GIS technologies, the use of digital elevation models (DEMs) has made it possible to significantly simplify and automate the process of determining zones of flooding by flood waters, modeling and forecasting flood phenomena on rivers. DEMs are very important for solving a wide range of geographic and cartographic problems. One of the most urgent among them is the problem of determining the zones of possible flooding of territories during flood events on rivers. The advantages of creating DEM based on remote sensing data are the efficiency of obtaining up-to-date data, automation of their processing, and a fairly high accuracy of the resulting models.

In the process of modeling flood zones based on RS data, no procedure for special calculations of the hydrological characteristics of the river during the flood period is required. The special significance of the use of RS for modeling and forecasting zones of inundation by flood waters is noted for territories with a rare network of gauging stations, in the absence of operational data from hydrometric observations.

The purpose of the research was to determine the areas of flooding by waters of the river. Yesil through modeling based on RS data in a GIS environment.

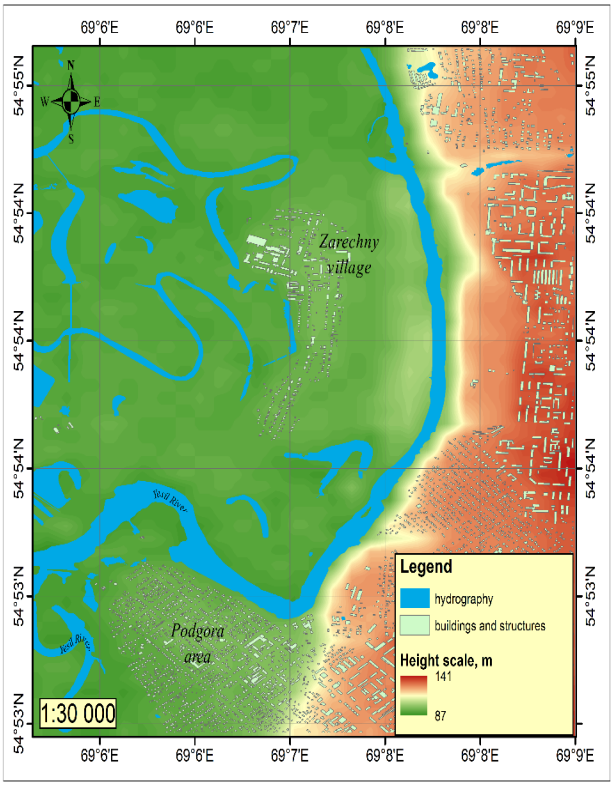

Figure 1 – Floodplain of the Yesil river (Petropavlovsk)

The purpose of the study was to test the methodology for modeling areas flooded by flood waters based on remote sensing data in a GIS environment. The study was carried out on the example of the site of the valley of the Yesil river near the city of Petropavlovsk, subject to periodic seasonal flooding by flood waters. The study area is located within the coordinates 54°52′-54°55′ N.L. and 69°6′-69°8′ E (fig.1).

Materials and methods

The methodological base of research is founded on the publications of a theoretical and practical nature on geoinformation mapping. Particular attention is paid to the study of the experience and results of research on mapping and geoinformation modeling of the relief and its parameters for solving practical problems. Among them there are works of the authors of the CIS on the basics of cartography (Berlyant, 2002; Salishchev, 1976), geoinformation systems and methods of spatial analysis (Pyankov, 2017), modeling of flood zones (Mushtaykin, 2021:1-11), methods for calculating the highest water levels of rivers (Orlyankin, 2017:98-101), geoinformation modeling of floods (Novakovsky, 2013:35-39). The experience of foreign authors in GIS and automated mapping (Dueker K., 1987:384-390), the basics of hydrological modeling (Spence C., Dalton A., Kite G., 1995: 62-66), the experience of preventing flooding of the Seine (Paris) (URL4:2018), etc.

During the research literary authors used stock and archival data, materials of hydrological observations of the Branch of RS Kazhydromet in the North Kazakhstan region, topographic maps (URL 4: 2022), schemes of territorial (agricultural) land management, materials obtained in the process of field and cameral work performed in the period 2019-2020, surveys zones of periodic flooding on the ground, a sociological survey of residents of settlements located in the valley of the river Yesil, in its lower flow.

When modeling flood events (or floods) and the high water caused by them, not only hydrological characteristics, information about the levels of water rise, but also accurate data on the terrain are required. Publicly available data from Earth remote sensing (ERS) – SRTM (Shuttle Radar Topography Mission, 2000), which are available in the public domain, were used as initial data for a detailed study and mapping of the relief of the study territory. The SRTM data are radar topographic surveys with a resolution of about 90 meters (3 arcseconds) (URL 5: 2022). To carry out cartographic work, section N50 was selected, covering the floodplain of the river Yesil.

It should also be noted that A.K. Korveul's, I. Ewiak's (Karwel A.K., Ewiak I., 2008: 169-172) studies revealed that SRTM is suitable for creating contour lines on topographic maps at a scale of 1:50,000 and smaller, as it has an error of 2.9 m for flat terrain and 5.4 m for hilly. This limits the scope of the study and determines the need for mapping and modeling in the specified interval in order to avoid errors and distortions. The solution to this problem can be the testing and improvement of remote methods and materials (radar, satellite observations). The use of images for different dates makes it possible to more accurately assess and determine the area of potential flooding. More detailed data can be obtained on the basis of aerial photography from unmanned aerial vehicles (UAVs).

The methods used in the study: comparative geographic, cartographic, modeling, observation, field methods, GIS technologies.

Terrain mapping and modeling was performed using ArcGIS 10.1 software (ESRI Inc.). This software product is characterized by a wide range of tools and modules, the functionality of which allows you to perform various operations, not only for mapping, developing various maps, spatial analysis, but also modeling processes and phenomena, and performing forecasting (URL 6: 2022).

A detailed study was carried out on the example of two key areas located in the lower flow of the river Yesil. These areas belong to the zone of periodic flooding. The key section 1 is the suburban settlement of Zarechny, the key section 2 is Podgora, one of the districts of the town of Petropavlovsk. The area of key plots was 105 ha and 52 ha, respectively. The study area is characterized by a slight difference in the heights of the surface of the territory and the water's edge. The floodplain section in this part of the valley has homogeneous morphometric conditions. According to topographic maps (URL 4:2022), the surface height in key areas is 100 m. The height of the water's edge (average level) near Petropavlovsk is 333 m.). For comparison, the lowest water level of the river Yesil is 304 m, recorded in November. The rate of water level rise per day at the Petropavlovsk Reservoir in recent years has been 5 cm, the rise of water since the beginning of the flood is 25 cm (as of 06/05/2020).

The study included a number of stages, solving the following tasks: collection and generalization of

analytical data on the hydrological regime, spring floods, flood events on the river Yesil, creation of a digital elevation model based on SRTM data, creation of a predictive model of flooding near the city of Petropavlovsk.

At the initial stage, in order to compile the initial characteristics of the territory, a conjugated analysis of the natural components of the valley of the river Yesil was carried out and special attention is paid to hydrological characteristics. Flood phenomena on the river Yesil with a significant rise in the water level are recorded annually. However, the coordinated actions of all structural divisions contribute to the timely prevention of especially dangerous (emergency) situations.

The main stage of the work consisted in bringing the materials of RS data into the required cartographic projection, and their interpretation. The interpretation of the images was carried out manually using the structural geomorphological method (SGM). Based on the SRTM materials, an orthophotomap, terrain elevation matrices were obtained. On their basis, a digital elevation model (DEM), a relief map and a 3D model of the study area were developed. The reliability of the obtained DEM was improved by adjusting and enhancing it with the "Fill" tool. The initial data on the relief of the floodplain are plotted by isohypses in vector form, the horizontal spacing is 5 m (Fig. 2).

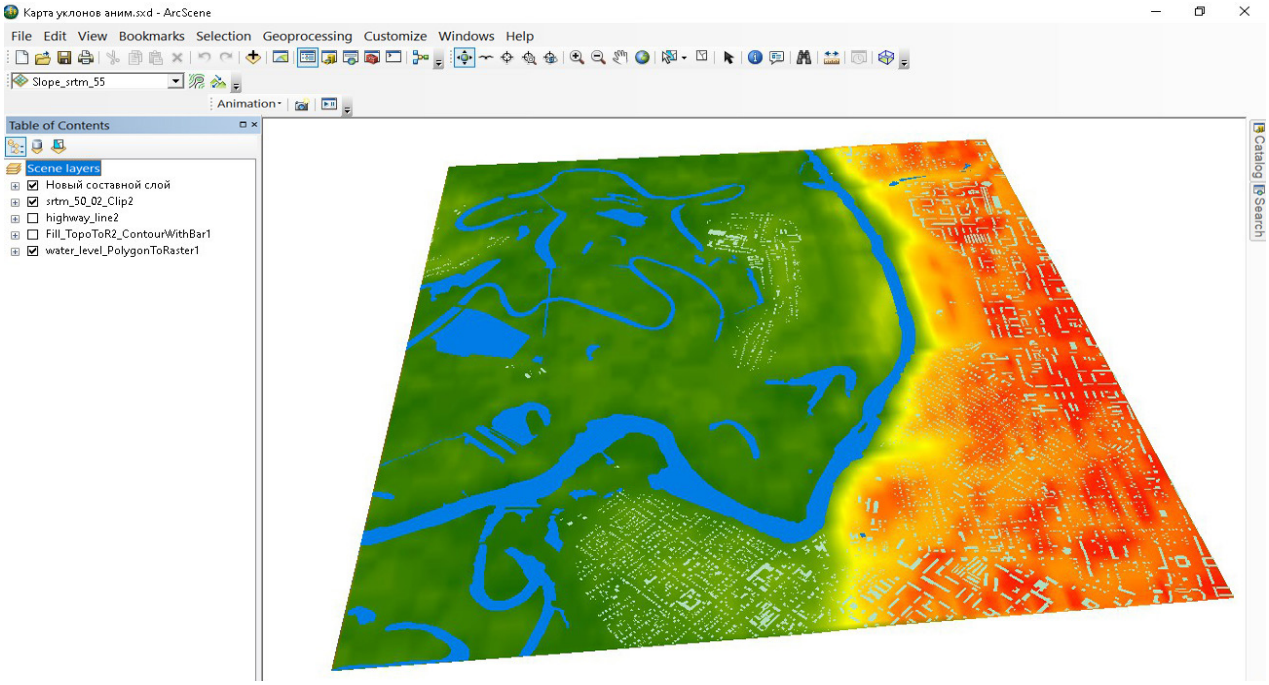

Figure 2 – Digital model of the relief of the river Yesil floodplain near Petropavlovsk

One of the areas of application of modern means of GIS technologies, materials of RS, which are of great practical importance, is their use in the construction and processing of DEM and geoinformation modeling of flood zones during flood events. The main way to determine flood zones during floods and high water in GIS is the construction of inclined surfaces. These surfaces allow to determine the most closely the water mirror or the degree of a possible rise in the water level. Next, the lines of intersection of these surfaces with a digital terrain model are determined, which make it possible to identify and outline the flood zones (Agnes Cabal, Marc Erlich, 1992: 395-406; Xiaoliu Y., Michel C., 2000; Kulp S. A., Strauss B. H., 2018: 231-239; Shakeel Mahmood, Atta-ur Rahman, Rajib Shaw, 2019: 573; Shokoufeh Khojeh, Behzad Ataie-Ashtiani, Seiyed Mossa Hosseini, 2022: 2673-2693). To solve this problem, we used the approach proposed in the following works Identification of the contours of the flood zones was carried out using the tools of the ArcScene software shell by overlaying a water layer on the relief map.

Using the GIS functionality in ArcScene, based on the slope map, a three-dimensional model of flooding of key areas was obtained, which was visualized and presented in the form of animation (Fig. 3). Modeling and construction of a flood map were carried out for the flood peak, when the greatest negative impact of flood waters on adjacent territories is manifested.

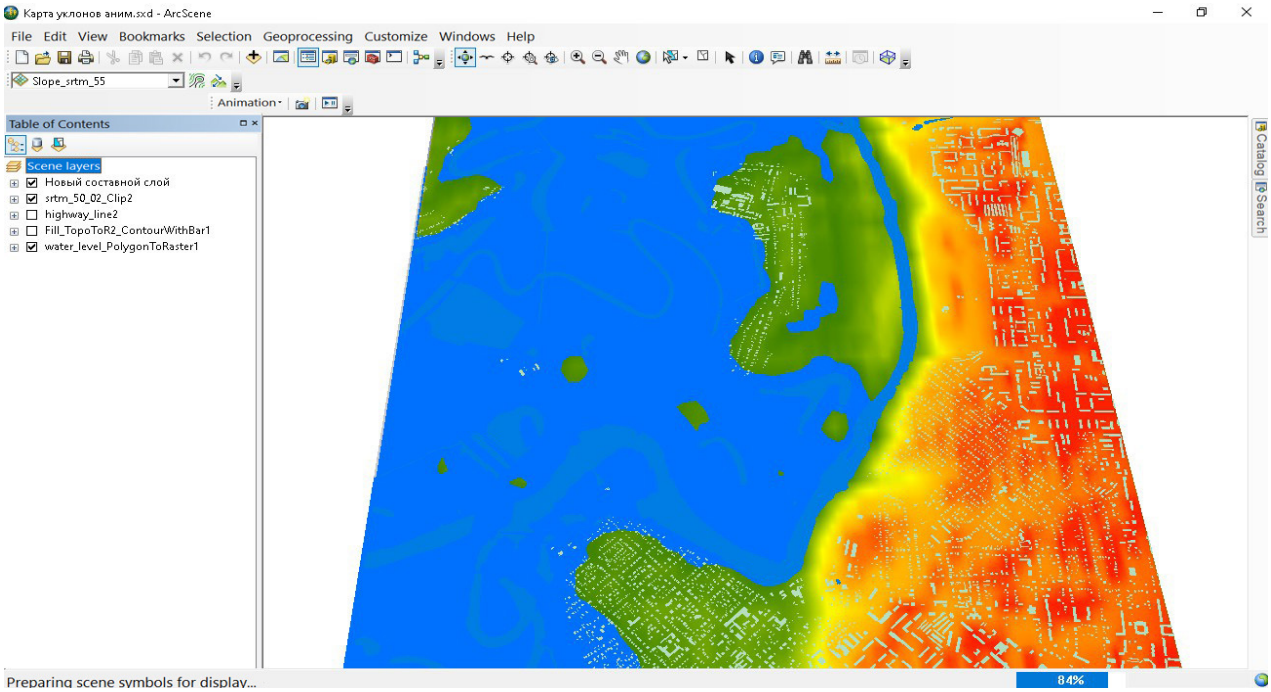

Figure 3 – Scenario of possible flooding in ArcScene

During the approbation of the modeling methodology, scenarios making it possible to determine the flood zones at the maximum level of water rise in the river Yesil were considered. According to the Department of Emergency Situations of the North Kazakhstan region, the maximum rise in the water level in the river Yesil at a gauging station near the city of Petropavlovsk in 2019 was 94.0 m (URL 2: 2022). The boundary of the zone obtained during the construction of the model allows to determine partially or completely flooded areas, settlements, roads, bridges and other infrastructure. By modeling the scenario of the consequences of flooding, it is possible to assess the possible extent of flooding, determine and take timely measures to prevent an emergency before they occur.

The degree of compliance of the flood zone modeling results obtained using GIS and RS was checked by comparing the flood boundary recorded on the date of the flood in 2019. In addition, a comparison was made with the flood boundary obtained by interpolating heights based on the values of water lines increased by the height of its rise during the flood. By comparing the territories that were flooded by flood waters in 2019, an error in modeling the flood zone in the eastern part of the settlement Zarechny was revealed. On the height map built on the basis of SRTM, this section is above 100 m, however, according to the Department of Emergency Situations of the North Kazakhstan region, it is subject to almost annual flooding by flood waters.

The development of the final map of the study area included the creation of layers of physical and geographical objects (the Yesil River, its tributaries, oxbow lakes, natural vegetation), layers of economic development of buildings (residential and industrial buildings, roads, fields, hayfields and pastures). The latest in mapping was the creation of a database, which included a list of characteristics of objects and phenomena.

Results and discussion

As a result of the research, the digital relief model and the three-dimensional model of the flooding of the valley of the Yesil river on the example of key areas were compiled. According to the compiled relief models, it can be seen that, under the condition of a maximum rise in the water level in the Yesil river, a significant area of the territory is subject to flooding. A significant part of the settlements Zarechny and the Podgora became completely flooded. More than 140 residential and industrial facilities, infrastructures, roads turned out to be under water. Omsk highway, road number P-49, 4 km long). Agricultural land, garden (country cottage) plots can be seriously affected. The area of potential flooding was more than 620 ha (Fig. 4). Extensive areas of flooding are noted in the south and west of the considered territory. The floodplain zone, the left bank of the river is subject to the greatest flooding by the Yesil river.

Figure 4 shows a map of the model of the flood zone of the site of the valley of the Yesil river, adjacent to the city of Petropavlovsk, during the period of maximum increase in water level. According to the official website of the Department of Emergency Situations of the North Kazakhstan region, in 2019 the peak of the water level in the river was on May 8 and amounted to 94.0 m relative to the zero of the gauging station. The left bank of the river Yesil to the south of the settlement Zarechny and Podgora area was flooded.

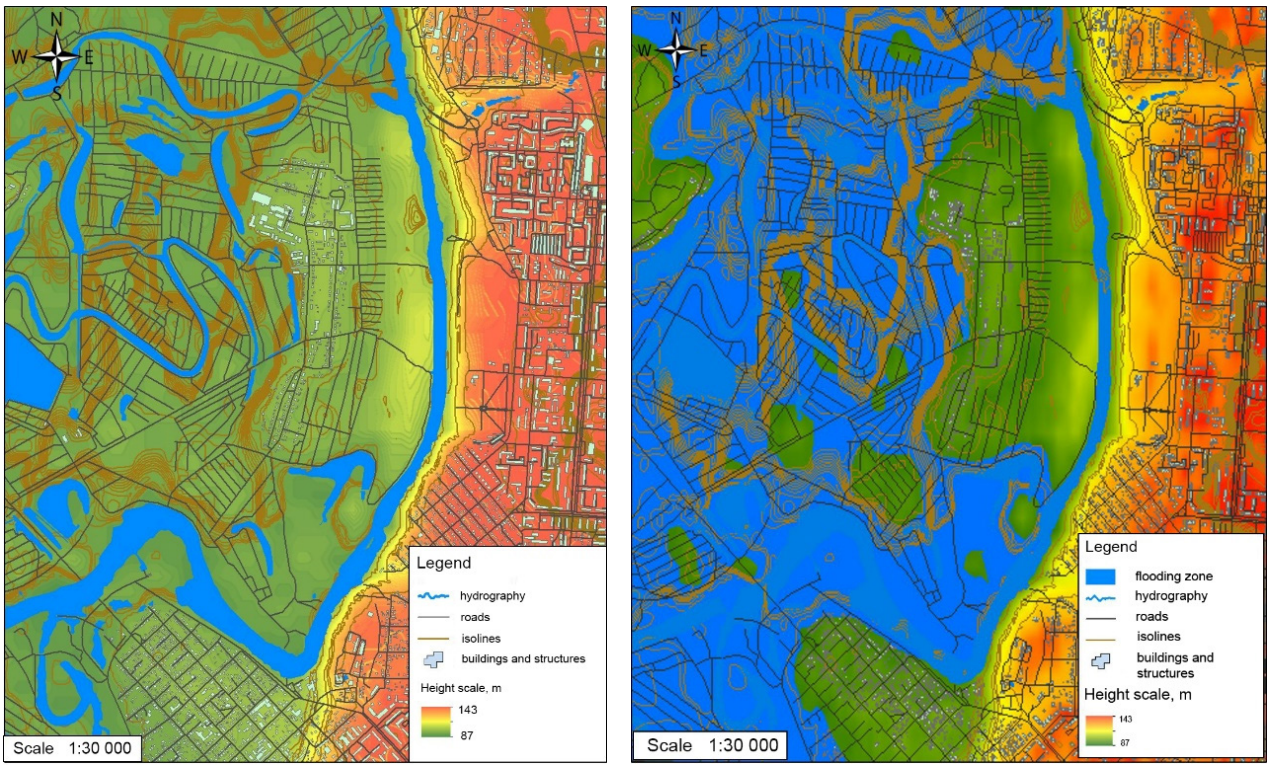

Figure 4 – Map of the relief and flood zone of the valley of the river Yesil

Thus, on the obtained model of flooding, it can be seen that the probable damage from the flooding of adjacent territories by the spring flood waters of the Yesil River is very significant, which will determine the need for operational monitoring and forecasting of hazardous hydrological phenomena.

The GIS package also gives the possibility to simulate the consequences of the emergency situation caused by a possible dam or dike break, to calculate the area of catastrophic flooding of the surrounding area. In addition, the statistical characteristics (minimum, average, maximum depth, water volume) of the flood zone can be calculated. Using the GIS-based forecasting function, it is possible to make short-term and long-term forecasting of flood events in the floodplain and channel system in space

and time. However, calculations of this level of complexity require a series of additional field studies with special equipment, as well as observation over a specific period of time. The obtained data will then allow to correctly compose a GIS flood model. In this article, a GIS modeling method was proposed with insufficient hydrological data.

In areas of possible flooding, the obtained cartographic materials can be useful in assessing the potential risk of emergency, developing the most rational hydraulic engineering methods for protecting this territory and adjacent areas, and will allow timely measures to be taken to help reduce material and social damage from flooding.

Along with this, the developed cartographic materials can serve as a basis for compiling maps of the manifestation of water erosion processes, waterlogging on agricultural land located in the valley, modeling and forecasting possible damage. This will make it possible to solve the strategic tasks of the economic development of the valley of the river Yesil and adjacent territories, to choose the best methods of agricultural production in terms of erosion resistance, to optimize the land management scheme. Such maps and models have a great practical importance for the implementation of design and construction work. The created models, in turn, can serve as the necessary basis for constructing more complex maps, in particular, for the development of synthetic integrated maps for the protection of the study area from hazardous processes, schemes for optimizing nature management and reducing environmental tension. On their basis, priorities and optimal options for economic activity and environmental protection measures can be determined.

The use of RS materials, in particular SRTM, in determining flood zones on rivers, certainly has advantages over existing traditional forecasting methods (water balance, physical and statistical methods, statistical, mathematical models that describe the formation of runoff processes using differential, integral, and other equations and etc.). However, some disadvantages should be noted when modeling a surface based on height matrix SRTM (URL 7: 2022, Kim D. E., Liong S. Y., Gourbesville P., Andres L., Liu J., 2020: 1-14). First of all, it is connected with the nature and features of the relief of the study territory. The region has a flat relief, with insignificant amplitudes of heights, and a weak dissection of the surface. In the conditions of a flat relief, the construction of its detailed model is difficult, because the height amplitude is insignificant. The presence of woody vegetation and forest areas reduces the accuracy of surface modeling. To eliminate possible errors in the construction of height matrix and models, a necessary condition is to conduct a detailed analysis of large-scale (topographic) maps, data on the morphometric structure of the floodplain, field studies with clarification of the morphometric features of the relief on the ground. In this work, modeling of flood zones using GIS was performed without determining and modeling the movement of a flood wave. Carrying out the flood wave modelling contributes to obtaining more accurate results. Also, it is necessary to take into account the difference in the water level along the study area compared to the amount of water rise during the flooding of adjacent territories. Such work should be based on a detailed study and mapping of the river valley in cooperation with the hydrological service.

As recommendations for the prevention of flood events and the adverse consequences associated with them, the following measures can be considered for implementation.

Improving the accuracy of observations of the flow and level of water on the river and the operational provision of hydrometeorological information. Particular attention should be paid to determining the height and amount of water reserves in the snow cover, because flood events are directly reflected in the intensity of spring snowmelt. No less important is the study of the water absorption capacity of the basin, monitoring the state of the soil, the composition of the underlying rocks. Improving the technical equipment of gauging stations, the observation network (for example, the installation of remote instruments for assessing water reserves in the snow cover).

Conclusion

Based on the study, it can be concluded that GIS technologies are important and effective tool for solving the problems of determining the quantitative indicators of the territory relief, which must be taken into account when developing potential flood zones.

