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अंतर्राष्ट्रीय विज्ञान सम्मेलन

# विज्ञान शिक्षा अभ्यास

# SCIENCE EDUCATION PRACTICE

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# CHINA UNDER GROWING GEOPOLITICAL RISKS: US ELECTIONS AND THE EXPECTED BATTLE FOR TAIWAN

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***Abstract.*** *This article is devoted to foreign economic cooperation between the Russian Federation and the People's Republic of China in order to determine the significance of China as a strategic partner of the Russian Federation. The need for analysis is caused by the peculiarities of changes in the economic situation in Russia in recent years due to sanctions pressure and the "pivot to the East", with growing volatility and changes in world geopolitics. As evidence of the reasoning, foreign trade statistics of the interaction of countries over the past few years are provided. In addition, the authors formulated recommendations and proposals for further strengthening of mutually