Earth remote sensing materials serve as a valuable source of data for creating accurate digital elevation models (DEMs). However, in the conditions of a flat plain relief, their use for the construction of DEMs and models should be based on taking into account possible systematic and random errors. The elimination of the errors can be carried out by introducing appropriate corrections

based on the alignment of DEMs with contour lines and elevations of geodetic network control points according to topographic maps obtained in the course of field research, ground topographic and geodetic measurements.

In general, SRTM data are suitable for topography analysis and use in modeling flood zones, taking into account possible systematic and random errors. Modeling on the basis of SRTM data of flood zones can be considered as one of the approaches to model representation and forecasting of flood zones to prevent negative and emergency situations caused by floods, a sharp rise in water levels. Positive effect from the application of this approach can be achieved through the use of remote sensing data in conjunction with other methods and approaches.

In the course of the study, on the example of a section of the valley of the Yesil river, a technique for creating models of flood zones using GIS technologies based on remote sensing data was tested under the conditions of a lack or absence of hydrological and hydrometric observations.

The obtained materials can be useful to the governing bodies, the Ministry of Emergency Situations of the North Kazakhstan region for solving practical problems, and also involved in the development of an integrated GIS of the basin of the Yesil river.

For the study area, in the future, it is important to conduct studies aimed at a more detailed study of the washout and erosion hazard indicators of soils and underlying soils.

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3-бөлім

МЕТЕОРОЛОГИЯ ЖӘНЕ ГИДРОЛОГИЯ

Section 3

METEOROLOGY AND HYDROLOGY

Раздел 3

МЕТЕОРОЛОГИЯ И ГИДРОЛОГИЯ

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ASSESSMENT OF BIOCLIMATIC CONDITIONS OF WEST KAZAKHSTAN

This article provides an assessment of the bioclimatic conditions of the warm and cold periods for 2010-2020 for the territory of West Kazakhstan on the basis of a comprehensive accounting of meteorological parameters. For this assessment, four bioclimatic indices were calculated, such as effective temperature, equivalent-effective temperature, normal equivalent-effective temperature, the Bodman severity index, on the basis of which the level of comfortness of climatic conditions for the population living in the studied territory was evaluated. The calculations used the initial data of daily temperature, relative humidity and wind speed for the main five stations in West Kazakhstan. The importance of this work is to determine the dependence of human health on climatic factors and to study with the help of the found bioclimatic indicators how favorable the climatic conditions of the territory of West Kazakhstan are for human life and recreation. The analysis of the obtained results revealed that in the cold half of the year a moderately severe type of weather conditions prevails, and in the warm period of the year the climate of the studied territory is considered comfortably warm. In general, the climate of West Kazakhstan can be considered comfortable for living, health and work of the population in this region.

Key words: biometeorology, climate, bioclimatic indices, effective temperature, equivalent effective temperature, Bodman index.

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Батыс Қазақстанның биоклиматтық жағдайларын бағалау

Бұл мақалада метеорологиялық параметрлерді кешенді есепке алу негізінде Батыс Қазақстан аумағы үшін 2010-2020 жылдардағы жылы және суық кезеңдердің биоклиматтық жағдайларына баға беріледі. Осы бағалауды жүргізу үшін төрт биоклиматтық индекстер есептелді, мысалы тиімді температура, эквивалентті тиімді температура, қалыпты эквивалентті тиімді температура, Бодман индексі және солардың негізінде зерттелетін аумақта халықтың өмір сүруі үшін климаттық жағдайлардың жайлылық деңгейі анықталды. Есептеу кезінде Батыс Қазақстандағы негізгі бес станция үшін тәуліктік температураның, ауаның салыстырмалы ылғалдылығының және жел жылдамдығының бастапқы деректері пайдаланылды. Бұл жұмыстың маңыздылығы адам денсаулығының климаттық факторларға тәуелділігін анықтау және табылған биоклиматтық көрсеткіштердің көмегімен Батыс Қазақстан аумағының климаттық жағдайлары адамның тыныстіршілігі мен тынығуы үшін қаншалықты қолайлы екенін зерттеу болып табылады. Нәтижелердің талдауы көрсеткендей, суық жартыжылдықта ауа-райының орташа қатал түрі басым болады, ал жылы мезгілде зерттелетін аумақтың климаты жылы болып саналады. Жалпы, Батыс Қазақстанның климатын осы өңірде халықтың тұруы, денсаулығы және жұмысы үшін қолайлы деп санауға болады.

Түйін сөздер: биометеорология, климат, биоклиматтық индекстер, тиімді температура, баламалы тиімді температура, Бодман индексі.

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Оценка биоклиматических условий Западного Казахстана

В данной статье на основе комплексного учета метеорологических параметров приводится оценка биоклиматических условий теплого и холодного периодов за 2010-2020 годы для территории Западного Казахстана. Для проведения данной оценки были рассчитаны четыре биоклиматических индекса, такие как эффективная температура, эквивалетно-эффективная

температура, нормальная эквивалетно-эффективная температура, индекс суровости Бодмана, на основе которых был выявлен уровень комфортности климатических условий для проживания населения на изучаемой территории. При расчетах были использованы исходные данные суточной температуры, относительной влажности воздуха и скорости ветра для пяти основных станций в Западном Казахстане. Важность данной работы заключается в определении зависимости здоровья человека от климатических факторов и в исследовании с помощью найденных биоклиматических показателей насколько благоприятны климатические условия территории Западного Казахстана для жизнедеятельности и отдыха человека. Анализ полученных результатов выявил, что в холодное полугодие преобладает умеренно суровый тип погодных условий, а в теплый период года климат исследуемой территории считается комфортно теплым. В целом, климат Западного Казахстана можно считать комфортным для проживания, здоровья и работы населения в этом регионе.

Ключевые слова: биометеорология, климат, биоклиматические индексы, эффективная температура, эквивалентно-эффективная температура, индекс Бодмана.

Introduction

For a successful assessment of the comfort of the climate of a certain territory, it is necessary to implement a complex biometeorological characteristic, which, firstly, characterizes the features of the natural environment, and secondly, it can be useful for taking preventive measures for some diseases. The assessment of the bioclimatic conditions of the territory should be carried out using various bioclimatic indices, which are based on various meteorological elements (Yakovenko, 2001). So, there are temperature-humidity and temperature-humidity-wind bioclimatic indices.

Research in the field of studying the impact of climate on human health is currently extensive. Many Russsian and foreign scientists assessed bioclimatic indices for different territories. For example, a bioclimatic assessment was carried out for the territory of the Udmurt Republic (Perevedentsev, 2016), Krasnodar Territory (Kuzyakina and Gura, 2020) and other regions of Russia (Sinitsyn, 2013) using standard indices such as effective temperature, Bodman's index, pathogenicity index, etc. For the territory of the Middle Ob region (Bikmukhametova, 2019), the overall impact of meteorological indicators was assessed using the Total Pathogenicity Index using the Boksha and Bogutsky method, which showed that severe weather conditions occur for most time of the year in the studied territory. In addition to that, this study used the Osokin, Bodman methods and calculated the Wind-Cold Index to assess the severity of the climatic conditions during winter. Isaeva (2008) used the same indexes and added Khairullin and Adamenko methods for the bioclimatic assessment of the severity of the winter in Kazan. A similar methodology was used for an assessment of biometeorological characteristic of the southeastern part of Kazakhstan (Beku, 2013; Nyssanbayeva, 2019). In addition to these bioclimatic indices, additional ones, such as Mean Radiant Temperature, were used to assess the thermal comfort of a person outdoors in sunny weather (Kantor and Unger, 2011). Also, several works are devoted to investigation of diseases associated with extreme weather events (Orimoloye, 2018; Ketterer, 2014; Matzarakis, 2011). For example, Orimoloye et al. (2018) considered diseases (skin cancer, heart disease, heat stroke, diarrhea, etc.) associated with elevated temperatures and radiation in African countries and highlights the importance of taking preventive measures in public health programs. Belkin et al (2015) considered possible health risks in the Antarctic (polar) region to prevent frostbite using the Wind Chill Index (WCI) and the Bioclimatic Climate Severity Index (BISCR). Recently, studies of the impact of climate change on human health are also gaining popularity (Orimoloye, 2019; Szwed, 2010).

Many studies have been devoted to the issues of assessing the impact of the modern climate on various spheres of human life, including tourism, recreation and sports. For example, Pestereva et al. (2018) analyzed the bioclimatic resources of the Russian Far East in the context of modern climate change to enhance health tourism due to the rapid pace of its development in Russia. Stefanovich (2019) analyzed the comfort of recreational conditions in the Crimean region. In their study, they use the calculation of the partial oxygen density according to the method of Ovcharova, which is actively used in the preparation of medical forecasts.

Pavel Ichim and Lucian Sfîcă (Ichim 2020) conducted a study to determine the conditions of human bioclimatic stress in the area of the city of

Yash in Romania using the Thermohygrometric Index (THI) as well as the Relative Deformation Index (RSI), the analysis of which showed that in general, rural areas are more comfortable for living in summer, while comfortable conditions are observed inside the city in winter.

Also, in connection with the outbreak of the global COVID-19 pandemic, some scientists have tried to find a connection between climatic conditions and the spread of this virus. For example, Werner P. et al. (2021) in their article investigated the influence of climate and bioclimate on cases of COVID-19 in Poland. They hypothesized that as the air temperature drops, the number of cases of COVID-19 increases (Werner, 2021).

This study provides an assessment of bioclimatic conditions for the area of West Kazakhstan using the most frequently used indices in practice, which are the most effective and informative: Effective Temperature, Equivalent-Effective Temperature, Normal Equivalent-Effective Temperature and Bodman's Severity Index. Meteorological data from five stations Aktau, Aktobe, Emba, Uralsk, Atyrau (Figure 1) were used in this study. When calculating the indices, we used the data of the average values of air temperature, relative humidity and wind speed for the period from 2010 to 2020 for the considered stations in West Kazakhstan. This work can be used in the field of public health and recreation.

Materials and methods

Currently, several dozen complex biometeorological indicators have been developed that are used to solve various problems. Bioclimatic indicators are calculated for warm and cold periods (Rusanov, 1981:70).

Radiation Equivalent Effective Temperature (REET) proposed by G. Sheleikhovsky is used to assess recreational and climatic resources for the warm period (Khairullina, 2005:231). REET is an indicator of a person's thermal sensation under the influence of the complex effects of several factors such as air temperature and relative humidity, wind speed and solar radiation.

For the purpose of an analytical assessment of the heat sensations of a dressed person (summer clothes of the same type), I. Butyeva proposed a Normal Equivalent-Effective Temperature (NEET), taking into account the influence of temperature, air humidity and wind speed. The NEET is recognized as comfortable in the temperature range from +17 to +22 °C (Khairullina, 2005:231).

Figure 1 – West part of Kazakhstan including West Kazakhstan, Aktobe, Atyrau and Mangystau regions

The Biologically Active Temperature (BAT) that was proposed by G. Tsitsenko makes it possible to determine the complex effect of temperature, air humidity, wind speed, total solar radiation, long-wave radiation of the underlying surface on a human. The BAT comfort zone is within the temperature range from +10 to +20 ºC (Khairullina, 2005: 231; Shtal, 1981:18).

Methods for assessing the severity of the weather also exist for bioclimatic assessment of the cold period. The severity of weather can be estimated by the values of low air temperature and wind speed, which affect the cooling of unprotected parts of body and respiratory organs. In other words, it can be considered not as an objective property of the weather, but as its influence on the cooling of a person, as a result of which the stay in the open air is limited and there is a need for clothing. To assess the severity of the weather the Bodman method is most often used (Kolokotroni, 2003: 26; Vitchenko, 2007:102).

Effective Temperature (ET) is one of the main biometeorological indices characterizing the effect of a complex of meteorological elements (air temperature and humidity) on a person through a single indicator, the so-called effective air temperature. The body's resistance to the environment depends on the physical characteristics of a person. Index ET combines the physiological and physical factors of the body, clothing and meteorological environmental factors. ET is designed for an “average” person, that is, an adult of average height and weight, dressed according to weather conditions and walking in shade (Khairullina, 2005: 231).

ET is directly proportional to air temperature and relative humidity. ET was calculated using Equation 1 that was also used in other similar studies (Perevedentsev, 2016: 533):

$$ET = t - 0{,}4 \cdot (t - 10) \cdot (1 - \frac{f}{100}) \quad (1)$$

where, t – dry air temperature (°C); f – relative humidity (%).

The calculation of ET can be used to assess thermal loads in different seasons and environmental comfortness and can also be used for climate treatment. Using the calculated values, it is possible to determine the thermal state at meteorological stations. Table 1 shows the comfort level scale based on ET values for warm (from April to September) and cold (from October to March) seasons.

Table 1 – Scale of effective air temperature during warm and cold periods

Warm period		**Cold period**	
Comfort level	**ET values °C**	**Comfort level**	**ET values ºC**
"very hot"	>30	"very cool"	-6-12
"hot"	24-30	"moderately cold"	-12-18
"comfortably warm"	18-24	"cold"	-18-24
"comfortable"	12-18	"very cold"	-24-30
"cool"	6-12	"frostbite threat"	>-30
"moderately cool"	-6-+6		

Equivalent Effective Temperature (EET) takes into account the complex effect of temperature, air humidity and wind speed on a person. EET is a combination of meteorological values that produces the same thermal effect as stationary air at 100% relative humidity and a certain temperature, and evaluates the heat sensation of a person naked to the waist. EET calculations are made according to the formula of A. Missenard (Beku, 2013: 68):

$$EET = 37 - \frac{37 - t}{0.68 - 0.0014f + 1/\left(1.76 + 1.4v^{0.75}\right)} - 0.29t\ \left(1 - f/100\right), \quad (2)$$

where t – air temperature (°C); v – wind speed (m/s); f – relative humidity (%).

The bioclimatic index EET can be used to characterize the comfortness of both warm and cold periods of the year (Table 2). EET is determined by a combination of meteorological factors in which a person naked to the waist experiences subjectively good heat sensation and maintains a normal body temperature. Unlike ET, this index takes into account wind speed, in addition to relative humidity and air temperature.

Table 2 – Equivalent – effective air temperature scale

Heat sensation category	EET for humans, °C	
	unclothed	clothed
Comfortable	20-30	16,7-20,6
Cooling zone	6-12	less 16,7
Overheating zone	higher 21,7	higher 20,6

In addition to the EET index, the Normal Equivalent-Effective Temperature (NEET) was calculated using formula of Butyeva (3) to assess the heat perception of a dressed person (Sinitsyn, 2013: 281):

$$NEET = 0.8 \cdot EET + 7\ °C \quad (3)$$

In NEET index the fact that at an air temperature below -7 °C any wind has a cooling factor was taken into account. The NEET indicator is used to assess the heat perception of a dressed person, and, accordingly, is a more informative indicator of the comfort of the climate than EET (Sinitsyn, 2013: 281).

For the bioclimatic assessment of the cold period, the Bodman Index can be used to evaluate the severity of the weather in points (Khairullin, 1997: 132). The index can be calculated using equation 4:

$$S = (1 - 0.04 \cdot t)(1 + 0.27 \cdot v), \quad (4)$$

where S – severity index (points); t – air temperature (°C); v – wind speed (m/s).

Table 3 provides a scale for the level of comfortness according to the Bodman's Index

Table 3 – Bodman Severity Index scale

Comfort level	Value S
"warm winter"	S < 1
"mild winter"	1–2
"moderately severe"	2–3
"severe"	3–4
"very severe"	5–6
"extremely harsh"	>6

In addition to the Bodman Index, the Adamenko-Khairulin "Reduced Temperature" Index was calculated (Tkachuk, 2012: 12; Abdirazak, 2016: 85). This index takes into account human heat losses depending on the combination of actual air temperatures and wind speeds, compared to heat losses with the same air temperature, but in calm wind conditions. The index is also used in assessing the severity and continentality of the climate. The index is considered to be more objective in assessment of the discomfort of the cold period compared to the Bodman Weather Severity Index since takes into account the warming effect of radiation. The Index of "Reduced Temperature" is calculated by the formula:

$$t_{red} = t - 1.8\sqrt{V}, \quad (5)$$

where $t_{red.}$ – reduced temperature; t – actual temperature; V – wind speed.

Results and discussion

The Effective Temperature Index characterizes the heat perception of an undressed human body. The same heat perception can be experienced with a wide variety of combinations of meteorological elements. Figure 2 shows a graph of annual distribution of the average effective air temperature for studied stations in West Kazakhstan for the period of 2010 – 2020.

The values of the ET depend more on air temperature than on humidity, and repeat the spatial distribution of temperature, slightly increasing from north to south. The difference between the northern (Uralsk, Aktobe, Emba) and southern (Atyrau, Aktau) stations can be from 2.5 до 10 °C. As a result of calculations, it was found that in the territory of West Kazakhstan during the year, the ET value ranges from 1.0 to -11.3 ºC in winter and 21.4 to 23.9 ºC during summer, which corresponds to the level of comfortness from "very cool" to "hot".

During the transitional seasons of the year, the Effective Temperature Index varies from -1.8 to 18.9 ºC. Thus, conditions in early spring and late autumn are characterized as “moderately cool”, while conditions in late spring and early autumn are characterized as “comfortable”. Thus, the climate from the first half of April to October, when the average monthly values of the ET are above 12.0 ° C, can be called comfortable for the population of West Kazakhstan.

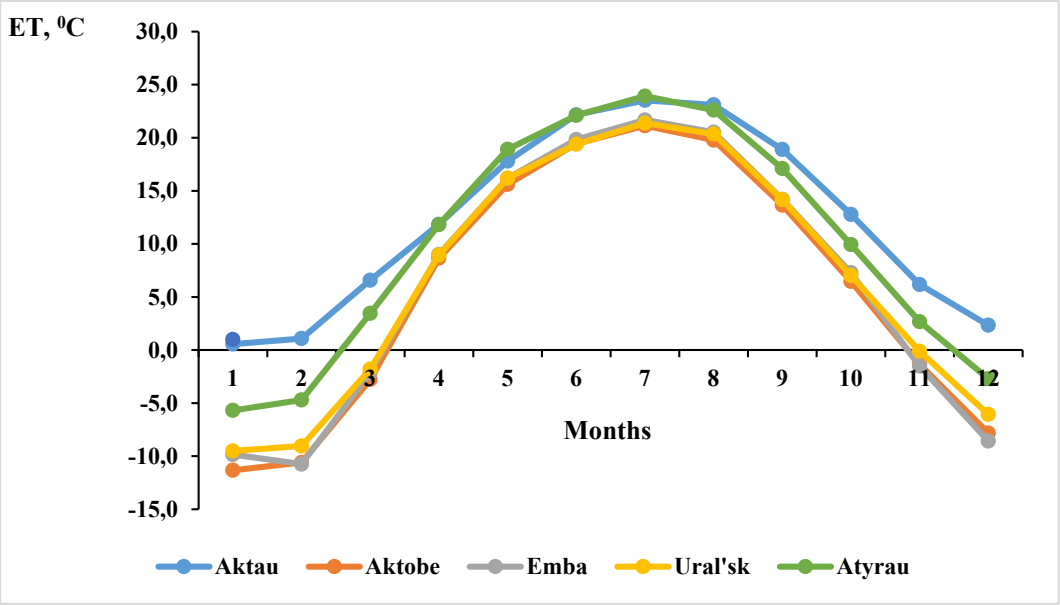

Figure 2 – Annual variation of the average effective temperature for considered stations in West Kazakhstan

Figure 3 shows the histogram of the average annual ET value for the stations in the region under study.

It was found that in the territory of West Kazakhstan during the year the value of ET ranges from 5.9 to 12.2 °C. Based on the graph shown in Figure 3, it can be seen that the highest average annual effective air temperature was noted at Aktau station (12.2 °C), and the lowest – at Aktobe station (5.9 °C) during the period from 2010 to 2020.

Figure 4 shows the dynamics of the average monthly January and July Effective Temperature over the last decade (2010-2020).

Based on Figure 4, there is a pronounced positive trend of the ET in January at all the stations studied. However, in July, there is a downward trend in the values of the ET for the same period under consideration. Over the past decade, the minimum values of the average monthly ET for January were observed in 2010 and the maximum average July ET values were observed in 2010, 2011 and 2018.

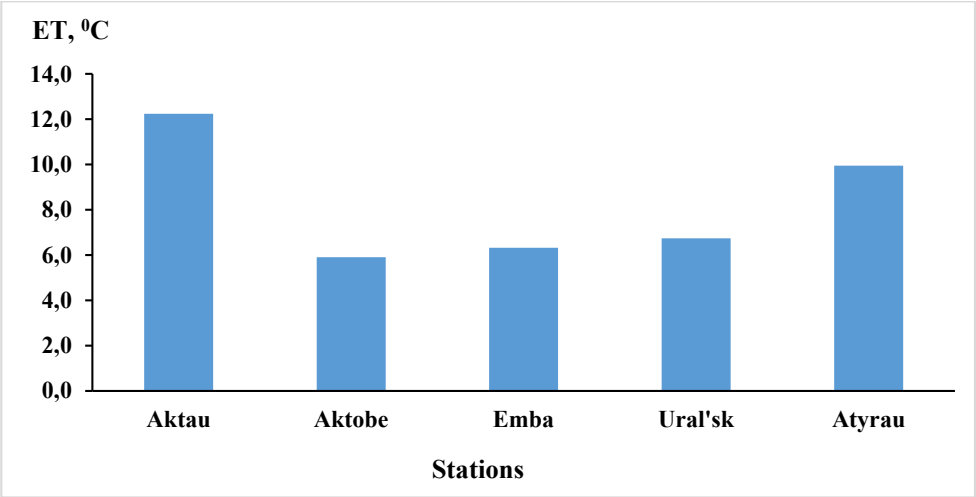

Figure 3 – Average annual values of ET for considered stations in West Kazakhstan for the period 2010-2020.

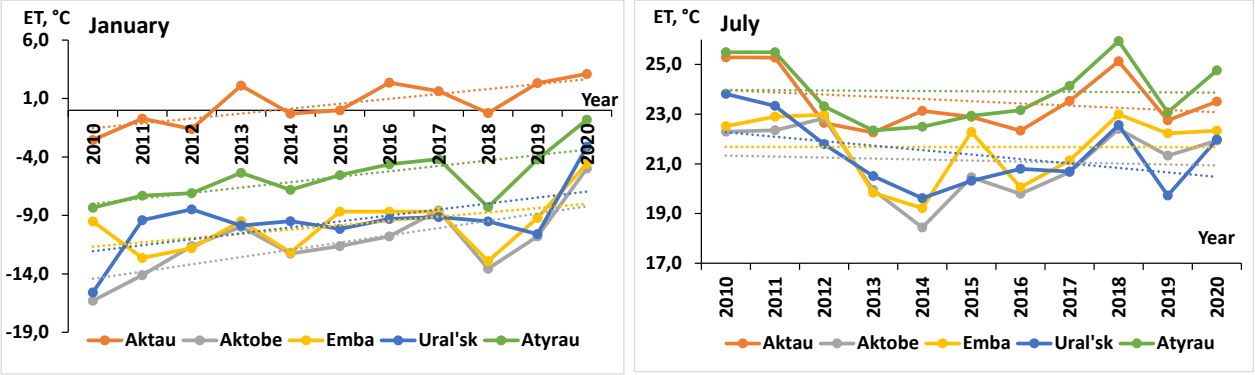

Figure 4 – Changes in the average January and Average July effective temperature (ET) for considered stations in West Kazakhstan (2010-2020)

The next index, which was calculated in the course of this work, is the EET indicator, which characterizes the heat perception of the human body in the dressed form. Figure 5 shows the graph of the annual variation of the average equivalent-effective air temperature for the studied stations for the period of 2010 – 2020.

According to the Missenard method, the average monthly values of human thermal sensitivity range from “comfortably warm” in summer to dangerous “frostbite threat” in winter months. In winter, the average EET values vary from -29.3 °C (Emba) to -10.2 °C (Aktau). In summer, the spatial variability of the EET is two times lower: the minimum values are typical for the northern stations (Uralsk, Emba, Aktobe) from +15.6 to +18.4 °C ("comfortable" conditions), the maximum values were observed in Aktau and Atyrau (+18.5 to 21.1 °C) ("comfortably warm" conditions). The spatial distribution of the index within the region repeats the distribution of the temperature and the ET index.

Figure 6 shows the graph of changes in the average monthly EET for January and July for the period 2010-2020.

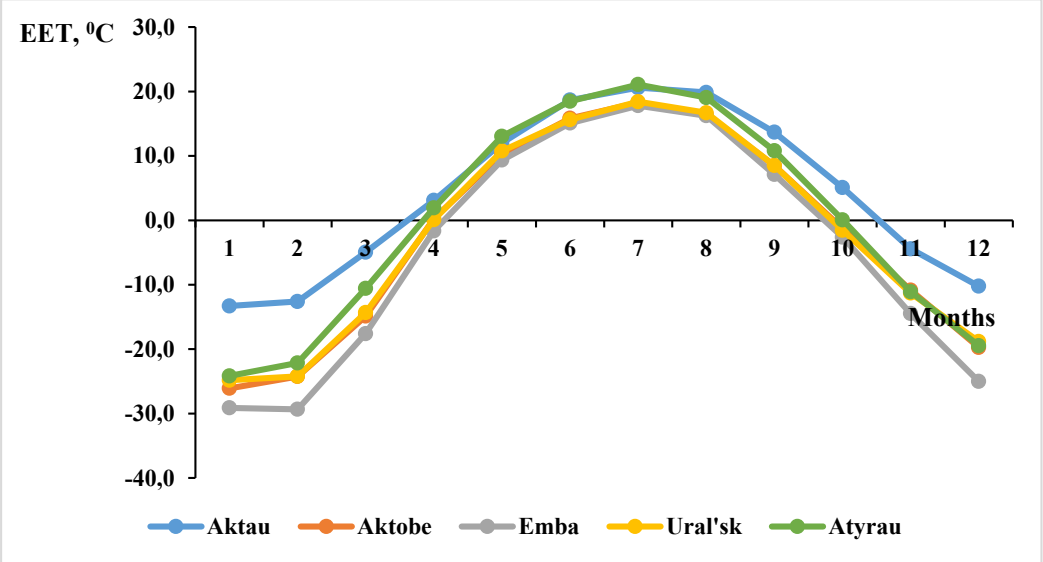

Figure 5 – Annual variation of the average equivalent-effective air temperature for considered stations in West Kazakhstan

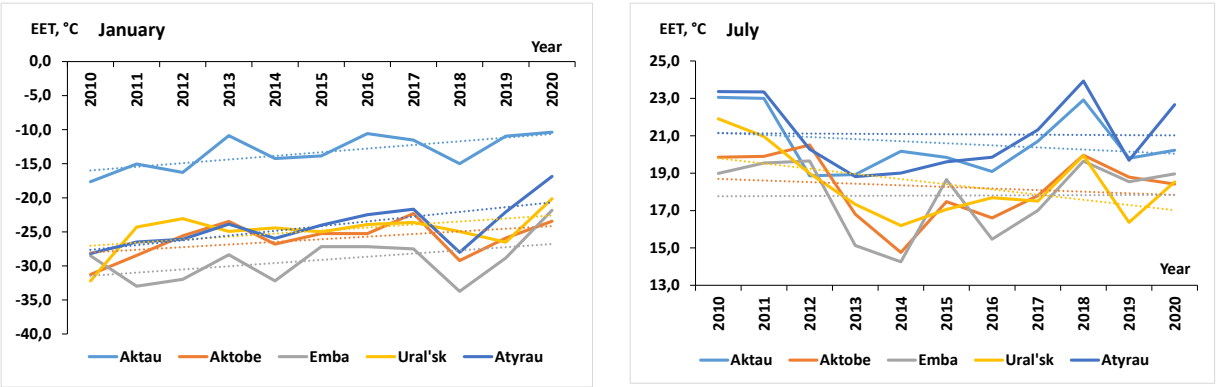

Figure 6 – Changes in the average January and average July equivalent-effective temperature (EET) for considered stations in West Kazakhstan (2010-2020)

From the Figure 6, it follows that in January, at all the stations under study, as it was with the case of ET, there is a positive trend in EET values. In July, almost all stations have a negative trend of EET values, with the exception of Emba station. The time course of the average January and average July EET values is analogous to the time course of the ET.

Figure 7 shows the annual distribution of the average normal equivalent-effective air temperature for the stations under consideration for the period 2010-2020.

It should be noted that the values of the NEET significantly exceed the corresponding values of the EET for the same annual course. The cold period of the year (October-April) is characterized by negative NEET values. Thus, in winter, according to the NEET value, Aktobe, Emba, Uralsk, Atyrau are in the zone of "very cold" discomfort, while Aktau is in the zone of "moderate cold". In December, January and February, the NEET values could reach -28.3, -33.1, -33.1 °C, respectively, which has negative consequences for the well-being and health of people. In the first half of spring and in the second half of autumn, West Kazakhstan is in the zone of "very cool" and "moderately cold", only Aktau is characterized by relatively "warm" NEET values (1.4 °C and 3.6° C, respectively) and is in "moderately cool" zone. May and September are

characterized as “cool” in terms of the NEET value (from 5.7 to 12.8 ° C). In all summer months, according to the NEET indicator, the climate of the region under consideration can be characterized as “comfortably warm”. Consequently, the climatic conditions in the summer are favorable for a person's stay in the open air and should not cause unfavorable heat sensations.

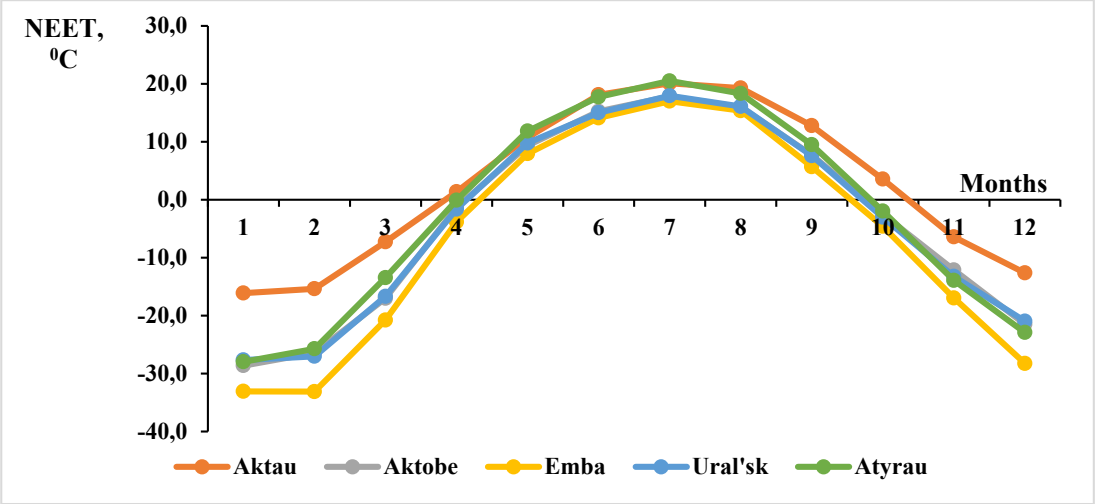

Figure 7 – Annual variation of the average normal equivalent-effective temperature for considered stations in West Kazakhstan

Figure 8 shows the time series of the average monthly Normal Equivalent-Effective Temperature (NEET) for January and July for 2010-2020.

Recently, there has been an increase in the trend of the NEET values for January, while in July there is no pronounced change in the trend. This result is similar to the results of studies conducted in other regions (Perevedentsev, 2016; Nysanbayeva, 2019).

Table 4 shows the average values of the Bodman Severity Index, calculated for the cold season months from 2010 to 2020 for stations in West Kazakhstan.

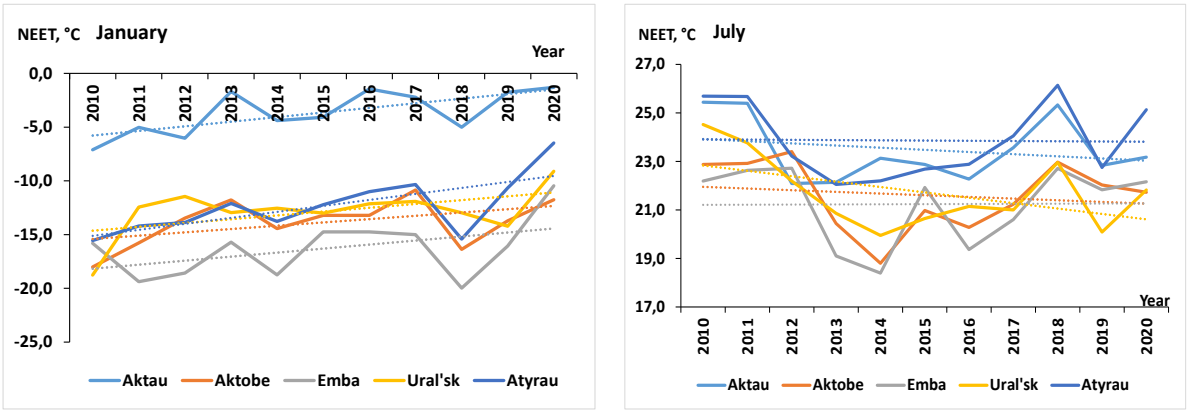

Figure 8 – Changes in the average January and average July normal equivalent-effective temperature (NEET) for considered stations in West Kazakhstan (2010-2020)

Table 4 – Average values of the Bodman Index for considered stations in West Kazakhstan from 2010 to 2020

Stations	January	February	March	October	November	December
Aktau	2,1	2,0	1,6	0,9	1,5	1,9
Aktobe	2,6	2,4	2,0	1,2	1,7	2,9
Emba	3,3	3,2	2,5	1,5	2,1	2,8
Uralsk	2,6	2,6	2,0	1,2	1,8	2,2
Atyrau	3,0	2,9	2,3	1,4	2,2	2,7
Average	2,7	2,6	2,1	1,2	1,8	2,5

Most of West Kazakhstan during the winter period is characterized as moderately severe by the Bodman Index (S = 1.9-3.0). During the study period, among all stations, Emba stands out with its highest values of the S index, for example, the average monthly value of S was 3.2 and 3.3 in January and February could be associated with significant wind speeds at low temperature values.

From the table 4, it follows that the Bodman Index in the territory of West Kazakhstan varies from 0.9 to 3.3 points with the lowest values in Aktau and Emba for the entire cold period of the year. The winter months are characterized by the highest values of the severity index. For example, the average value of the Bodman Index for West Kazakhstan is 2.4, 2.7, 2.5 for December, January and February, respectively, while in October and November these values were 1.3 and 2.0. Thus, the bioclimatic conditions of the cold half of the year in this territory are characterized as low and moderately severe.

Table 5 shows the average values of the Reduced Temperature, calculated for the cold season months from 2010 to 2020 for considered stations in West Kazakhstan.

Table 5 – Average values of the Reduced Temperature considered stations in West Kazakhstan from 2010 to 2020

Station	Months					
	January	February	March	October	November	December
Aktau	-3,6	-3,1	2,6	9,9	2,5	-1,7
Aktobe	-16,0	-15,1	-7,0	3,2	-5,0	-11,8
Emba	-15,4	-16,1	-7,3	3,3	-5,9	-13,6
Uralsk	-14,2	-13,6	-6,3	3,7	-3,9	-10,0
Atyrau	-10,5	-9,8	-1,7	6,0	-2,2	-7,6
Average	-11,9	-11,5	-3,9	5,2	-2,9	-8,9

According to the values of the Reduced Temperature, there were no severely uncomfortable conditions in the West Kazakhstan region. The lowest values of the Reduced Temperature of Khairullin-Adamenko were observed in January (from -3.6 to -16 °C) at all stations, except for Emba, where the minimum is in February (-16.1 °C). Among all considered stations, the minimum values were observed at Aktobe and Emba stations during the cold season. In January and February in Uralsk, Emba and Aktobe the given temperatures were considered to be relatively favorable. At other stations in the remaining months, the index indicates the favorable climate of the region.

Conclusion

Active synoptic activity during the cold half of the year in West Kazakhstan can form uncomfortable conditions, which were confirmed by the results of this work based on values of ET, EET, NEET, Bodman's Index, Reduced Temperature.

ET, EET and NEET indices show that during the cold half of the year (October-April), the northern part of the West Kazakhstan is in the "very cold" zone, while the southern part (Aktau) is in the "moderate cold" zone. Very low values of these indices in the northern part of West Kazakhstan can lead to negative consequences for the well-being

and health of people. In the first half of spring and in the second half of autumn, West Kazakhstan is in the zone of "very cool" and "moderately cold", only Aktau is characterized by "warmer" values of ET, EET and NEET. May and September are characterized as "cool" months. In all summer months, according to the indicators of ET, EET and NEET, the climate of the studied region can be described as "comfortably warm". Therefore, the climatic conditions in the summer are favorable for a person's stay in the open air and should not cause unfavorable heat sensations.

According to the calculated values of the Bodman Severity Index for the cold period of time (October-March), it was found that the Bodman Index in the territory of West Kazakhstan varies from 0.9 points to 3.3 points. In general, the bioclimatic conditions of the cold half of the year in the study area are characterized as low and moderately severe.

Based on the obtained results, the climate of West Kazakhstan from the first half of April to October, when the average monthly values of ET are above 12 °C, can be called comfortable for the population of this region. Bioclimatic conditions of West Kazakhstan vary significantly from season to season and knowledge of climatic features makes it possible to choose the optimal conditions for people to live in a particular zone. The values of the Reduced Temperature indicate favorable climatic conditions in the West Kazakhstan region.

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ОСОБЕННОСТИ ЛЕДООБРАЗОВАНИЯ НА ОЗЕРЕ БАЛКАШ В ЭКСТРЕМАЛЬНО ХОЛОДНЫЕ И ЭКСТРЕМАЛЬНО ТЕПЛЫЕ МЕСЯЦЫ

В статье рассматриваются процессы ледообразования на оз. Балкаш в экстремально холодные и экстремально теплые месяцы. Была выявлена тесная связь между среднемесячной температурой воздуха ноября и сроками появления первого льда и установления ледостава. Для ноября был рассчитан критерий аномальности Багрова-Токарева и определены экстремальные годы с 2000 по 2022 гг. Были рассчитаны средние даты характерных ледовых явлений за период 1971-2018 гг. Были проанализированы особенности ледообразования в осеннезимний период в эти годы. Рассчитаны числа дней с определенными разновидностями ледовых явлений и представлены в виде гистограмм. Были проанализированы различные виды и формы ледяных образований (забереги, сало, несплошной ледостав, торосы, ледостав с торосами, подвижка льда) в экстремально холодные и экстремально теплые месяцы до срока установления сплошного ледостава. Были построены карты с распределением толщины льда. Было найдено отклонение (количество дней) сроков появления первого льда и установления ледостава от средних в экстремально холодные и экстремально теплые годы.

Источником результата анализа являлись данные из гидрологических ежегодников, данные среднемесячной температуры воздуха, а также данные реанализа климатической базы данных CDS COPERNICUS Европейского центра.

Ключевые слова: ледообразование, толщина льда, ледостав, забереги, экстремально холодный месяц, экстремально теплый месяц.

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Features of ice formation on Lake Balkash in extremely cold and extremely warm months

In this paper we are considering the processes of ice formation on Balkash Lake during extremely cold and extremely warm months. A significant correlation found between the average monthly air temperature of November, the dates of the first ice formation and the dates of continuous ice cover formation. The Bagrov-Tokarev anomaly criterion for November was calculated and the extreme years since the earlier 2000s were determined. The most common dates of inherent ice phenomena for the period 1971-2018 were calculated. The features of ice formation during the autumn-winter season for these years were analyzed. The number of days with certain types of ice phenomena are calculated and presented in the form of histograms. It was analyzed the various types and forms of ice formations for extremely cold and extremely warm months before the date of complete ice cover formation. The maps of ice thickness distribution were compiled. The deviation of the dates of the first ice formation and dates of continuous ice cover formation (in days) from the mean value extremely cold and extremely warm years was found.

The data source were hydrological guides, monthly average air temperature data, and data reanalysis using the CDS COPERNICUS climate database of the European Center.

Key words: ice formation, freeze-up, ice thickness, ice cover, extremely cold month, extremely warm month.

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Экстремалды суық және экстремалды жылы айларда Балқаш көлінде мұздың қалыптасу ерекшеліктері

Бұл мақалада Балқаш көлінің экстремалды суық және экстремалды жылы айладра мұздың қалыптасу мәселелері қарастырылады. Қарашаның орташа айлық ауа температурасы мен алғашқы мұздың пайда болуы және мұз жамылғысының орнауы мерзімдері арасында тығыз байланыс анықталды. Қараша айы үшін Багров-Токарев аномалия өлшемі есептелді және 2000 жылдардан бастап экстремалды жылдар анықталды. Мұз құбылыстарының орташа күндері 1971-2018 жылдар аралығында есептелді. Осы жылдардағы күзгі-қысқы кезеңдегі мұздың пайда болу ерекшеліктері талданды. Мұз құбылыстарының белгілі бір түрлері бар күндер саны есептелді және гистограмма түрінде ұсынылған. Мұз қалыптасуының әр түрлері мен формалары (алғашқы мұз түрлері, толық мұз жамылғысы, мұздың қозғалысы) экстремалды суық және экстремалды жылы айларда мұз жамылғысы орнау мерзімі дейін талдануы өте маңызды. Мұз қалыңдығының көл аквтароиясы бойныша таралу карталары салынды. Алғашқы мұздың пайда болу және мұз жамылғысын орнауы экстремалды суық және экстремалды жылы жылдардағы орташа мерзімдерден ауытқуы (күндер саны) табылды.

Деректер көзі гидрологиялық жылнамалардан алынған ақпарат, ауаның орташа айлық температурасы, Еуропалық орталықтың CDS COPERNICUS климаттық базасынан алынған реанализ ақпараты болды.

Түйін сөздер: мұз қалыптасуы, мұз қалыңдығы, мұз жамылғысы, экстремалды суық айлары, экстремалды жылы айлары.

Введение

Озеро Балкаш – это водоем с ежегодным ледообразованием в течение года с отрицательными суточными температурами воздуха. Западная и восточная часть озера, соединенная проливом Узынарал, различна по химическим характеристикам. Минерализация воды в западной части составила 1,70 г/л, а восточной части – 4,91 г/л (Скоцеляс, 1995). Процесс ледообразования в восточной части замедлен изза повышенной минерализации (Ресурсы поверхностных вод, 1970). Озеро Балкаш является крупным региональным водоемом, которому посвящено огромное количество работ (Бейлинсон, 1989, Чередниченко, 2009, Шиварева, 2009, Ивкина, 2015, Турсунов, 2015, Вилесов, 2017, Белдеубаев, 2019).

Озерный лед имеет очень важное значение в физических, химических и биологических процессах. Наличие и отсутствие ледового покрова важно для транспорта (использование ледового покрова в качестве дорог и переправ, сезонное судоходство в безледоставный период) (Bonsal et al., 2007). При разрушении ледового покрова, вызванного воздействием ветра или течений, могут создаваться условия для образования опасных ледовых явлений. Дрейф льда, навалы льда, торосы могут оказать разрушительные воздействия на берега, гидротехнические сооружения и инфраструктуру (Богородский, 1971). Роль ледового покрова имеет большое значение в зимнем режиме водоема, так как через слой льда и снега на нем происходит теплообмен между водой и воздухом (Одрова,1979). Исследование процессов взаимодействия озерного льда и климата необходимо для климатического моделирования и прогноза погоды (Brown et al., 2010, Eerola et al., 2010). Сроки появления первого льда, установления ледостава, вскрытия и разрушения ледостава являются хорошими индикаторами изменения климата (Magnuson et al., 2000, Duguay et al., 2006, Assel et al., 2003, Latifovich et al., 2006). Поскольку озерные и речные льды, являются частью криосферы, их характеристики также подвержены трансформации в результате климатических изменений. На озерах и реках северного полушария сокращается ледовый период, наблюдаются сдвиги дат начала ледостава в сторону более поздних и дат разрушения ледостава в сторону более ранних (IPCC. Climate change 2013, Magnuson et al., 2000, Newton et al., 2021). Несмотря на общую тенденцию изменения характерных дат ледовых явлений оз. Балкаш (Белдеубаев, 2021), имеет смысл рассмотреть отдельные экстремальные годы осеннезимнего периода. Необходимо выявить насколько и в ка-

кую сторону отклоняются даты появления льда и начала ледостава от средних дат на оз. Балкаш.

Материалы и методы

В данной работе использовались данные о ледовых явлениях с гидрологических постов, среднемесячная температура воздуха с метеорологических станций и данные реанализа по толщине льда ERA5-Land data (ERA5-Land hourly data from 1950 to present (copernicus.eu)). К данным о ледовых явлениях относятся сроки появления первого льда и установления ледостава. За дату появления первых ледяных образований принята дата образования устойчивых заберегов, плавучего льда, шуги или ледостава. За начало ледостава принята дата появления устойчивого неподвижного ледяного покрова продолжительностью не менее 20 суток.

На рисунке 1 изображены расположения метеорологических станций (МС) и гидрологических постов (ГП).

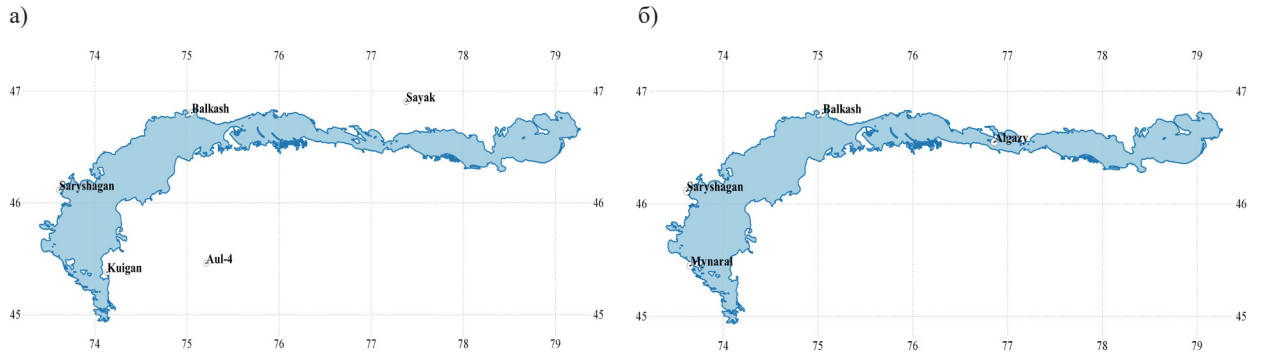


Рисунок 1 – Расположение а) метеорологических станций и б) гидрологических постов исследуемого объекта.

Результаты и обсуждение

Холодный период на оз. Балкаш по данным 5-ти метеорологических станций (Аул4, Балкаш, Куйган, Сарышаган, Саяк) длится с ноября по март (рис. 2).

Из рисунка 2 видно, что распределение средней многолетней температуры воздуха на всех метеорологических станциях аналогично.

Температура воздуха является одним из главных факторов ледообразования. На появление ледяных образований и установление ледостава значительное влияние оказывает температура воздуха в ноябре.

На рисунках 3 и 4 приведены зависимости средней месячной температуры воздуха в ноябре и сроками появления первого льда, а также сроками установления ледостава.

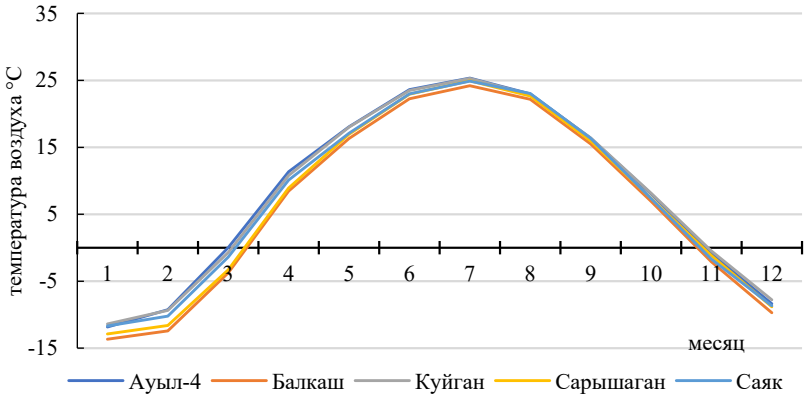


Рисунок 2 – Годовой ход средней месячной многолетней температуры воздуха за 1971-2020 гг.

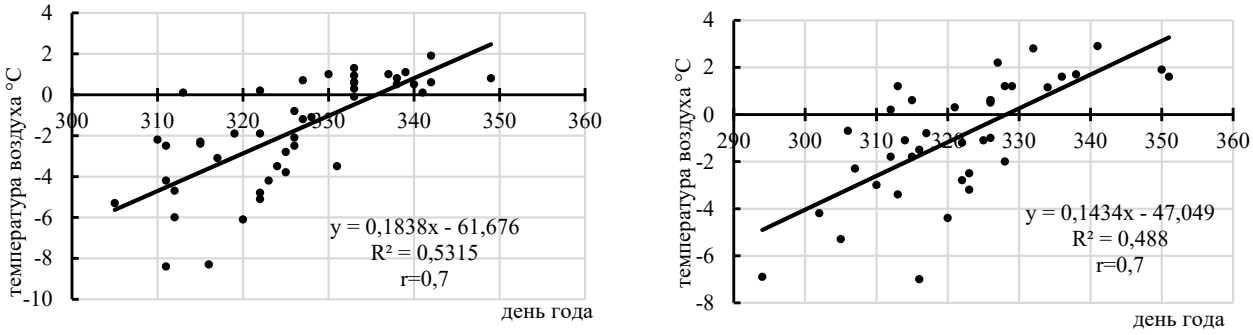


Рисунок 3 – Диаграммы рассеяния между средней месячной температурой воздуха и датами появления ледяных образований на постах Балкаш и Сарышаган

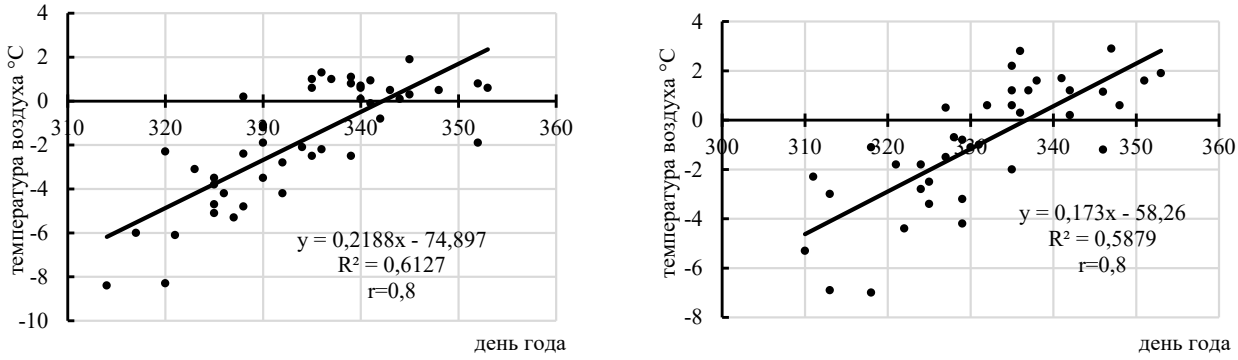


Рисунок 4 – Диаграммы рассеяния между средней месячной температурой воздуха и датами начала ледостава на постах Балкаш и Сарышаган

По данным рисунков 3 и 4 видно, что связь между температурой и сроками ледовых явлений прямая, теснота корреляционной связи высокая 0,7-0,8 доля вклада тренда в общую дисперсию приемлема для превышающих 50 %.

По критерию аномальности БагроваТокарева (Багров, 1966) был выполнен расчет экстремально холодных (ЭХ) и экстремально теплых (ЭТ) лет для ноября за период 2000-2020 гг.

$$К_Т = \frac{1}{N+M}\left[\sum_{n=1}^{N}\left(\frac{\Delta T_i}{\delta_i}\right)_n^2 - \sum_{m=1}^{M}\left(\frac{\Delta T_i}{\delta_i}\right)_m^2\right], \quad (1)$$

где ΔT_i – аномалия параметра в точке i;

δ_i – среднее квадратическое отклонение величины;

N – количество точек, при T>0;

M – количество точек, при T<0.

Для индекса аномальности БагроваТокарева установлены пороговые значения: при К ≥ 1,15 аномальность поля значительна, при К ≤ 0,75 отмечается незначительная аномалия и при 0,75 < К < 1,15 аномалия имеет среднюю интенсивность.

В таблице 1 приведен экстремально холодные и экстремально теплые годы для ноября за период 2000-2020 гг.

В таблице 2 приведены среднемесячная температура воздуха и его аномалия.

Анализ таблицы 2 показывает, что в экстремально холодные годы аномалия варьирует в пределах минус 3,9 – минус 3,4 °С, а в экстремально теплые годы в пределах 2,7-3,5 °С.

В таблице 3 приведены средние значения сроков появления первого льда и сроков установления ледостава.

В соответствии с таблицей 3 видно, что по данным четырех гидрологических постов средний срок появления первого льда приходится на вторую половину ноября. Средний срок установления ледостава по данным постов Балкаш и Сарышаган приходится на конец ноября, а на постах Мынарал и Алгазы на начало декабря.

В таблице 4 представлены сроки появления первого льда и установления ледостава в 2000 году.

Таблица 1 – Экстремально холодные и экстремально теплые годы для ноября за период 2000-2020 гг.

ЭХ		ЭТ	
годы	значение индекса	годы	значение индекса
2000	-2,74	2002	1,69
2016	-2,03	2006	1,35
2018	-1,76		
2020	-1,43		

Таблица 2 – Средняя месячная температура воздуха и аномалия относительно периода 1981-2020 гг. в ноябре 2000, 2002, 2006, 2016, 2018, 2020 гг.

Годы	Ауыл-4		Балкаш		Куйган		Сарышаган		Саяк	
	T	**ΔT**	T	**ΔT**	T	**ΔT**	T	**ΔT**	T	**ΔT**
2000	-4,5	-3,8	-6	-4,2	-4,2	-3,9	-5,4	-4,4	-5,5	-4,3
2002	2,8	3,5	1,0	2,8	3,2	3,5	2,0	3,0	2,0	3,2
2006	2	2,7	1,0	2,8	2,4	2,7	2,2	3,2	1,8	3,0
2016	-4,2	-3,5	-5,1	-3,3	-3,9	-3,6	-4,4	-3,4	-5,1	-3,9
2018	-4,6	-3,9	-4,8	-3,0	-2,9	-2,6	-3,7	-2,7	-5,4	-4,2
2020	-4,0	-3,3	-4,7	-2,9	-3,5	-3,2	-3,8	-2,8	-3,6	-2,4

Таблица 3 – Средние сроки появления первого льда и средние сроки установления ледостава

Балкаш		Сарышаган		Мынарал		Алгазы	
Средний срок появления первого льда	Средний срок установления ледостава	Средний срок появления первого льда	Средний срок установления ледостава	Средний срок появления первого льда	Средний срок установления ледостава	Средний срок появления первого льда	Средний срок установления ледостава
21 ноября	30 ноября	17 ноября	27 ноября	17 ноября	2 декабря	26 ноября	4 декабря

Таблица 4 – Сроки появления первого льда и сроки установления ледостава в 2000 году

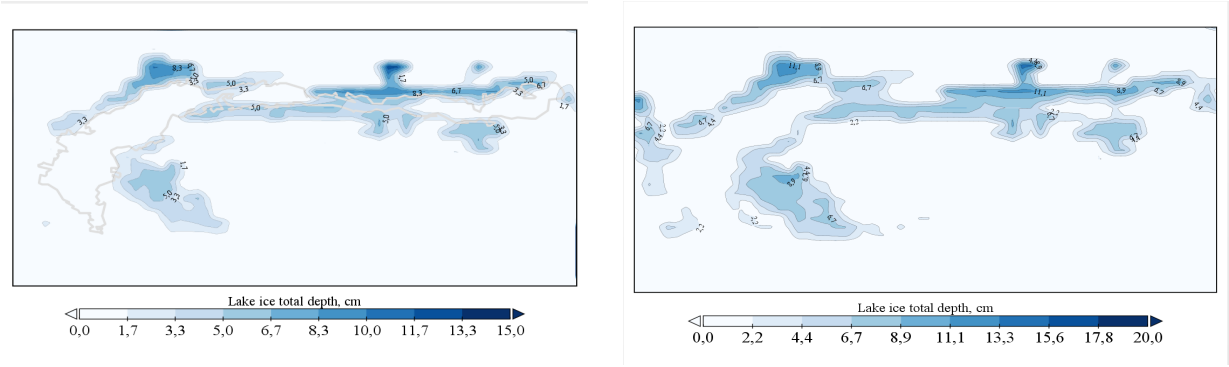
Балкаш		Сарышаган		Мынарал		Алгазы	
Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава
7 ноября	12 ноября	-	-	6 ноября	9 ноября	15 ноября	23 ноября

По данным таблицы 4 в экстремально холодный ноябрь 2000 года первые ледяные образования появились на 11-14 дней раньше средней даты, а ледостав установился на 11-23 дня раньше.

Самые ранние сроки появления первого льда по данным прибрежных гидрологических постов (Балкаш, Сарышаган) было отмечено 6-7 ноября, а установление ледостава 9 и 12 ноября.

Данные инструментальных наблюдений проводятся на одной точке и могут быть не репрезентативны для всего озера (IPCC. Climate change 2007), (Howell et al. 2009). Поэтому возникает необходимость использования даных из других источников

На рисунке 5 приведены значения толщины льда по акватории озера Балкаш за 6-7 ноября 2000 г. по данным реанализа.



06.11.2000 07.11.2000

Рисунок 5 – Распределение толщины льда на озере Балкаш 6-7 ноября 2000 г.

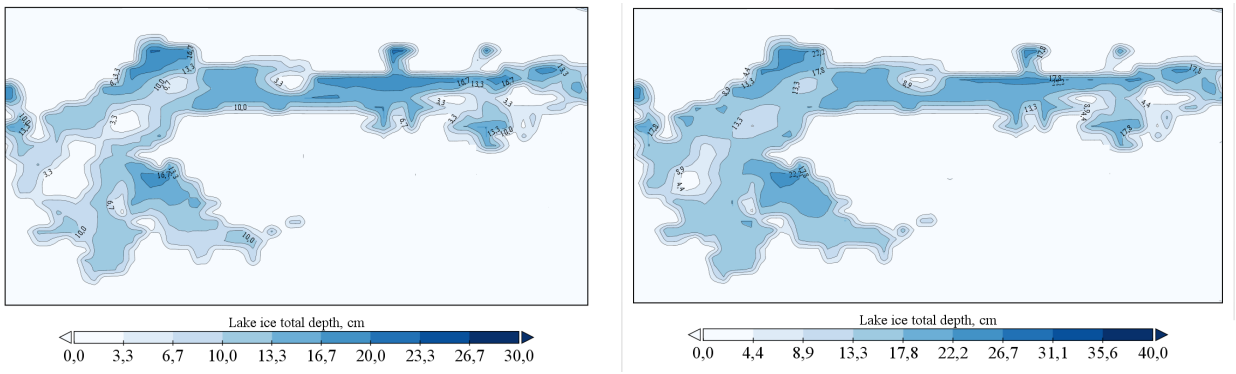
Анализ рисунка 5 показывает, что 6-7 ноября, по данным реанализа ледообразование отмечается в прибрежной и узкой части озера, на мелководье, а также в устье реки Или. Максимальная толщина льда достигала 8-11 см.

На рисунке 6 представлена карта толщины льда по данным реанализа на озере Балкаш в сроки, когда 9 и 12 ноября на постах установился ледостав.

Из рисунка 6 видно, что в эти сроки почти все озеро покрыто ледовым покровом. Значение максимальной толщины льда достигало 17-22 см.

Ледообразование на водоеме начинается с появления заберегов, реже – сала или шуги, а в прибрежных мелководных районах, защищенных от ветра, – сплошной ледяной корки.

На рисунке 7 представлены гистограммы количества дней с видами ледовых явлений в 2000 году.



09.11.2000 12.11.2000

Рисунок 6 – Распределение толщины льда на озере Балкаш 9 и 12 ноября 2000 г.

В соответствии с рисунком 7 видно, что на посту Балкаш 7 ноября первым ледяным образованием был несплошной ледостав, что является следствием понижения суточного максимума температуры воздуха на 6,6 °С и сменой его знака с положительного на отрицательный. Забереги наблюдались на всех постах от 3 до 8 дней. Перед установлением сплошного ледового покрова, на постах Балкаш (6 дней) и Мынарал (15 дней) наблюдался несплошной ледостав. Сплошной ледостав на этих постах установился 18 и 24 ноября. На посту Алгазы 23 ноября установился ледостав с торосами.

В таблице 5 представлены сроки появления первого льда и установления ледостава в 2016 году.

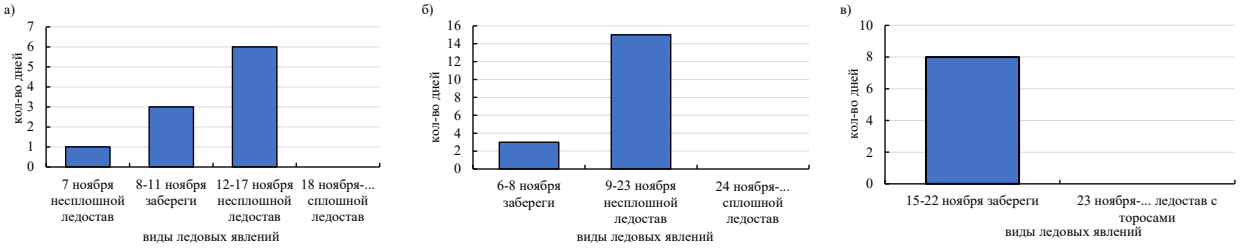


Рисунок 7 – Виды ледовых явлений в 2000 году на гидрологических постах Балкаш (а), Мынарал б), Алгазы (в)

Таблица 5 – Сроки появления первого льда и установления ледостав в 2016 году

Балкаш		Сарышаган		Мынарал		Алгазы	
Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава
17 ноября	20 ноября	15 ноября	17 ноября	17 ноября	20 ноября	-	-

Из таблицы 5 видно, что первые ледяные образования наблюдались с середины ноября (15-17 ноября) и через 2-3 дня установился ледостав. Первые ледяные образования наблюдались на 2-4 дня раньше, а ледостав установился на 10-12 дней раньше средних дат.

На рисунке 8 изображены карты толщины льда на озере Балкаш 17-20 ноября 2000 г.

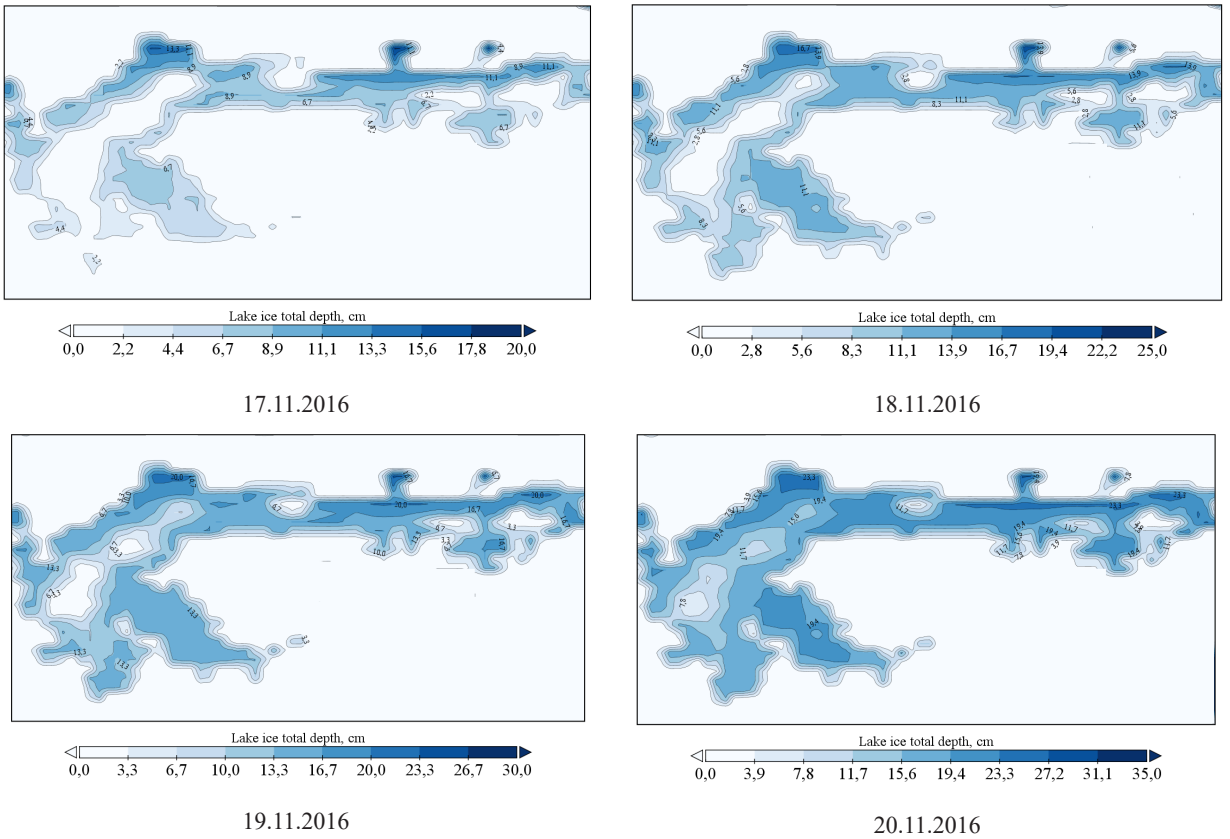


Рисунок 8 – Распределение толщины льда на озере Балкаш 17-20 ноября 2000 г.

Из рисунка 8, основанного на данных реанализа отмечается интенсивное ледообразование с 17 по 20 ноября 2016 г. Ледяные образования 17-18 ноября присутствуют на большей части озера и в устье реки Или, однако заметны также открытые участки воды. Максимальная толщина льда составила 13-17 см. Почти вся акватория озера 19-20 ноября покрыта ледовым покровом, максимальная толщина льда составила 20-23 см.

На рисунке 9 изображены гистограммы количества дней с видами ледовых явлений в ноябре 2016 г.

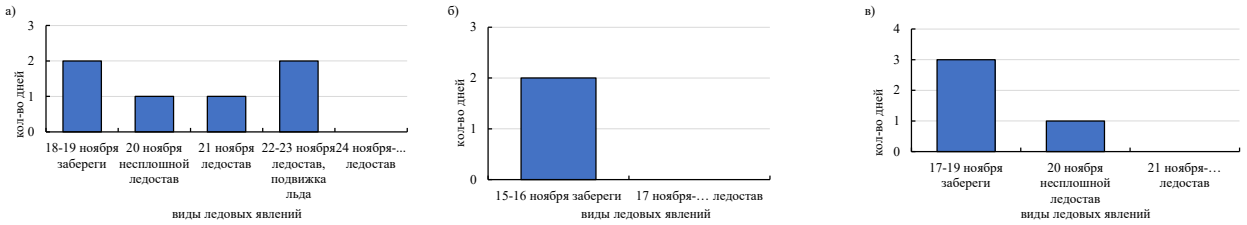


Рисунок 9 – Виды ледовых явлений в 2016 году на гидрологических постах Балкаш(а), Сарышаган (б) и Мынарал (в)

Как видно из рисунка 9, в ноябре наблюдались забереги (2-3 дня), несплошной ледостав и подвижка льда. Сплошной ледостав установился раньше на посту Сарышаган (17 ноября), а на постах Алгазы и Балкаш 21 и 24 ноября.

В таблице 6 представлены сроки появления ледяных образований и установления ледостава в 2002 году.

Первые ледяные образования в 2002 году наблюдались 18 ноября на посту Мынарал. На постах Балкаш и Алгазы ледообразование началось 2 декабря. Отклонение сроков первых ледяных образований 2002 года от средних в сторону более позднего появления составило на посту Мынарал – 1 день, а на постах Балкаш и Алгазы 11 и 7 дней соответственно. Сроки установления ледостава (3-4 декабря) отклоняются от средних дат в сторону более поздних на 1-3 дня.

На рисунке 10 изображены карты распределения толщины льда на озере Балкаш по данным реанализа.

Таблица 6 – Сроки появления первого льда и установления ледостава в 2002 году

Балкаш		Сарышаган		Мынарал		Алгазы	
Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава
2 декабря	3 декабря	-	-	18 ноября	3 декабря	2 декабря	4 декабря

Из рисунка 10 на картах за 12 декабря 2002 г. ледообразование отмечается в прибрежной и узкой части озера, на мелководье и в дельте реки Или. Заметны пространства в открытой части озера, свободные ото льда. Максимальная толщина льда – 14 см. Большая часть озера покрыта льдом 3-4 декабря, максимальная толщина 19-22 см.

На рисунке 11 изображены гистограммы количества дней с различными видами ледовых явлений в 2002 г.

В соответствии с рисунком 11 на посту Балкаш в 2002 г. ледостав установился на второй день после первого ледообразования. На посту Мынарал ледяные образования появились раньше (18 ноября) относительно других постов, а ледостав установился 3 декабря. Ледостав с торосами был установлен 5 декабря на посту Алгазы.

В таблице 7 представлены сроки появления первого льда и установления ледостава в 2006 г.

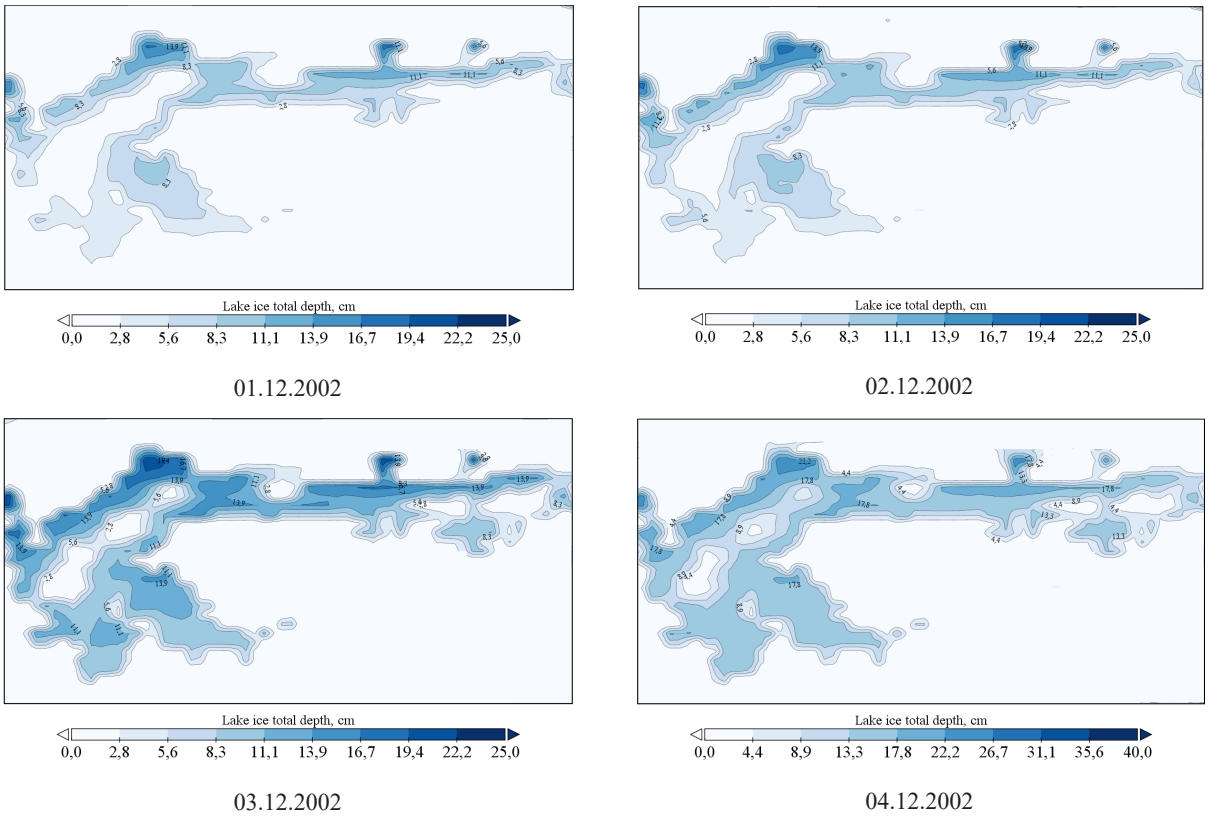


Рисунок 10 – Распределение толщины льда на озере Балкаш 14 декабря 2002 г.

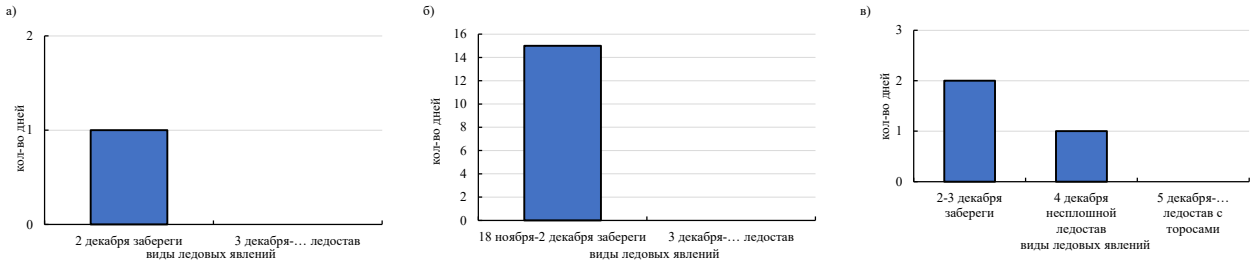


Рисунок 11 – Виды ледовых явлений в 2002 г. на постах Балкаш (а), Мынарал (б), Алгазы (в)

Таблица 7 – Сроки появления первого льда и установления ледостав в 2006 году

Балкаш		Сарышаган		Мынарал		Алгазы	
Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава	Срок появления первого льда	Срок установления ледостава
25 ноября	1 декабря	23 ноября	1 декабря	23 ноября	2 декабря	4 декабря	7 декабря

По данным таблицы 7 в 2006 г. на постах Балкаш, Сарышаган и Мынарал ледообразование началось 23-25 ноября, ледостав установился 12 декабря. На посту Алгазы первое ледообразование наблюдалось позже – 4 декабря, ледостав был установлен 7 декабря. Сроки первых ледяных образований и установления ледостава отклонялись в сторону более поздних на 48 дней и 14 дня.

На рисунке 12 изображены карты толщины льда по данным реанализа.

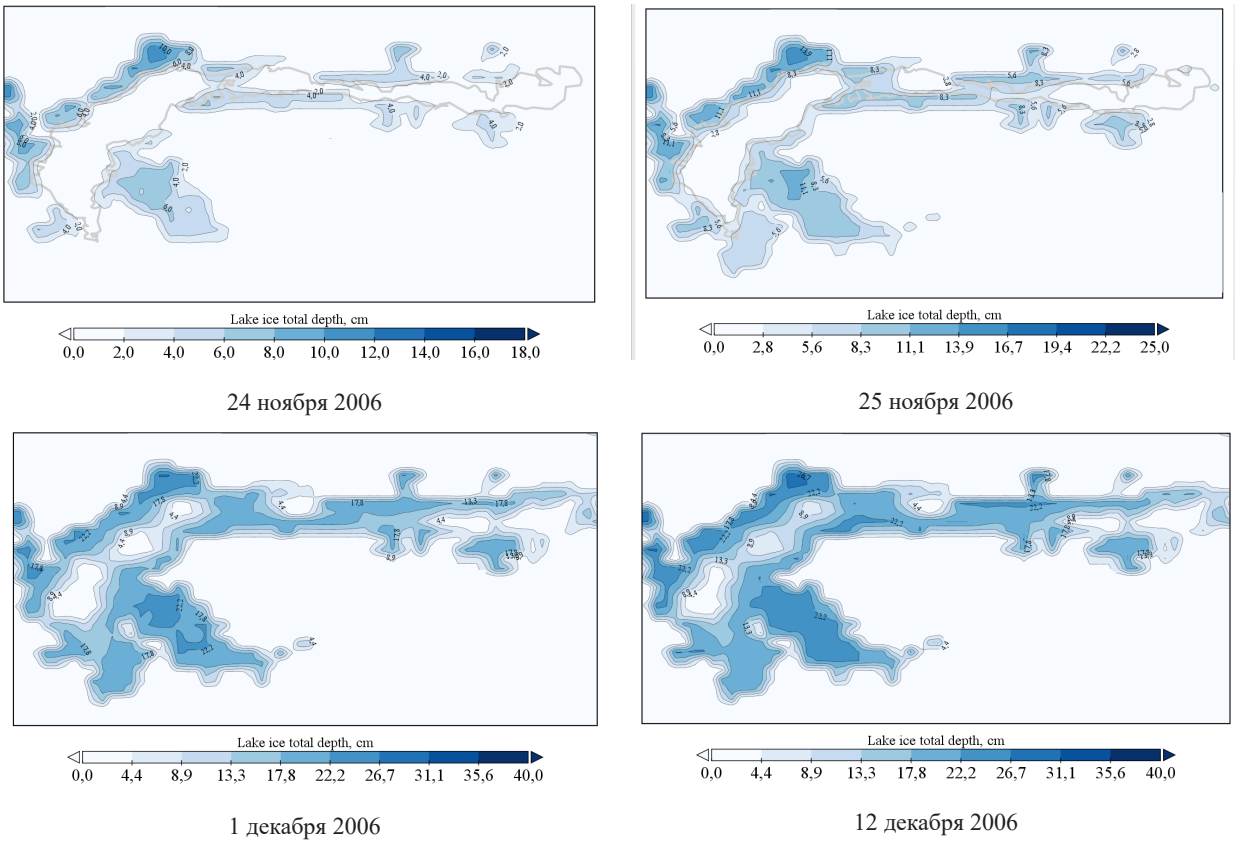


Рисунок 12 – Распределение толщины льда на озере Балкаш 24-25 ноября и 12 декабря 2006 г.

Из рисунка 12 видно, что 24-25 ноября 2006 г. ледообразование отмечается в прибрежной части озера и в устье реки Или. В открытой части озера вода свободна ото льда. Максимальная толщина льда составляет 10-14 см. Большая часть озера покрыта льдом 12 декабря, максимальная толщина составила 22-27 см.

Заключение

В ходе выполнения работы были рассмотрены особенности ледообразования оз. Балкаш в экстремально холодные и экстремально теплые месяцы.

По результатам исследований можно сделать следующие выводы:

- Температура воздуха ноября является определяющей для начала ледообразования на оз. Балкаш. Коэффициенты корреляции составили 0,7-0,8;

- По критерию аномальности БагроваТокарева для ноября были выявлены экстремально холодные (2000, 2016) и экстремально теплые (2002, 2006) годы;

- В экстремально холодный 2000 г. сроки появления первых ледяных образований отклонялись на 11-14 дней в сторону ранних, ледостав установился на 11-23 дней раньше средней даты;

- В экстремально холодный 2016 г. сроки появления первых ледяных образований и срок ледостава отклонялись в сторону более ранних на 24 дня и 10-12 дней;

- В экстремально теплый 2002 г. первое ледообразование наблюдалось на 1-11 дней позднее средней даты, а ледостав установился на 13 дня позже;

- В экстремально теплый 2006 г. сроки первых ледяных образований отклонялись в сторону более поздних на 48 дней, ледостав был установлен на 14 дня позже средней даты.

Таким образом, вместе с общей тенденцией сдвигов дат ледообразования в сторону более поздних, присутствуют отдельные случаи с экстремальными месяцами, значения которых не сходятся с общими трендами.

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NATURAL AND ANTHROPOGENIC FACTORS IN THE FORMATION OF THE FLOW OF PLAIN RIVERS OF KAZAKHSTAN IN THE CONDITIONS OF NON-STATIONARY CLIMATE

The change in the flow of plain rivers in Kazakhstan in recent decades is done due to the influence of both climatic factors and anthropogenic impacts. Revealing their role is extremely important for understanding the genesis of hydrological changes that have already occurred and possible in the future, as well as for taking measures to reduce their undesirable consequences. The complexity of solving this problem lies in the fact that climatic and anthropogenic changes in river runoff are closely interrelated and often interact on the runoff not directly, but indirectly. The intensity of anthropogenic impact, the variability of climate characteristics determine changes in the hydrological regime of water bodies. Climatic variability leads to an increase in the likelihood of adverse hydrometeorological phenomena, and human economic activity in the watershed and in the riverbed leads to a quantitative and qualitative change in the main characteristics of the hydrological regime, degradation of river ecosystems. The changes in the annual runoff of plain rivers are estimated based on the method based on the restoration of the natural runoff of the last decades, during which significant anthropogenic changes took place. It is shown that climatic and anthropogenic factors act on the runoff both unidirectionally, increasing or decreasing it, and in opposite directions. At the same time, the influence of anthropogenic factors, mainly reservoirs and water consumption, is commensurate with the influence of climatic factors, and in many cases exceeds it.

Key words: river runoff, base period, long-term runoff fluctuations, anthropogenic factors, climatic factors.

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Өзгермелі климат жағдайында Қазақстан өзендері ағындысын қалыптастырушы табиғи және антропогендік факторлар

Қазақстанның жазықтық өзендері ағындысының соңғы жылдардағы өзгерісі климаттық және антропогендік факторлармен айқындалады. Қазіргі және болашақта байқалуы мүмкін гидрологиялық өзгерістердің себебін түсіну және осы өзгерістердің әсерінен туындайтын қолайсыз зардаптарды жеңілдету бойынша шаралар қабылдау үшін олардың рөлін айқындау өте маңызды. Өзен ағындысының климаттық және антропогендік өзгерісі өзара тығыз байланысты болғандықтан және көп жағдайда өзен ағындысына тікелей емес жанама әсер ететіндіктен қойылған міндеттерді шешу өте күрделі. Су нысандарының гидрологиялық режимінің өзгерісі ағындығы әсер ететін антропогендік факторлардың қарқындылығы және климаттық сипаттамалардың құбылмалылығымен айқындалады. Климаттың өзгергіштігі қолайсыз гидрометеорологиялық құбылыстардың қайталану жиілігін арттырады, ал су жинау алаптары мен өзен арналарында жүргізілетін адамның шаруашылық іс-әрекеті өзендердің негізгі

гидрологиялық сипаттамаларының сандық және сапалық өзгерісіне, өзен экожүйесінің бұзылуына алып келеді. Зерттеу тақырыбының өзектілігі өзендерден алынатын су көлемінің артуына, суды тұтыну көлемінің ұлғаюына және климаттың қолайсыз өзгерістеріне байланысты су ресурстары жетіспеушілігімен анықталады. Жазықтық өзендердің жылдық ағындысының өзгерісі соңғы онжылдықтар ішінде айтарлықтай антропогендік өзгеріске ұшыраған табиғи ағындыны қалпына келтіру әдісі арқылы бағаланады. Бұл мақсатта су режимі салыстырмалы аз өзгеріске ұшыраған өзендердің (қарастырылып отырған өзендердің салалары мен жоғарғы ағысы) ағындысы жөніндегі деректер пайдаланылды. Қалпына келтірілген ағынды деректері осы кезең аралығында антропогендік өзгеріске ұшыраған ағынды деректерімен және оған дейінгі антропогендік әсерді ескермеуге болатын негізгі кезең ағындысымен салыстырылды. Климаттық және антропогендік факторлар өзен ағындысын бір бағытта ұлғайтатыны немесе азайтатыны, сондай-ақ қарама-қарсы бағытта әсер ететіні көрсетілген. Оның үстіне антропогендік факторлардың негізінен бөгендер мен су тұтынудың ағындыға тигізетін ықпалы климаттық факторлардың ықпалымен шамалас және көп жағдайда одан асып түседі.

Түйін сөздер: өзен ағындысы, негізгі кезең, ағындының көпжылдық тербелісі, антропогендік факторлар, климаттық факторлар.

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Природные и антропогенные факторы в формировании стока равнинных рек Казахстана в условиях нестационарности климата

Изменение стока равнинных рек Казахстана в последние десятилетия обусловлено влиянием, как климатических факторов, так и антропогенных воздействий. Выявить их роль чрезвычайно важно для понимания генезиса уже произошедших и возможных в будущем гидрологических изменений, а также для принятия мер по снижению их нежелательных последствий. Сложность решения этой задачи заключается в том, что климатические и антропогенные изменения речного стока тесно взаимосвязаны и часто взаимодействуют на сток не непосредственно, а косвенно. Интенсивность антропогенного воздействия, вариабельность характеристик климата определяют изменения гидрологического режима водных объектов. Климатическая изменчивость приводит к увеличению вероятности неблагоприятных гидрометеорологических явлений, а хозяйственная деятельность человека на водосборе и в русле реки приводит к количественному и качественному изменению основных характеристик гидрологического режима, деградации речных экосистем. Актуальность темы исследований определяется нарастающим дефицитом водных ресурсов в связи с увеличением изъятия объемов воды из рек, увеличением объемов водопотребления и неблагоприятными климатическими тенденциями. Оценены изменения годового стока равнинных рек на основе метода, основанного на восстановлении естественного стока последних десятилетий, в течение которых происходили его существенные антропогенные изменения. Для этих целей использованы данные о стоке рек (притоков рассматриваемых рек и их верхних частей), водный режим которых относительно слабо изменен антропогенным воздействием. Данные о восстановленном речном стоке сравнивались с антропогенно-измененным стоком за этот период и за предшествующий ему базовый период, когда антропогенным воздействием можно пренебречь. Показано, что климатические и антропогенные факторы действуют на сток как однонаправленно, увеличивая или уменьшая его, так и в противоположных направлениях. При этом влияние антропогенных факторов, главным образом водохранилищ и водопотребления, соизмеримо с влиянием климатических факторов, а во многих случаях превосходит его.

Ключевые слова: речной сток, базовый период, многолетние колебания стока, антропогенные факторы, климатические факторы.

Introduction

Significant changes in climatic conditions and the rapid transformation of the economic complex in recent decades have led to negative changes in river flow. In the basins of lowland rivers in Kazakhstan, over the past few decades there has been a marked warming of the climate, which is accompanied by an expand in air temperature and, to a lesser degree, in atmospheric moisture. These changes are char-

acterized by considerable spatial heterogeneity and lead to multidirectional changes in flow. They are superimposed on changes caused by a wide range of anthropogenic influences, both in river channels and in their watersheds. At the same time, the ratio of the contribution of natural-climatic and anthropogenic factors in the occurring and scenario changes in the flow remains insufficiently studied, despite the studies conducted by scientists-hydrologists.

The territory of Kazakhstan is characterized by uneven distribution of water resources in space and time, the possibility of using water resources has reached such a size that the flow deficit has become a limiting factor for socio-economic growth of the area. At present, major water problems are clearly observed in the river basins, which in a few years may become a factor hindering the socio-economic development of the region. Therefore, it is necessary to take urgent measures taking into account long-term nature of water projects development and implementation.

The flow of the lowland rivers of Kazakhstan is characterized by long-term changes that are caused by natural-climatic and anthropogenic factors. A large number of scientific studies have been devoted to the dynamics of long-term changes in river flow and the role of individual factors of such changes (Galperin et al., 2012; Shiklomanov, 2008; Koronkevich et al., 2003; Shiklomanov, 1989; Shiklomanov, 1979). While identifying separately the contribution of climatic and anthropogenic factors to these changes remains one of the urgent problems. First of all, the issue is the difficulty of separating their influence on river flow, since natural and anthropogenic factors act simultaneously and are closely interrelated. Various studies and assessments of the contribution of factors are often timed to different time periods and there remain periods not covered by scientific research (Dostay et al., 2012; Abishev et al., 2016; Georgiadi et al., 2014; Georgiadi et al., 2009; Koronkevich, 1990).

The list of anthropogenic factors taken into account significantly differs, and indirect anthropogenic influences on runoff are rarely taken into account. Different methods are used in studies to identify the hydrological role of climatic and anthropogenic factors and to assess the ratio of these factors in hydrological changes (Alimkulov et al., 2018; Koronkevich et al., 2015; Andreyanov, 1959; Kuzin, 1970; Alimkulov et al., 2021; Georgiadi et al., 2012; Georgiadi et al., 2014; Moldakhmetov et al., 2014; Moldakhmetov et al., 2020; Georgiadi et al., 2017).

According to Sustainable Development Goal 6, "Ensure availability and sustainable use of water resources and sanitation for all," by 2030 it is necessary to significantly improve the efficiency of water use in all sectors of the economy (ensuring sustainable freshwater abstraction and supply to address scarcity) and ensure integrated water resources management at all levels. Under the Goal 13 "Take urgent action to combat climate change and its effects" requires the inclusion of responses to climate change in policies, strategies and planning at the national level and the adoption of meaningful measures to mitigate the effects of climate change (World Sustainable Development Report, 2020).

In the late XX and early XXI centuries, the accomplished fact of global warming was acknowledged (Galperin et al., 2012; Shiklomanov, 2008; Koronkevich et al., 2003; Shiklomanov, 1989; Modern global changes in the natural environment, 2006; Georgievsky, 1996), but the debate about the causes of contemporary climate change remains incomplete. Many scientists acknowledge the fact of anthropogenic climate change due to carbon dioxide accumulation in the atmosphere, while others firmly believe that the energy power of the processes taking place in the natural cycle is some orders of magnitude higher than the technogenic energy capabilities. Rhythms of space, natural rhythmicity and its phases have a significant influence on many processes occurring on the Earth, including long-term fluctuations of river runoff, which is an integral indicator of climate change (Ineson et al., 2015; Gray et al., 2010).

The problem of global climate change and its forecast is now given great attention in the world; this problem is reflected, in particular, in the following scientific works (Makhmudova et al., 2021; Frolova et al., 2013; Meleshko, 2008). According to scientific research given in (Meleshko, 2008) it follows that at least since the beginning of XX century the global problem has been growing – according to smoothed values by 0.75 ^{0}C. After a temporary cooling from the mid-1940s to the mid-1960s, there was already a continuous rise in temperature, but, it is very indicative, an exceptionally powerful warming since the mid-1970s. This phenomenon was noted much earlier – so, O.A. Drozdov (Drozdov, 1992) pointed out that a new warming in the world began in 1973 and, on this basis, doubt was expressed about the possibility of predicting future water resources on the basis of long series of observations. According to V.P. Meleshko's research (Meleshko, 2008) the probability of warming since the mid-20th

century is related to the concentration of greenhouse gases more than 90 %, it follows that warming will continue (Makhmudova et al., 2021).

As for anthropogenic changes in runoff of the last modern period, they are quite reasonably disturbing for humanity. These changes really exist, but their values are not comparable with natural cyclical climate changes of different nature. The danger of anthropogenic changes lies in their irreversibility. Besides, a combination of accumulating anthropogenic and cyclic natural climate changes is dangerous because there are periods of years when anthropogenic and natural changes are directed in the same direction and can manifest with threatening rapidity, so minimizing the anthropogenic component is a safety net for mankind.

For a reliable integrated assessment of water resources and water availability in the basin or region for the present and future, in addition to data on fluctuations in river flow, it is necessary to quantify its changes under the influence of climatic and anthropogenic factors.

According to the research of the following authors (Alimkulov et al., 2018) since the one thousand nine hundred seventy, the relevance of dependable assessment of water resources and their projected changes below the influence of economic action has increased even more in connection with the genuine problem of changes in global and regional climatic characteristics. These changes are already taking space in the plain rivers of Kazakhstan and can lead to large-scale transformations of the hydrological cycle, changes in water resources and their use, distribution in time and space, extreme characteristics of river flow and their variability.

Scientific studies (Meleshko, 2008) contain the following statement, in the distribution of water resources in the future: in areas of excessive moisture water resources will increase, and in areas where water availability is now insufficient, its further reduction is foreseen. Apparently, such feature of water resources dynamics is typical for Kazakhstan as well. Indeed, in the inland areas of middle latitudes, increasing temperature causes an increase in evaporation, reducing the period of snow accumulation (Makhmudova et al., 2021; Moldakhmetov et al., 2013), which has a negative impact on river runoff.

Anthropogenic changes in climatic characteristics are so significant that they have led to significant violations of the hydrological cycle, the quantity of water resources, their distribution over time and territory, the extreme characteristics of river flow and their variability, which cannot be ignored when developing long-term integrated use plans when designing long-term water management measures (Alimkulov et al., 2018).

Most of the researches devoted to the study of water resources of Kazakhstan and the regularities of their spatial and temporal changes operate with the values of annual runoff and inter-annual variability (Shults, 1965; Sosedov, 1984; Boldyrev, 1965; Galperin, 1970; Dostaev, 1990). Far fewer works study the maximum and minimum flow, intra-annual regime and other hydrological issues of narrow focus (Boldyrev, 1965; Galperin, 1970; Dostaev, 1990). Meanwhile, the annual values of river runoff consist of water volumes of individual genetically based phases of its formation, during which, in fact, significant responses to climatic and anthropogenic changes are observed.

The first major works that carried out comprehensive hydrological studies, including the water regime and intra-annual flow distribution of rivers in Kazakhstan, were the series of monographs "Surface Water Resources of the USSR", published in 1950-1970. Peculiarities of the regularities of flow formation, distribution, and water regime of individual regions of Kazakhstan were considered in the works of Soviet scientists (Kuzin, 1953; Berkaliev, 1959). The early works of Kazakh scientists such as V.M. Boldyrev, R.I. Galperin, S.K. Davletgaliev, A.A. Tursunov, J.D. Dostay, and others also belong to this group (Boldyrev et al., 1994; Galperin, 1992). It should be noted that in all works of this period, hydrological assessments were carried out from the position of climate stationarity and flow formation processes.

In scientific researches of foreign authors (Hughes et al., 2000; Technical report, 2010; Pekarova et al., 2008; Piniewski et al., 2011), methods and principles of trends accounting, water resources assessment, water regime changes are given. These works are aimed at studying water regime and management developed by methodologies financed by water departments of countries and UNESCO. In recent years, it is possible to note studies of the impact of climate change on river flow in the works of scientists of the Institute of Water Problems of the Russian Academy of Sciences A. Georgiadi, N. Koronkevich, I. Milyukova, A. Kislov, O. Anisimov, E. Barabanova, etc. (Report on research, 2012) on the rivers of the Arctic basin and the Russian plain.

Therefore, the relevance of the topic is determined by the growing scarcity of water resources due to increased withdrawal of water from rivers,

unfavourable climatic trends, and increase in water consumption.

The main goal – study of long-term trends in flow changes in the plain river basins under climate variability and anthropogenic load for effective decision-making on water resources management, sustainable development of the region and food security.

Materials and methods

When performing various methods and techniques were used for research work, such as: analytical generalization of known scientific and scientific-technical results; content – analysis; methods of system analysis; statistical methods (analysis of linear trends in multi-year runoff fluctuations; comparison of annual and seasonal runoff values for multi-year periods with the same meteorological characteristics, but with different levels of economic activity development; methods of hydrological analogy; numerous correlations between runoff and meteorological characteristics; analysis of runoff dependencies in catchment areas where it is formed and used for economic needs; territorial multiple dependencies of river runoff on physical-geographical, meteorological and anthropogenic factors); quantitative methods; methods of probability theory and mathematical statistics.

To solve these problems, studies have been conducted based on methods common in hydrology, considering the spatial patterns of changes in river flow, such as a comprehensive physical and geographical analysis, taking into account factors of formation and flow changes, as well as climate modify and anthropogenic influence will be performed.

Hydrological calculations were performed in accordance with the regulatory document SP 33-101-2003 and Methodical Recommendations (Code of Rules, 2004; Rozhdestvensky et al., 2009; Rozhdestvensky et al., 2007; Rozhdestvensky et al., 2010; Standard of the organization, 2017).

The data of RSE (Republican State Enterprise) “Kazhydromet” were used as source materials for the implementation of research works – data from observations on the hydrological and meteorological network of plain rivers of Kazakhstan (average monthly, annual, seasonal flow of the rivers in question, monitoring of meteorological data) for the entire period of instrumental observation.

The research concept is based on an independent approach, in which the integral assessment of the influence of the flow factors under consideration is based on the reconstruction of the conditional-natural annual flow. Using regression relations of annual and seasonal flow of large rivers and their tributaries (river indicators) located in the area of flow formation of the main river under conditions of relatively low anthropogenic impact, and comparison of the restored flow with the actual flow (Georgiadi et al., 2013; Georgiadi et al., 2019). The developed approach gives an opportunity to reveal long-term integral changes of river runoff – assessment of river runoff changes caused by natural-climatic factors (according to relations between runoff of the main-river and river indicators).

For each river in the study basins, the boundaries of base periods, average values of annual and seasonal runoff and their difference are calculated for these periods (the difference will show the total changes in the runoff, which occurred under the influence of both anthropogenic impacts and climatic factors).

To determine the contribution of anthropogenic and climatic factors in the total change of annual and seasonal runoff, the method based on the reconstruction of natural runoff of the studied rivers was applied. The method is founded on regression relations between runoff of large rivers and their tributaries. For this method, assessment of the contribution of anthropogenic impacts and climatic changes in the total runoff changes is based on comparing the runoff for the baseline period, which was relatively weakly affected by economic activities, with the actual and restored (conditionally natural) runoff for the period of significant anthropogenic impact (Georgiadi et al., 2019).

Studies of long-term flow changes are based on the concept of long-term phases of increased or decreased water availability and the influence of anthropogenic factors on them (based on which the contribution of natural-climatic and anthropogenic factors to the observed changes in annual and seasonal flow is estimated) (Georgiadi et al., 2020).

Methodological methods, based mainly on the use of network observations, provide only an integral assessment of the impact of a set of anthropogenic factors in the basin, but do not allow to identify the role of each factor individually and thus do not always provide the possibility of scientifically based forecasts of the river regime in the future, taking into account economic development plans. Therefore, for watersheds with intensive use of water resources, assessment of flow changes should be made in parallel by two mutually independent methods, namely by restoring the conditionally natural

annual runoff using regression relationships and by analyzing long-term water discharge fluctuations in gauging stations (with regard for meteorological factors fluctuations). When calculating for the future, it is important to assess runoff changes under the influence of economic activity not only for average water availability, but also for exceptionally low-water and high-water years. In general, the above methods together serve as a methodological basis for achieving the goals of the scientific researches and the chosen scientific approach.

Results and discussion

Choosing a billing period in a changing climate for such a large and complex orographically territory as lowland Kazakhstan is very difficult. Firstly, it's challenging to expect complete consistency of fluctuations in the hydro-climatic characteristics in all basins. Secondly, river flow is affected by economic activity, but it's not the same in different parts of the territory and varies significantly over time. Further, it's quite obvious that the common hydroclimatic patterns should be better manifested in large basins. In nearly all large and medium rivers of flat Kazakhstan, the climatic flow is strongly distorted, in particular, by reservoirs (Makhmudova et al., 2021). When analyzing, one should keep in mind the features of runoff time series in a significant part of Kazakhstan: exceptional, unparalleled, low water in the 1930s, and very high runoff in the 1940s (Galperin et al., 2003). Difference integral curves are widely used to identify the phases of increased and decreased water content of rivers, the moments of change of these phases. But, it should be borne in mind that they illustrate the course of the accumulated anomaly only relative to the sample mean. An analysis of the river runoff dynamics in the region under consideration shows that runoff fluctuations occur cyclically (Table 1), which has been repeatedly noted by most researchers (Galperin et al., 2003; Makhmudova et al., 2021). An analysis of the data for all hydrological series of the territory under consideration reveals one common feature of the long-term course – the increase in runoff values since the mid-1970s regardless of whether this period belongs to the low-water or high-water phase. The moment of transition to the high-water phase corresponds to the data on the long-term variation of global meteorological characteristics (Shiklomanov, 2008; Modern global changes in the natural environment, 2006).

Table 1 – Low-water and high-water periods on plain rivers

Low water periods			High water periods			Cycle duration	Average consumption for the period, m^3/s
Period, years	Cycle, yy.	Average consumption for the period, m^3/s	Period, yy.	Cycle, yy.	Average consumption for the period, m^3/s		
Tobyl – Kostanay							
1931-1939	9	5.85	1940-1943	4	36.4	13	15.2
1944-1945	2	7.46	1946-1953	8	25.9	10	22.2
1954-1956	3	6.93	1957-1964	8	15.5	11	13.1
1965-1969	5	2.09	1970-1973	3	17.6	9	8.46
1974-1984	11	1.94	1985-1986	2	11.1	13	3.35
1987-1989	3	4.57	1990-1994	5	23.4	8	16.3
1995-1996	2	4.23	1997-2005	9	16.1	11	14.0
2006-2011	6	5.58	2012-2019	8	7.26	14	6.54
Yesil – Petropavlovsk							
1933-1939	7	13.9	1940-1949	10	111	17	70.7
1950-1953	4	18.7	1954-1964	11	66.8	15	54.0
1965-1969	5	22.8	1970-1974	5	67.2	10	45.0

Table continuation

Low water periods			High water periods			Cycle duration	Average consumption for the period, m^3/s
Period, years	Cycle, yy.	Average consumption for the period, m^3/s	Period, yy.	Cycle, yy.	Average consumption for the period, m^3/s		
1975-1982	8	26.5	1983-1997	15	81.9	23	62.7
1998-2001	4	15.5	2002-2007	6	69.6	10	48.0
2008-2013	6	19.5	2014-2019	6	112	12	65.7
Nura – Romanovka							
1933-1937	7	6.11	1940-1943	4	19.7	11	11.1
1944-1947	4	14.1	1948-1950	3	38.1	7	24.4
1951-1953	3	8.58	1954-1955	2	24.5	5	15.0
1956-1957	2	6.74	1958-1962	5	30.4	7	23.6
1963-1970	8	8.80	1971-1973	3	28.3	11	14.1
1974-1977	4	13.5	1978-1979	2	22.6	6	16.6
1980-1982	3	13.2	1983-1993	11	34.2	14	29.7
1994-2001	8	13.6	2002-2004	3	29.1	11	17.8
2005-2014	10	11.4	2015-2019	5	65.7	15	30.0
Sarysu – №189							
1932-1939	8	0.64	1940-1945	6	3.77	14	1.98
1946-1947	2	0.28	1948-1949	2	8.18	4	4.23
1950-1953	4	0.69	1954-1955	2	8.91	6	3.43
1956-1957	2	0.31	1958-1960	3	5.90	5	3.66
1961-1963	3	0.52	1964-1966	3	3.36	6	1.94
1967-1968	2	0.14	1969-1973	5	4.61	7	3.33
1974-1975	2	0.47	1976-1977	2	3.30	4	1.89
1978-1979	2	1.29	1980-1992	13	3.82	15	3.48
1993-2001	9	1.84	2002-2006	5	2.91	14	2.22
2007-2014	8	0.78	2015-2019	5	12.0	13	5.10

At the hydrological post Tobyl – Kostanay city over the period of instrumental observations, two complete cycles were identified (1940-1989 and 1990-2019 yy.). High-water phases lasting from 2 to 9 years are replaced by low-water phases lasting from 2 to 11 years, the duration of cycles is from 8 to 14 years. The lowest average annual water discharges in Kostanay were observed in 1979 (0.93 m^3/s) and in 1977 (1.02 m^3/s). The highest average annual water discharges were observed in 1942 (64.5 m^3/s), in 1947 (63.0 m^3/s), and in 1941 (58.2 m^3/s).

In the closing section at the hydrological post of the river Yesil – Petropavlovsk over the period of instrumental observations revealed two complete cycles (1940-1982 and 1983-2013 yy.). High-water phases lasting 5-15 years are replaced by low-water phases lasting from 4 to 8 years, the duration of cycles is from 10 to 23 years. The lowest average annual water discharges in Petropavlovsk were observed in 1968 (1.38 m^3/s) and in 1977 (7.26 m^3/s). The highest average annual water discharges were observed in 1948 (227 m^3/s), in

1941 (175 m^3/s), in 2007 (139 m^3/s) and in 1990 (127 m^3/s).

In the closing section at the hydrological post of the river Nura – Romanovka over the period of instrumental observations revealed two complete cycles (1940-1982 and 1983-2014 yy.). High-water phases lasting 2-11 years are replaced by low-water phases lasting from 2 to 10 years, the duration of cycles is from 5 to 15 years. The lowest average annual water consumption in the village Romanovka were observed in 1939 (1.44 m^3/s) and in 1936 (1.52 m^3/s). The highest average annual water discharges were observed in 1993 (63.6 m^3/s), 1990 (62.4 m^3/s), 1949 (54.6 m^3/s), and 1948 (51.6 m^3/s).

At the hydrological post Sarysu – № 189 over the period of instrumental observations, two complete cycles were revealed (1940-1979 and 1980-2014 yy.). High-water phases lasting from 2 to 13 years are replaced by low-water phases lasting from 2 to 9 years, the duration of cycles is from 4 to 15 years. The lowest average annual water discharges were observed in 1937 (0.010 m^3/s) and in 1947 (0.092 m^3/s). The highest average annual water discharges were observed in 2015 (29.3 m^3/s), in 2017 (15.4 m^3/s), and in 1949 (11.9 m^3/s).

Atmospheric circulation processes have a decisive influence on the distribution of the cyclic phases of climate elements and the hydrological regime over the territory. In addition, the conditions of the underlying surface also play a significant role in this distribution, particularly in relation to the cyclic phases of precipitation and river runoff. The revealed runoff cyclicity can be associated both with the regulating capacity of watersheds and with other factors (peculiarities of atmospheric circulation, etc.). A reflection of climatic variability can also be a modify in runoff variation over time. Water cycles are understood as a series of adjacent runoff years, including one low-water and one high-water grouping of years of the same order of duration. Changes in water content in these periods are due to the predominance of certain types of atmospheric circulations.

The concept of the study makes it possible to identify long-term integral changes in river runoff – an assessment of the modify in river runoff due to natural and climatic factors (by relationships between the flow of the main river and the flow of indicator-rivers). At the same time, as it can be seen, the boundaries of the periods differ on the rivers (Table 2) under consideration, which is explained by the time of the onset of a significant anthropogenic impact (Galperin et al., 2012; Makhmudova et al., 2021; Meshyk et al., 2022; Georgiadi et al., 2020).

Table 2 – Change in the volume of annual runoff under the total impact influence of climatic and anthropogenic factors, relative to the base period

River – point	Base period		Period of significant anthropogenic impact		Flow change		
	years	runoff volume, million m^3	years	runoff volume, million m^3	average for the year		total, million m^3
					million m^3	%	
Tobyl – Kostanay	1931-1963	523	1964-2019	293	-230	-44.0	-12880
Yesil – Astana	1933-1970	183	1971-2019	129	-54.0	-29.5	-2646
Yesil – Kamennyi Karier	1933-1970	1302	1971-2019	1211	-91.0	-6.99	-4459
Yesil – Petropavlovsk	1932-1970	1772	1971-2019	1930	158	8.92	7742
Nura – Balykty	1935-1973	189	1974-2019	325	136	72.0	6256
Nura – Romanovka	1933-1973	529	1974-2019	636	107	20.2	4922
Sarysu – №189	1932-1965	84.7	1966-2019	80.7	-4.00	-4.72	-216

Changes in the annual runoff on the rivers that is under consideration (Table 2) had a multidirectional character – the total runoff on the Tobyl River during the period of significant anthropogenic impact decreased, and on the Nura River it increased due to the transfer of runoff from the Ertis – Karaganda canal. At the same time, the runoff of Tobyl near the city of Kostanay changed most noticeably in 1964-2019 decreased in comparison with the base period by more than 12800 million m^3 (over

200 million m^3/year), on the river Yesil in the alignment of Astana for the period from 1971-2019 the decrease in annual runoff amounted to more than 2600 million m^3 (about 50 million m^3/year), on the river Sarysu decline in annual runoff over the period from 1966-2019 amounted to more than 200 million m^3 (5 million m^3/year), which had a very negative impact on the water management and hydro ecological situation in the basins.

When restoring the conditionally natural runoff, it's taken into account: long-term data relating to the period before the onset of a noticeable impact of anthropogenic factors; the second part consists of a long-term series, the annual runoff in which is changed to varying degrees as a result of the anthropogenic factors impact (Georgiadi et al., 2019). The annual runoff was restored by two methods. One of them proceeds from regression relationships between the runoff of the main river and the runoff of rivers that are indicators of climatic conditions (tributaries and upper parts of the main river), characterized by relatively feeble anthropogenic disturbances of the water regime. One of the first to use it was I.A. Shiklomanov (Shiklomanov, 1989; Shiklomanov, 1979). In the Table 3 shows the results of assessing the contribution of climatic and anthropogenic factors to these changes, calculated using the restoring conditionally natural flow method.

Table 3 – Changes in annual runoff over the period of significant anthropogenic impact, calculated by the restoring its conditionally natural values method, million m^3

River – point	Anthropogenic changes		Climate change	
	total for the period	average for the year	total for the period	average for the year
Tobyl – Kostanay	– 10416	– 186	– 2464	– 44
Yesil – Petropavlovsk	– 13328	– 272	21070	430
Nura – Balykty	3404	74.0	2852	62.0
Nura – Romanovka	– 5566	-121	10488	228
Sarysu – №189	– 1528	-28.3	1312	24.3

As follows from Table 3, anthropogenic and climatic changes in the annual runoff on the river Tobyl were unidirectional – downward, and the share of anthropogenic changes is more than 80 %, respectively, the share of climate change is 20 %. On the rivers Yesil, Nura, Sarysu, the effect of anthropogenic and climatic factors was multidirectional with the predominant influence of anthropogenic factors. On the river Nura, the share of anthropogenic changes in the upper reaches is more than 54 %, respectively, the share of climate changes is 46 %, in the lower reaches 87 and 13 %, respectively.

Conclusion

The conducted scientific research is devoted to the complex problem of assessing the role of natural and anthropogenic factors in the formation of the flow of plain rivers. The main emphasis in solving these studies was placed on the problems of non-stationary climate and the uncertainty of hydrological phenomena. The results of scientific research have shown that there is every reason to believe that a certain phase of climate and runoff, which characterizes the current period, began in the 60-70s. XX century, the intensification of economic activity in Kazakhstan also occurred during this period. From the 70s in the XX century, a new phase began in the changes in the water resources of vast territories, with some slowing down of the process or even grouping of years of the opposite sign of the anomaly from the end of the 90s do not give grounds to believe that this phase has ended and been replaced by a new one, these are just random groupings against the backdrop of an established trend. The modern period in the long-term course of the water content of the rivers of the territory under consideration can be considered the period from the mid-70s to the last century. For the rivers of the river basin Tobyl is characterized by runoff cyclicity from 8 to 14 years, for the river Yesil is characterized by a cyclic flow with a period of 10-23 years, for the basin of the river Nura from 5 to 15 years and for the rivers of the

river basin Sarysu is characterized by runoff cycles from 4 to 15 years.

The obtained estimates of changes in the volume of annual runoff under the influence of the climatic and anthropogenic factors total impact of relative to the base period showed the following:

– Tobyl – the decrease in runoff is more than 40 %;

– Yesil in the alignment of Astana, the decrease leaves 30 %, further downstream in the alignment with Kamennyi Karier – 7 %;

– Nura – increase in runoff due to the transfer of runoff from the Ertis – Karaganda canal;

– Sarysu – the decrease in runoff is 5 %.

An assessment of the anthropogenic and climatic factors contribution to changes in annual runoff observed river basins: Tobyl, Yesil, Nura, Sarysu, showed the following picture – the share of anthropogenic and climatic factors in the decrease in annual runoff when using the method of restoring conditionally natural runoff is estimated on the river Tobyl in 80 % and 20 %; on the river Yesil 70 % and 30 %; on the river Nura 87 % and 13 % respectively.

The practical significance of the research results lies in the following: the identified long-term and seasonal patterns of the main hydrological characteristics of the plain rivers of Kazakhstan will make it possible to plan and adjust economic activities in the watersheds of the rivers under consideration in conditions of climate variability. The results obtained are necessary as recommendations on the current volumes of rational water use and water consumption in the context of climate change and the impact of human economic activity, in order to change the irrigated areas and plans for the development of the agro-industrial complex.

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ГЕОЭКОЛОГИЯ

Section 4
GEOECOLOGY

Раздел 4
ГЕОЭКОЛОГИЯ

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ОЦЕНКА РАДИАЦИОННО-ЭКОЛОГИЧЕСКОГО СОСТОЯНИЯ ПОДЗЕМНЫХ ВОД НА ТЕРРИТОРИИ БЫВШЕГО ИСПЫТАТЕЛЬНОГО ПОЛИГОНА АЗГИР В ЗАПАДНОМ КАЗАХСТАНЕ

Полигон Азгир является одним из радиационно опасных объектов Казахстана. На полигоне в исследовательских целях для отработки технологии создания под землей полостей различного назначения в массиве каменной соли было осуществлено 17 подземных ядерных взрывов (ПЯВ) в период 1966-1979 гг. В результате проведенных работ было создано 9 подземных полостей различного объема и на различной глубине.

В статье представлены результаты изучения микроэлементного и радионуклидного состава поземных вод полигона «Азгир», с учетом новых данных, полученных после бурения новых наблюдательных скважин в 2021 году. Показано, что значения удельных активностей искусственных радионуклидов в воде исследуемых скважин и колодцев находится на фоновом уровне и сопоставимо с многолетними данными радиоэкологического мониторинга на полигоне, что свидетельствует об отсутствии процессов миграции радионуклидов из подземных ядерных полостей в настоящее время. Локальмым сборником подземных вод полигона является мульда «Ужунтатор», распололоженная между соляными куполами Западный и Восточный Азгир. Подземные воды полигона также залегают отдельными разрозненными линзами.

Представлена оценка токсичности вод из наблюдательных скважин и колодцев по содержанию в воде тяжелых металлов с использованием индекса загрязнения тяжелыми металлами (HPI). Доминирование химических элементов в подземных водах установлено в порядке Fe > Mn > Ni > Cr > Co > Mo > Cu > Zn. Подтверждены выводы о непригодности этих вод для использования в питьевых целях. Значение индекса HPI до 72,6 раз превышает критическое значение для питьевых вод, что обусловлено гидрогеологическими условиями залегания подземных вод.

Исследование проведено на базе Центра комплексных экологических исследований РГП Институт ядерной физики.

Ключевые слова: подземные воды, подземные ядерные полости, радионуклиды, тяжелые металлы, индекс загрязнения тяжелыми металлами, испытательный полигон Азгир.

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Assessment of the radiation-ecological state of groundwater on the territory of the former Azgir test site in Western Kazakhstan

The Azgir test site is one of the radiation hazardous facilities in Kazakhstan. At the test site, for research purposes, 17 underground nuclear explosions were carried out in the period 1966-1979 to develop the technology of creating cavities for various purposes underground in the rock salt massif. As a result of the work carried out, 9 underground cavities of different volumes and at different depths were created.

The article presents the results of studying the trace element and radionuclide composition of the ground water of the Azgir test site, taking into account new data obtained after drilling new observation wells in 2021. It is shown that the values of specific activities of artificial radionuclides in the water of the bore holes and wells under study are at the background level and are comparable with long-term data of radioecological monitoring at the test site, which indicates the absence of migration processes of

radionuclides from underground nuclear cavities at the present time. The local collection of underground water of the test site is the "Uzhuntator" mulda, located between the salt domes of the Western and Eastern Azgir. The underground water of the test site also lie in separate disparate lenses.

An assessment of the toxicity of waters from observation the bore holes and wells by the content of heavy metals in water using the heavy metal pollution index (HPI) is presented. The dominance of chemical elements in groundwater is established in the order Fe > Mn > Ni > Cr > Co > Mo > Cu > Zn. The conclusions about the unsuitability of these water for drinking purposes have been confirmed. The value of the HPI index is up to 72.6 times higher than the critical value for drinking water, which is due to the hydrogeological conditions of groundwater occurrence.

The study was conducted on the basis of the Center of Complex Environmental Research of the RSE Institute of Nuclear Physics.

Key words: groundwater, underground nuclear cavities, radionuclides, heavy metals, heavy metal pollution index, Azgir test site.

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Батыс Қазақстандағы бұрынғы Азғыр сынақ полигоны аумағындағы жерасты суларының радиациялық-экологиялық жай-күйін бағалау

Азғыр полигоны Қазақстанның радиациялық қауіпті нысандарының бірі болып табылады. 1966-1979 жылдар аралығында полигонда зерттеу мақсатында жер астында әртүрлі мақсаттағы қуыстар жасау технологиясын пысықтау үшін 17 жерасты ядролық жарылыстары (ЖЯЖ) жүзеге асырылды.

Мақалада 2021 жылы жаңа бақылау ұңғымаларын бұрғылағаннан кейін алынған жаңа деректерді ескере отырып, «Азғыр» полигонының жер асты суларының микроэлементтік және радионуклидтік құрамын зерттеу нәтижелері берілген. Зерттелетін ұңғымалар мен құдықтардың суындағы жасанды радионуклидтердің үлестік белсенділігінің мәні фондық деңгейде және полигондағы радиоэкологиялық мониторингтің көп жылдық деректерімен салыстырмалы түрде көрсетілген, бұл қазіргі уақытта жерасты ядролық қуыстарынан радионуклидтердің миграциялық процестерінің жоқтығын көрсетеді. Полигонның жер асты суларының оқшау жинағы Батыс және Шығыс Азғыр тұз күмбездері арасында орналасқан «Ужунтатор» ойысы болып табылады. Полигонның жер асты сулары да бөлек-бөлек линзалар түрінде орналасқан.

Ауыр металдармен ластану индексін (HPI) пайдалана отырып, судағы ауыр металдардың құрамы бойынша бақылау ұңғымалары мен құдықтардан алынған сулардың уыттылығын бағалау ұсынылған. Жер асты суларындағы химиялық элементтердің үстемдігі Fe > Mn > Ni > Cr > Co > Mo > Cu > Zn тәртібінде орнатылған. Нәтижесінде бұл сулардың ауыз суы мақсатында пайдалануға жарамсыздығы туралы тұжырымдар расталды. HPI индексінің мәні ауыз су үшін сыни мәннен 72,6 есеге дейін асып түседі, бұл жер асты суларының гидрогеологиялық жағдайларына байланысты.

Зерттеу «Ядролық физика институты» РМК Кешенді экологиялық зерттеулер орталығының базасында жүргізілді.

Түйін сөздер: жерасты сулары, жерасты ядролық қуыстары, радионуклидтер, ауыр металдар, ауыр металдармен ластану индексі, Азғыр сынақ полигоны.

Введение

В 1965-1987гг. на территории республики Казахстан было проведено 39 мирных подземных ядерных взрывов для нужд народного хозяйства, из них 17 были выполнены на полигоне «Азгир», расположенном в Курмангазинском районе Атырауской области в Западном Казахстане. С 1964 г. на полигоне были развернуты работы по опытно-промышленным исследованиям для отработки технологии создания с помощью камуфлетных ядерных взрывов в массивах каменной соли подземных полостей, предназначенных в качестве хранилищ большого объема. Работы проводились на 10 технологических площадках А1-А5, А7-А11, на глубине от 165 до 1500 м (рисунок 1) (Глущенко, 2020 б:21).

Место проведения подземных ядерных взрывов выбиралось тщательно. Полигон расположен на соляно-купольном поднятии Большой Азгир, на западной периферии Прикаспийской соленосной провинции, расположенной к северу от

Каспийского моря. Солянокупольное поднятие Большой Азгир представляет собой два крупных соляных купола – Западный и Восточный Азгир, геологически разделенных компенсационной мульдой Ужунтатор. Местами на этой территории соляной купол выходит на дневную поверхность, представляя собой смесь песчанных почв с преобладанием соли. Технология проведения ядерных взрывов предусматривала полное исключение попадания продуктов ядерного взрыва на дневную поверхность и в геологические структуры. При проведении подземного ядерного взрыва в глубине массива каменной соли, при воздействии высоких температур, каменная соль расплавлялась, растекалась по стенкам полости и застывала в виде прочного стеклообразного барьера, препятствующего выходу продуктов ядерного взрыва. Однако при проведении взрывов произошел ряд нештатных ситуаций. При проведении взрыва на площадке А-9 произошел непреднамеренный провал грунта диаметром 600 м и глубиной 35 м., который впоследствии стал заполняться талой и дождевой водой. В настоящее время площадка А-9 представляет собой искусственное «озеро» объемом около 20 тыс. куб.м.. Пять полостей (А1-А5) после взрыва заполнились водой, две полости А7 и А10 заполнились водой частично. Растворившая в себе соль, вода внутри полости представляет собой высокосолёный радиоактивный рассол. Полости А8 и А11 сухие. Боевые скважины после законсервированы бетонной пробкой. После закрытия полигон получил статус радиационно-опасного объекта и стал являться объектом радиоэкологических исследований. Особое значение в этих исследованиях занимает изучение возможных процессов миграции радионуклидов из подземных ядерных полостей.

Подземный ядерный взрыв является одним из самых сильных техногенных воздействий на геологическую среду, приведший к изменению строения больших объемов подземных систем. Вокруг полости взрыва формируются зоны механического разрушения, которые в случае изменения геофизической ситуации могут являться каналами поступления радиоактивных рассолов из водонаполненных полостей в вышележащие водоносные горизонты и дневную поверхность. Главными путями возможной миграции радионуклидов из подземных полостей являются «полость взрыва – вмещающая геологическая среда – дневная поверхность» и «полость взрыва – вмещающая геологическая среда – подземные воды». Только зная современное состояние этих геотехногенных систем можно строить прогнозы и предпринимать необходимые меры по снижению экологических рисков, связанных с этими опасными объектами.

С 1991 года на территории полигона и прилегающей территории РГП «Институтом ядерной физики» проведен ряд масштабных комплексных радиационно-экологических исследований, проведены рекультивационные мероприятия по обнаружению, изъятию и захоронению радиационно-загрязненного грунта и технологического металлолома, оставшихся после проведения взрывных и опытных работ. Территории технологических площадок полигона огорожены для исключения проникновения скота и местного населения, расставлены предупреждающие знаки радиационной опасности. Для охраны технологических объектов полигона, оперативного контроля радиационной обстановки (дозиметрия), непосредственно на месте действует Азгирская научно-производственная экспедиция РГП «Институт ядерной физики». Для контроля радиационно-экологической ситуации на полигоне и прилегающей территории с 2001 года функционирует система комплексного радиоэкологического мониторинга, предусматривающая два уровня: контроль текущей радиоэкологической ситуации на полигоне и контроль возможных процессов миграции радионуклидов из подземных ядерных полостей. Для контроля подземных вод на полигоне имеется парк наблюдательных пунктов. До 2021 года она включала 10 наблюдательных скважин и 5 колодцев (скважины: С-2001, С-2002, С-2003, С-2004, С-2005, С-2006, С-1064, С-1081, С-1084, С-2; колодцы: Азгир 1, Азгир 2, Азгир 4, Жартык, Булак). Наблюдательные скважины рассредоточены в местах геологического расположения соляных куполов Западный и Восточный Азгир, в ближайших к расположению подземных полостей точках. Входящие в систему мониторинга колодцы исторически были организованы местным населением в населенных пунктах и места водопоя скота и т.д. В 2021 для усовешенствования системы мониторинга подземных вод парк наблюдательных скважин был расширен шестью новыми наблюдательными скважинами, расположенными в зоне распространения мульды «Ужунтатор» (С-2007, С-2008, С-2009, С-2010, С-2011, С-2012). При выборе места размещения новых скважин принималось во внимание что

мульда Ужунтатор, расположенная между соляными куполами Западный и Восточный Азгир. В гидрогеологическом отношении, мульда может представлять локальный бассейн и играть роль сборника передвигающихся вод и содержащихся в них примесей (и при нарушении полостей боевых скважин – возможно радионуклидов). Глубина наблюдательных скважин и колодцев составляет до 20 м., за исключением наблюдательной скважины С-1081 (40 м.). Схема расположения наблюдательных скважин на полигона «Азгир» представлена на рисунке 1.

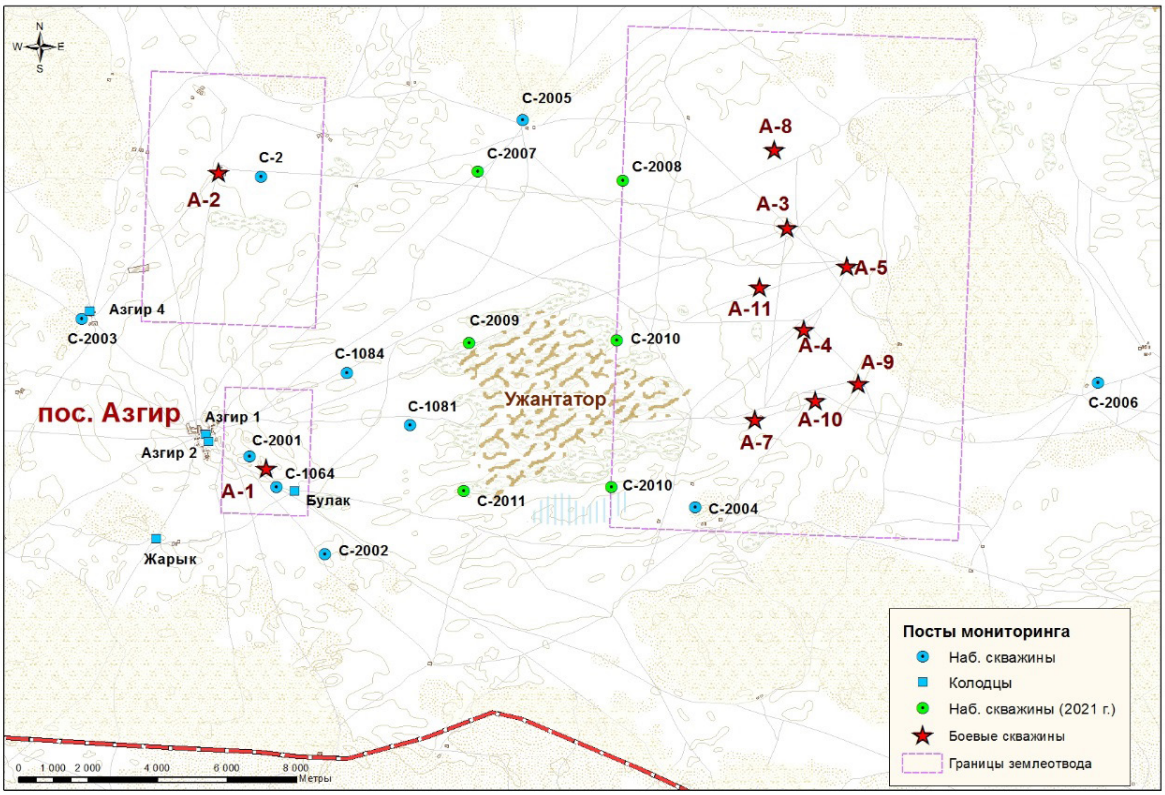


Рисунок 1 – Схема расположения наблюдательных скважин и колодцев системы комплексного радиоэкологического мониторинга полигона «Азгир» и прилегающих территорий

В представленной статье показаны результаты исследования подземных вод бывшего испытательного полигона «Азгир» с учетом новых данных, полученных после бурения новых наблюдательных скважин. Целью этих работ являлось изучение подземных вод первого водоносного горизонта на территории полигона, исследование их радионуклидного, элементного состава для углубления знаний о гидрогеологических условиях полигона, уточнения гидрогеологических условий полигона и отсутствия или наличия единого водоносного горизонта, связывающего между собой подземные полости и направления возможной миграции радионуклидов.

Материалы и методы

Солянокупольная тектоника и новейшие восходящие движения создали сложнейшие гидрогеологические условия для формирования химического состава верхних водоносных горизонтов. В пределах площади исследований и прилегающих к ней районов распространены подземные воды от соленых вод до рассолов, как по площади, так и в разрезе. На описываемой площади наиболее полно исследованы воды четвертичных отложений, глубина залегания грунтовых вод в аллювиальных отложениях зависит от рельефа пойменной террасы и уровня поверхностных вод в водоемах и изменяется от 0,5 до

6,8 м. Схема распространения водоносных горизонтов полигона, составленная на основе архивных материалов представлена на рисунке 2.

В стратиграфической последовательности гидрогеологические подразделения расположены следующим образом (Мясников, 1996а:56; Мясников, 1996б:23; Мясников, 1997:102)

• водоносный горизонт современных эоловых отложений (vQIV) распространен в виде пятен незакрепленных песчаных массивов. Подземные воды приурочены к хорошо отвеянным пескам кварцевым, мелкозернистым. В силу своего неглубокого залегания (от 0,2 до 4,2 м) питание подземных вод получают за счет атмосферных осадков и весеннего снеготаяния. Обычно это плавающие линзы пресных и слабосоленых вод с минерализацией от 0,3-3,2 г/л. Химический состав воды меняется от гидрокарбонатных до хлоридно-сульфатных и магниево-натриевых.

• водоносный горизонт современных озерно-соровых отложений (lQIV) приурочен к локальным понижениям, иногда вытянутым в различных направлениях вплоть до кольцевых форм. Ужунтатор – крупная солончаковая мульда площадью 68 км^2. Водовмещающими породами являются илы, иловатые супеси и пески, насыщенные хлористыми или сернокислыми солями. Породы обладают коэффициентом фильтрации от 0,2 м/сут до 0,8 м/сут. Воды относятся к группе рассолов с минерализацией от 50 г/л до 120 г/л. По химическому составу воды хлоридные натриево-магниевые. Общая жесткость от 260,6 мг/экв до 730,0 мг/экв. Присутствует бром, йод, бор в больших количествах. Питание грунтовых вод идет за счет снеготаяния и инфильтрации дождевых вод;

• водоносный горизонт верхнечетвертичных хвалынских отложений (QIIIhv). Подземные воды хвалыно-хазарских отложений развиты повсеместно и отсутствуют только в районе солянокупольных поднятий Балкудук и Большой Азгир, где эти отложения не получили развития.

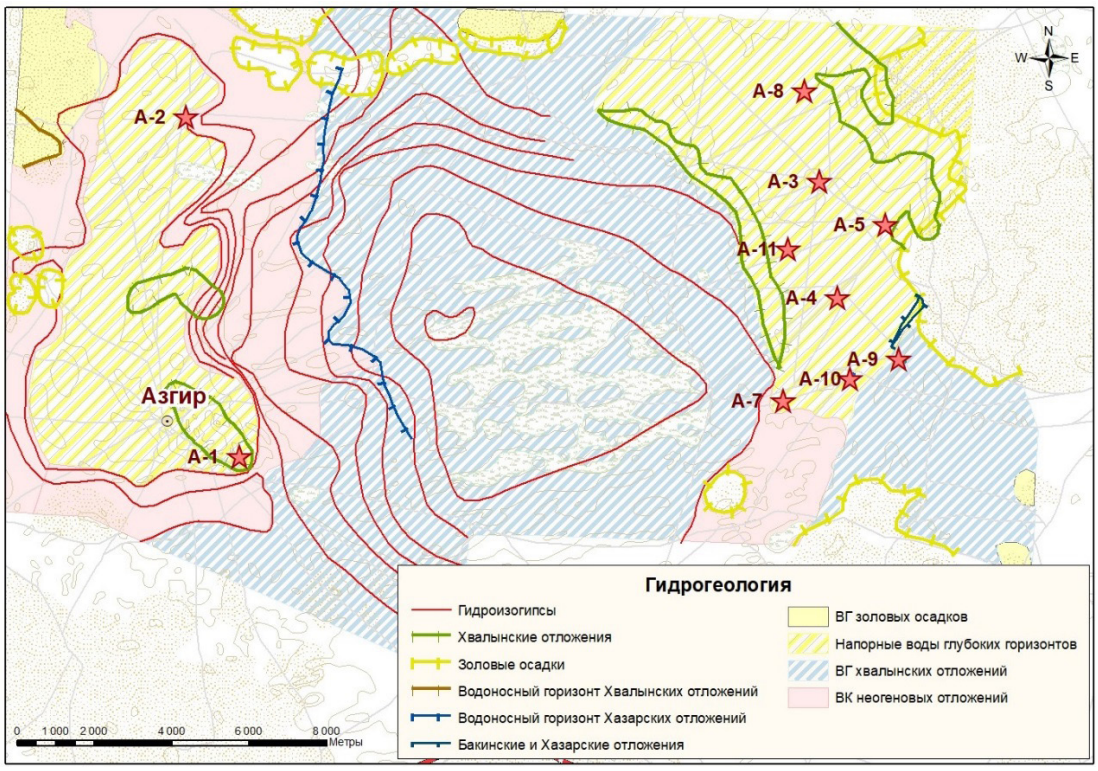


Рисунок 2 – Водоносные горизонты полигона Азгир по архивным материалам

В основе исследования подземных вод полигона, представленных в настоящей статье, лежат данные о результатах мониторинга за 2021 год. Аналитические испытания отобранных проб проводились в аккредитованном на соответствие ГОСТ ISO/IEC 17025-2019 Центре комплексных экологических исследований РГП «Институт ядерной физики». Изучен радионуклидный со-

став воды по присутствию природных (^{3}H, ^{232}Th, ^{226}Ra, ^{40}K) и техногенных (^{137}Cs, ^{90}Sr, $^{239+240}Pu$) радионуклидов и суммарной альфа- и бета-активности, а также элементный состав на содержание Na, Mg, K, Ca, V, Cu, Se, As, U, Hg, Cd, Ni, Pb, Al, Co, Cr, Mn, Fe, Ba, Zn, Sr, Li, Mo, Be, а также и общей минерализации (хлорид (Cl^-) и сульфат (SO_4^{2-}) ионов). При лабораторных анализах проб воды использовались методы инструментальной спектрометрии, радиохимический анализ и масс-спектрометрии с индуктивно связанной плазмой.

Интерпретирование результатов лабораторных анализов проводилось с применением компьютерных технологий, включая Географическую информационную систему (для построения тематических карт), программ для анализа данных методами математической статистики. Применение методов математической статистики обусловлено тем фактом, что результаты микро- и макроэлементного анализа каждой пробы воды представлены 27 элементами (переменными) и проведение комплексного анализа данных, визуализации и осмысления результатов вручную невозможно. На первом этапе был выполнен анализ данных с помощью метода главных компонент (PCA анализ). Целями такого анализа являются сокращение числа переменных и определение структуры взаимосвязей между переменными, т.е. их классификация (Электронный учебник по статистике, 2022). Такая процедура помогла отсеять факторы, влияние которых на дальнейший анализ данных незначительно. На следующем этапе выполнена работа по разделению всей совокупности данных на группы, используя некоторую меру сходства между объектами. Решение этой задачи проведено с использованием кластерного анализа (это метод классификационного анализа, который предназначен для разбиения множества исследуемых объектов (образцов) и признаков на однородные группы, или кластеры) (Методы статистического анализа данных, 2022). В данном исследовании кластерный анализ проведен по совокупности содержания компонентов в пробе воды из разных (существующих и новых) скважин и колодцев.

Дополнительно к исследованию, связанному с математической обработкой данных по химическому составу вод существующих и новых наблюдательных скважин, проведена оценка степени токсичности вод по комплексному присутствию в ней тяжелых металлов. Для оценки степени токсичности воды в зарубежной литературе широко используются такие индексы как HPI (индекс загрязненности тяжелыми металлами), WQI (индекс качества воды) (Abdullah, 2013:63), EWQI (энтропийный индекс качества воды), ImpWQI (индекс улучшения качества воды) и др. Общей целью расчетов этих индексов является классификация проб воды по степени отношения комплексного содержания химических элементов в воде к стандарту воздействия или безопасных пределов загрязняющих веществ, которые устанавливаются национальными стандартами (Санитарные правила, 2015). В настоящем исследовании применялся Индекс загрязненности тяжелыми металлами (HPI), представляющий собой одно число, которое обобщает общее качество воды в определенном месте и в определенное время на основе концентрации отдельных химических элементов (Singh et al., 2015:1920). HPI основан на средневзвешенном арифметическом значении качества, которое присваивает рейтинг или весовую единицу (Wi) для каждого тяжелого металла (Jareda et al., 2016: 80) и рассчитывается по формуле:

$$HPI = \frac{\sum_{i=1}^{n} Q_i W_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

где W_i – удельный вес/весовая нагрузка, который обратно пропорционален рекомендуемому стандарту (Si) (Руководство ВОЗ, 2022:329). соответствующего параметра (Martha et al., 2021).

$$W_i = \frac{1}{S_i} \quad (2)$$

где Qi – это субиндекс i-го параметра, а Vi – измеренная концентрация i-го параметра в мкг/л.

$$Q_i = \frac{V_i}{S_i} \cdot 100 \quad (3)$$

На основе расчета индекса HPI производится классификация воды HPI от Ghaderpoori et al., 2018: 685

- < 100 низкий риск
- 100 пороговый риск
- >100 воды с высоким риском.

Как правило, критическое значение индекса загрязнения тяжелыми металлами HPI принимается равным 100 (Singh et al., 2015: 1920).

В расчет индекса HPI из всей совокупности данных об элементном составе подземных вод

из наблюдательных скважин и колодцев выбраны элементы, относящиеся к категории «тяжелые металлы»: Fe, Mn, Ni, Cr, Co, Mo, Cu, Zn.

Обзор литературы

На основании архивных отчетах ВНИПИпромтехнология (Мясников, 1996а:56; Мясников, 1996б:23; Мясников, 1997:102; Жотабаев, 2006:60; Черепанов., 2003-2006:22; Дидичин, 1982:37; Дидичин, 1983:133), Института геофизических исследований (Тулеушев, 2010: 19) трехлетнего отчета РГП Институт ядерной физики (Глущенко, 2011: 8.) об исследовании экологического состояния подземных вод в ареале полигона, отчета РГП ИЯФ (Глущенко,2021:42), в котором собраны сведения о результатах бурения новых наблюдательных скважин (С-2007-2012), авторами проанализированы данные и получены сведения о гидрогеологических условиях полигона «Азгир».

О современных результатах радиоэкологического мониторинга бывшего испытательного полигона «Азгир», материалы публикуются авторами из Института ядерной физики (Глущенко, 2019:174; Глущенко, 2021:38; Глущенко, 2020а:21; Глущенко, 2020б:13). Как следует из вышеуказанных источников, текущая радиационно-экологическая ситуация на полигоне стабильна. Демонстрируется высокая эффективности проведенных на полигоне дезактивационных мероприятий и результативность существующей системы мониторинга. При этом привлекается внимание к тому, что, несмотря на отсутствие техногенного загрязнения дневной поверхности и подземных вод полигона, мониторинг и исследования на полигоне необходимо продолжать.

Являясь участниками исследований на полигоне «Азгир», авторы настоящей статьи представляют результаты собственных работ, проведенных в 2021 году.

Результаты и обсуждение

Радионуклидный состав подземных вод

По результатам гамма-спектрометрического и радиохимического анализа проб воды из новых скважин (таблица 1) видно, что значения удельных активностей большинства изученных техногенных радионуклидов находятся значительно ниже установленного норматива для Казахстана – уровень вмешательства (УВ) (Гигиенические нормативы, 2022), что свидетельствует об отсутствии радиационного загрязнения подземных вод. Максимальное значение удельной активности Cs-137 не превышает 0,38 Бк/л, Pu-239+240 – 7,7 мБк/л, H-3 – 8,5 Бк/л, что многократно ниже нормируемых показателей. *Отсутствие трития, как одного из наиболее миграционно-активных радионуклидов (*Kryazhych, 2017:62*), образующихся при ядерном взрыве и находящихся в подземной полости, также показывает об отсутствии процессов миграции.*

Суммарная альфа- и бета-активность воды в отдельных пробах немного превышает норматив «допустимый уровень» (ДУ) (Об утверждении гигиенических нормативов..., 2022), что обусловлено присутствием в них природных радионуклидов уранового ряда (Ra-226 и Th-232) что характерно для Западного Казахстана. Повышенные значения удельной активности Th-232 в воде новых скважин, скорее всего, обусловлено природными геологическими процессами выщелачивания из горных пород, и это процесс будет изучен в ходе дальнейшего мониторинга.

Таблица 1 – Средние значения (за весну и осень 2021) удельной активности естественных и техногенных радионуклидов в пробах воды существующих и новых скважин

Скважина /колодец	K-40, Бк/л	Th-232, Бк/л	Ra-226, Бк/л	Pu-239+240, мБк/л	Sr-90, мБк/л	Cs-137, Бк/л	H-3, Бк/л	∑α	∑β
С-2001	11,5	0,28	0,42	0,18	31,70	0,36	8,5	0,42	0,15
С-2002	12,5	0,30	0,41	7,68	18,55	0,32	6,0	0,14	0,10
С-2003	12,5	0,29	0,42	7,60	18,35	0,37	6,5	0,07	0,15
С-2004	12,0	0,29	0,40	0,16	20,40	0,38	7,5	0,14	0,15
С-2005	12,5	0,29	0,42	0,17	23,70	0,37	6,0	0,12	0,35

Продолжение таблицы

Скважина /колодец	K-40, Бк/л	Th-232, Бк/л	Ra-226, Бк/л	Pu-239+240, мБк/л	Sr-90, мБк/л	Cs-137, Бк/л	H-3, Бк/л	∑α	∑β
С-2006	12,5	0,37	0,40	0,19	20,45	0,37	7,0	0,30	0,25
С-1084	12,0	0,40	0,43	0,17	42,15	0,38	7,0	0,12	0,20
С-1081	11,5	0,37	0,42	0,31	24,30	0,33	6,0	0,06	1,10
С-1064	11,0	0,47	0,41	0,19	51,05	0,34	6,5	0,40	0,50
Скв. С-2	12,5	0,27	0,46	0,21	19,55	0,35	8,5	0,24	0,10
к.Жартык	12,5	0,33	0,44	0,20	52,55	0,38	8,5	0,33	0,15
к.Булак	12,5	0,59	0,43	0,19	17,00	0,36	7,0	0,27	0,10
к.Азгир-1	12,5	0,27	0,42	0,21	17,15	0,35	6,5	0,13	0,25
к.Азгир-2	12,5	0,44	0,42	0,21	28,20	0,37	8,5	0,40	0,40
к.Азгир-4	12,0	0,28	0,42	0,27	17,75	0,33	8,0	0,29	0,10
С-2007	13,0	1,73	0,44	0,16	16,3	0,34	6,0	0,02	0,10
С-2008	12,0	0,93	0,42	0,18	17,0	0,36	6,0	0,02	0,10
С-2009	12,0	1,47	0,45	0,21	36,2	0,35	6,0	0,24	0,10
С-2010	11,0	0,89	0,41	0,14	64,0	0,35	8,0	1,0	0,20
С-2011	12,0	1,63	0,64	0,21	30,5	0,35	6,0	0,58	0,20
С-2012	12,0	1,27	0,43	0,17	17,3	0,34	6,0	0,64	0,10
УВ	-	0,6	0,49	1100	4900	11	7600	0,20	0,10

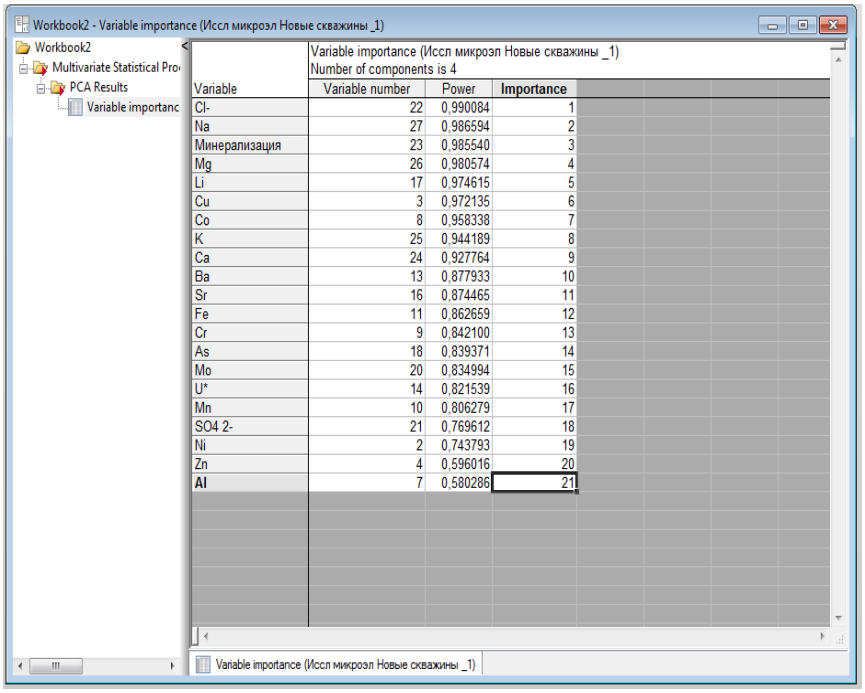
Макро-и микроэлементный состав и общая минерализация подземных вод

Для оценки результатов лабораторных исследований подземных вод проведен анализ макро-, микроэлементного состава и общей минерализации подземных вод всех (существующих и новых) наблюдательных скважин и колодцев. Согласно одной из целей исследования, анализ данных проведен для попытки установления связи между химическим составом воды исследуемых скважин и уточнения гидрогеологической обстановки на полигоне. По результатам анализа главных компонент (PCA анализ) (рисунок 3) получено, что вес переменных (значений концентрации химических элементов) изменяются от 0,99 до 0,58. Для последующей обработки была отобрана совокупность тех данных, которые представляют наибольший статистический интерес, а именно 12 переменных с весом близким к 0,9 – это концентрация аниона Cl^-, общая минерализация и микроэлементов Na, Mg, Li, Cu, Co, K, Ca, Fe, Ba, Sr.

Выявленная первая главная компонента описывает 68% данных, вторая – 23% (рисунок 4). Таким образом, первые две главные компоненты описывают 91% данных, то есть для анализа 12 переменных (элементов) далее можно использовать только две переменные (две главные компоненты).

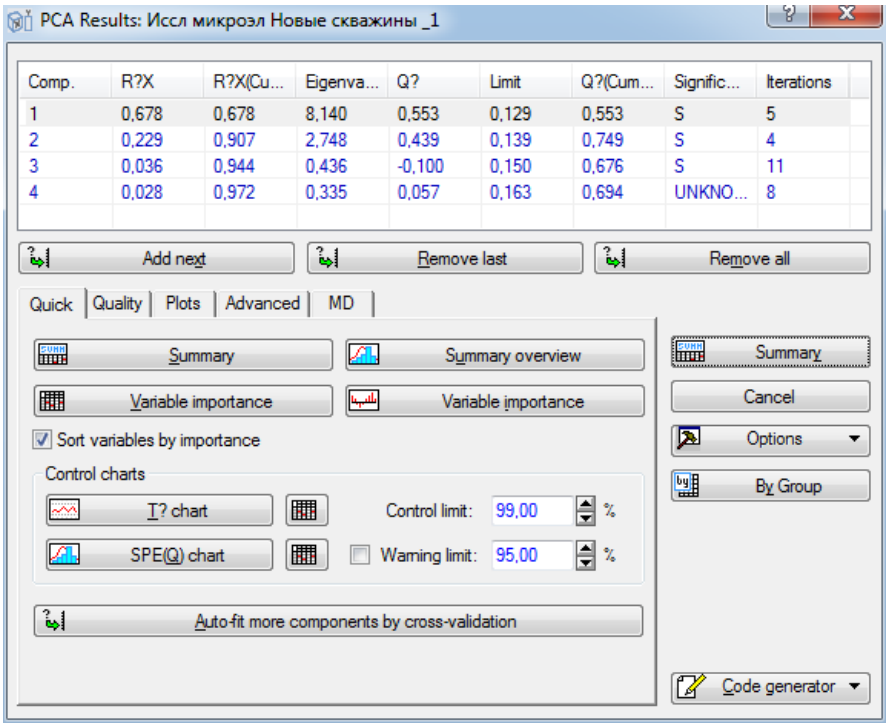
При проведении факторного анализа проб воды из наблюдательных скважин и колодцев были рассчитаны две главные компоненты (F1 и F2), которые описывают 91% данных. Результаты расчетов визуализированы в виде точечного графика Excel (рисунок 5).

На полученном графике можно выделить четыре группы, объединяющие скважины по химическому составу. Первая: скважина С-1064; вторая: скважины С-2007, С-2008, С-1084, С-2006, С-2, С-2005, С-2004, С-2003, С-2002 и колодцы Булак, Жартык, №1 и №4; третья: скважины С-2010, С-2009, С-2012, С-2011, С-1081; четвертая: скважина С-1064.



Variable	Variable number	Power	Importance
Cl-	22	0,990084	1
Na	27	0,986594	2
Минерализация	23	0,985540	3
Mg	26	0,980574	4
Li	17	0,974615	5
Cu	3	0,972135	6
Co	8	0,958338	7
K	25	0,944189	8
Ca	24	0,927764	9
Ba	13	0,877933	10
Sr	16	0,874465	11
Fe	11	0,862659	12
Cr	9	0,842100	13
As	18	0,839371	14
Mo	20	0,834994	15
U*	14	0,821539	16
Mn	10	0,806279	17
SO4 2-	21	0,769612	18
Ni	2	0,743793	19
Zn	4	0,596016	20
Al	7	0,580286	21

Рисунок 3 – Оценка важности переменных по данным PCA анализа.



Comp.	R?X	R?X(Cu...	Eigenva...	Q?	Limit	Q?(Cum...	Signific...	Iterations
1	0,678	0,678	8,140	0,553	0,129	0,553	S	5
2	0,229	0,907	2,748	0,439	0,139	0,749	S	4
3	0,036	0,944	0,436	-0,100	0,150	0,676	S	11
4	0,028	0,972	0,335	0,057	0,163	0,694	UNKNO...	8

Рисунок 4 – Информация о главных компонентах, описывающих всю совокупность данных

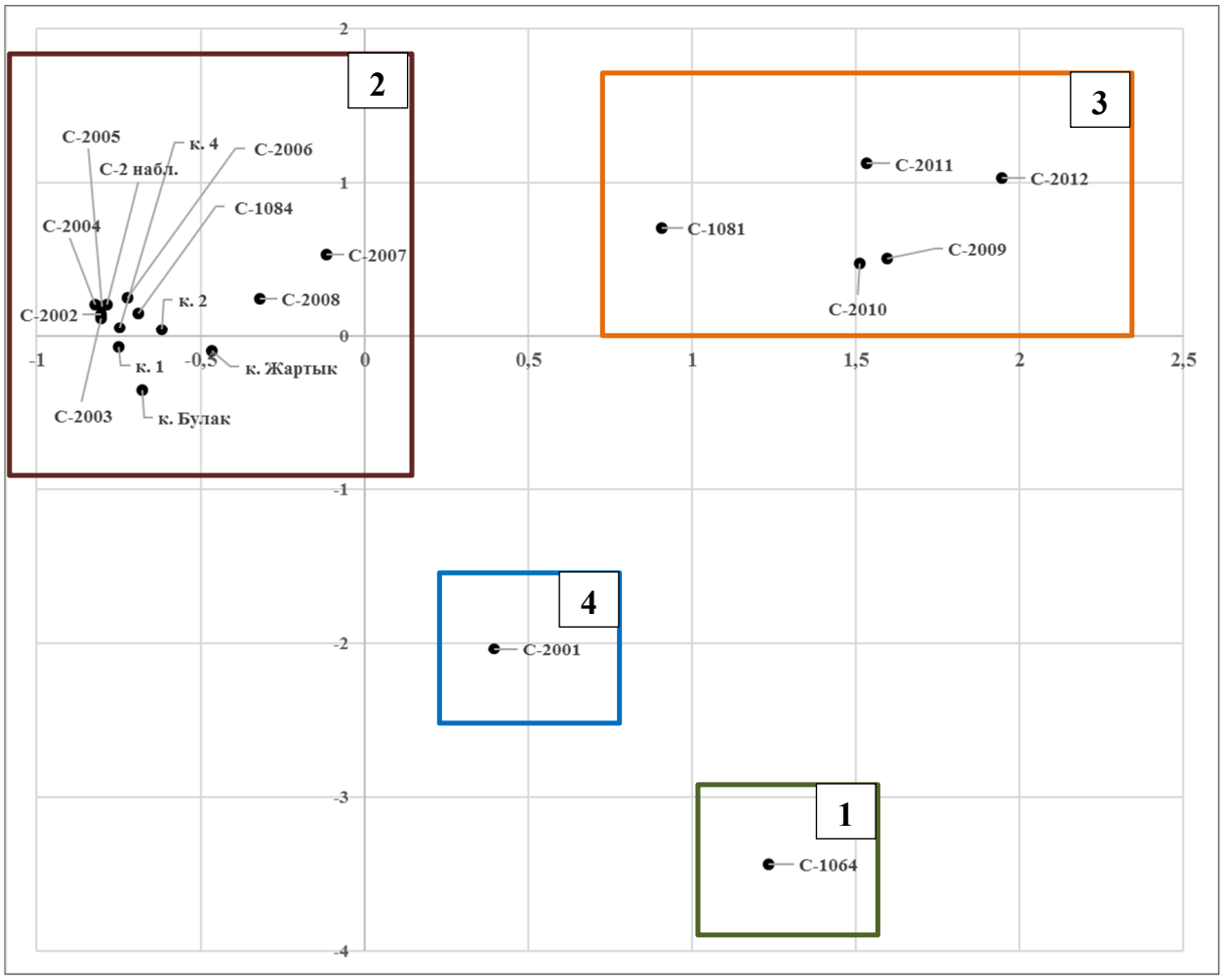


Рисунок 5 – Результаты многомерного факторного анализа по данным элементного состава водных проб из существующих и новых наблюдательных скважин

Результаты кластерного анализа, проведенного для проверки результатов расчета в виде древовидной диаграммы представлены на рисунке 6.

На полученной диаграмме можно выделить несколько кластеров – первый – скважина С-1064, второй – скважины С-2007, С-2008, С-1084, С-2006, С-2, С-2005, С-2004, С-2003, С-2002 и колодцы Булак, Жартык, №1 и №4, третий кластер – скважины С-2010, С-2009, С-2012, С-2011, С-1081, четвертый – скважина С-2001. При этом, вода из скважины С-1064 по микроэлементному составу более всего отличается от всех остальных скважин и колодцев. А вода скважины С-2001 небольшие различия с водой из скважин, отнесенных к третьему кластеру. Таким образом, можно предположить, что каждый из выделенных кластеров характеризуется общим набором признаков и могут иметь общие черты (например, относиться к единому водоносному горизонту).

В результате кластерного и факторного анализа показан хорошо сходимый результат: по совокупности макро-, микроэлементного состава и общей минерализации выделяются четыре группы скважин, описанных выше. Путем наложения карты расположения подземных водоносных горизонтов, расположения наблюдательных скважин и результатов вышеприведённого анализа, построена карта, представленная на рисунке 7.

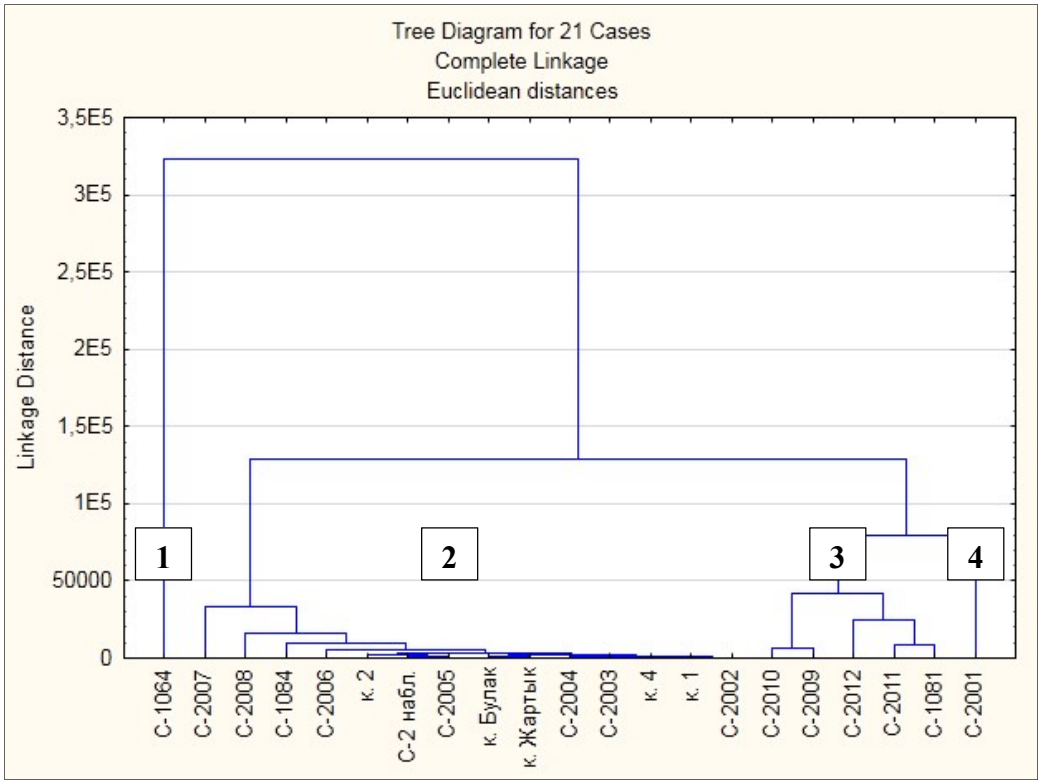


Рисунок 6 – Результаты многомерного кластерного анализа
по данным элементного состава водных проб из существующих и новых наблюдательных скважин

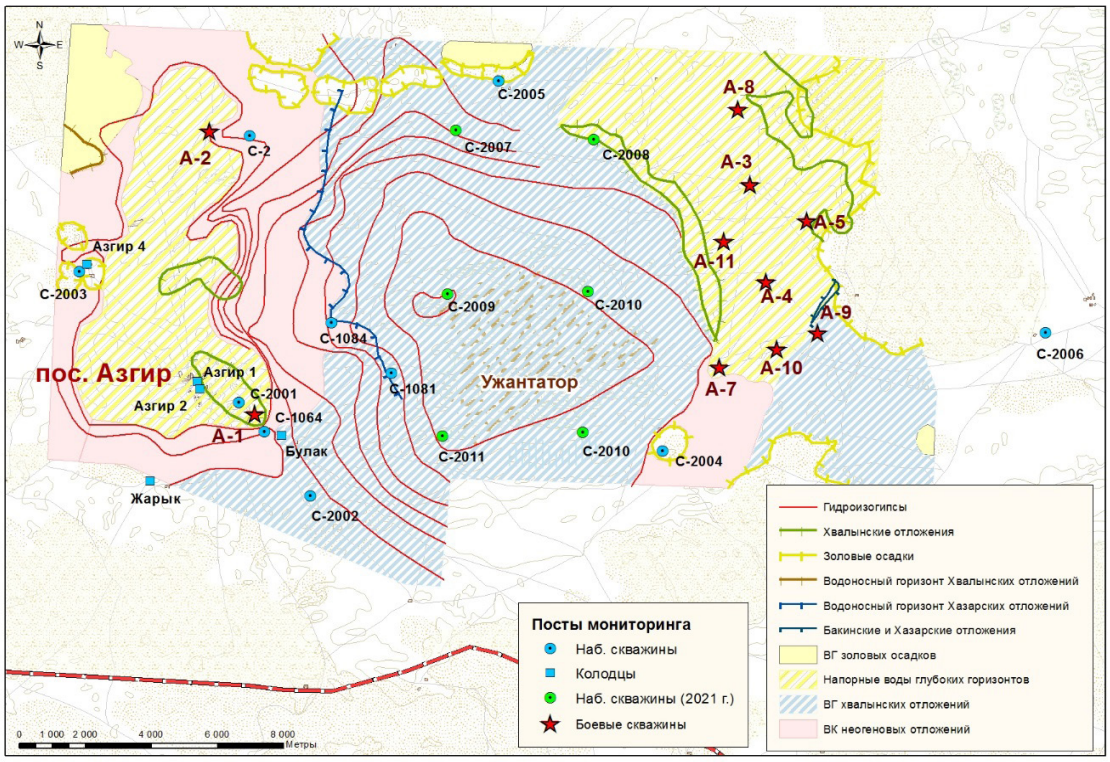


Рисунок 7 – Карта расположения водоносных комплексов и наблюдательных
скважин и колодцев полигона «Азгир»

Таким образом, исходя из статистического анализа по макро-, микроэлементному составу и общей минерализации подземных вод существующих и новых скважин, а также анализа их совместного расположения (рисунок 7) следует:

- Скважина С-1064 и С-2001 имеют наибольшие отличия макро-, микроэлементного состава и общей минерализации от всех скважин и между собой, несмотря на их близкое расположение друг к другу и к колодцам Азгир (№1 и №2), Булак и Жартык. Подземные воды здесь могут быть представлены в виде отдельных мелких разрозненных линз.

- Скважина С-2006 имеет наибольшую удаленность от всех имеющихся скважин, однако имеет подземные воды, схожие по составу с С-2007, С-2008, С-1084, С-2, С-2005, С-2004, С-2003, С-2002. Вероятнее всего, подземные воды этих скважин имеют общие признаки, обусловленные природными факторами наличия геологических соляных структур, но являются представителями единого водоносного горизонта.

- Скважины С-2010, С-2009, С-2012, С-2011, С-1081, возможно расположены в зоне единого водоносного горизонта. Подтверждается предположение о том, что мульда Ужунтатор, расположенная между соляными куполами является локальным сборником подземных вод хвалынских отложений.

Ожидается, что более подробная картина о распространении подземных вод полигона будет получена после создания новых скважин в 2022 году, а также в ходе проведения мониторинга в последующие годы.

Оценка токсичности вод

На рисунке 8 представлены средние концентрации восьми тяжелых металлов для каждого источника воды в весенний и осенний периоды 2021 года, и соответствующие гигиенические стандарты качества вод Республики Казахстан стандартами (Санитарные правила, 2015).

Из результатов следует, что по содержанию Ni в пробах воды лишь в скважине С-1081 зафиксирована концентрация (153 мкг/л) превышающая максимально допустимый предел, который составляет по стандарту ВОЗ – 70 мкг/л, по стандарту РК – 100 мкг/л. Среднее значение составило 18,2 мкг/л.

По содержанию Cu, Zn, Co, Cr и Mo все полученные концентрации находятся в пределах допустимой нормы для каждого из заявленного элементов. Таким образом, максимальное значение Cu составило 66,1 мкг/л в весенний период, 57,5 мкг/л в осенний период в скважине С-1064 (ПДК по стандарту ВОЗ – 2000 мкг/л, РК – 1000 мкг/л). Средняя концентрация равна 10,5 мкг/л. Содержание Zn находится в незначительных пределах, максимальная концентрация которого равна 128 и 71 мкг/л в весенний и осенний периоды соответственно (колодец Азгир-4). При этом норма для Zn составляет 3000 мкг/л по стандарту ВОЗ и 5000 мкг/л по стандарту РК. Средняя концентрация – 17 мкг/л.

Средние значения для Co и Mo составляют 3,3 и 4,3 мкг/л соответственно. Максимальные значения Co зафиксированы в скважине С-1064, которые составили 24,1 мкг/л (весна) и 16,1 мкг/л (осень). Но превышающие допустимую норму в 100 мкг/л концентрации не зафиксированы. Аналогичная ситуация и по содержанию Mo в пробах воды, где фактические значения были значительно ниже допустимой нормы.

Иная картина складывается по содержанию Mn и Fe в исследованных пробах воды. В случае с Mn, только 5 из 30 исследованных проб соответствовали стандартам ВОЗ (80 мкг/л) и РК (100 мкг/л). При этом среднее значение Mn составило 1256 мкг/л, что в 12 раз превышает допустимую норму. Такие же результаты по содержанию Fe в воде, где максимально зафиксированная концентрация превышает допустимую норму в 696 раз, а среднее значение в 79 раз.

На основе полученных средних значений концентрации, с учетом нормативов для питьевых вод Казахстана были рассчитаны HPI для каждого сезона и в целом для каждой точки отбора проб (таблица 2).

Как показано в таблице 2, высокие значения HPI, превышающие критическое значение индекса загрязнения равным 100, наблюдались в ряде скважин в течение всех сезонов. Низкий уровень загрязненности тяжелыми металлами зафиксированы в местах отбора С-2002, С-2003, С-2004, С-2005, С-2006, С-2, к.Жартык, к.Азгир-4. В скважине С-2001 HPI составил в среднем 954, что в ~9,5 раз превышает пороговое значение. HPI в скважинах С-1084 и С-1081 составили в среднем 333 и 617 соответственно. Максимально зафиксированное среднегодовое значение HPI составляет 7260 в скважине С-1064. В колодцах Булак, Азгир-1 и Азгир-2 индекс загрязненности тяжелыми металлами составило 214, 275 и 110 соответственно. То есть эти источники подземных вод представляют высокий уровень риска токсичности вод для питьевого использования.

Рисунок 8 – Концентрации тяжелых металлов в местах отбора проб в весенний и осенний периоды 2021 года

Таблица 2 – HPI подземных вод наблюдательных скважин и колодцев за весенне-осенний период 2021 года

Скважина/колодец	HPI
С-2001	954
С-2002	29
С-2003	70
С-2004	38
С-2005	37
С-2006	73
С-1084	333
С-1081	617
С-1064	7260
С-2	24
Жартык	42
Булак	214
Азгир-1	275
Азгир-2	110
Азгир-4	17
С-2007	796
С-2008	665
С-2009	4462
С-2010	2690
С-2011	6153
С-2012	2776

Таким образом, показано и еще раз подтверждено, что ряд проб грунтовых вод, отобранных их скважин и колодцев полигона «Азгир» содержат критические для здоровья человека концентрации тяжелых металлов. Высокие концентрации тяжелых металлов связаны с геологическим условиями района, контакта подземных вод с соляными геологическими структурами.

Заключение

В результате исследования подземных вод, проведенного на полигоне «Азгир» с применением новых данных, полученных после бурения в 2021 г. шести новых наблюдательных скважин показано, что подземные воды полигона, на глубине 20 м, не имеют признаков радиоактивного загрязнения. Удельная активность техногенных радионуклидов в подземных водах из новых наблюдательных скважин значительно ниже гигиенических нормативов республики Казахстан и сопоставимо с удельными активностями радионуклидов в воде существующих скважин: Cs-137 (0,32-0,38 Бк/л), Sr-90 (16,3-64,0 Бк/л), Pu-239+240 (0,14 – 7,68 мБк/л). Не зафиксировано значимой удельной активности наиболее миграционно-активного радионуклида H-3 (60-8,5 Бк/л) в пробах подземной воды из скважин.

Водоносный горизонт полигона на глубине 20 м. представлен в виде отдельных линз, а также имеется локальный бассейн, расположенный на месте мульды «Ужунтатор». Это определяет основной возможный путь миграции радионуклидов из подземных ядерных полостей. Располагаясь между двумя геологическими соляными куполами, именно мульда может являться сборником подземных вод на этой глубине. В точки зрения радиоэкологической безопасности, даже в случае появления процессов миграции радиоактивности из подземных полостей, загрязненные подземные воды будут направлены в этот локальный бассейн, где, вероятнее всего будут задерживаться. Следует отметить, что авторы ожидают получения более подробной картины о распространении подземных вод полигона после завершения второго этапа бурения скважин, намеченных на конец 2022 года, а также в ходе проведения мониторинга в последующие годы. Несмотря на то, что исследованием показано отсутствие миграции радионуклидов из подземных полостей в настоящее время, существуют постоянные опасения того, что в случае геофизических изменений геологических структур может быть спровоцировано постепенное разрушение стенок полости и выхода радиоактивности через зоны поствзрывной трещиноватости в подземные водоносные горизонты и дневную поверхность. Только регулярные наблюдения позволяют отслеживать текущую радиоэкологическую ситуацию для своевременного реагирования даже на самые малейшие изменения.

Расчет индекса токсичности вод с применением индекса HPI, основанного на значении средней концентрации ряда тяжелых металлов (Ni, Cu, Zn, Co, Cr, Mo, Fe, Mn), демонтрирует высокий риск токсического воздействия. Полученный факт подтверждает предыдущие заключения (Глущенко, 2019:174, Глущенко, 2020:13) о непригодности подземных вод полигона для питьевых целей. Это связано с геологической структурой района.

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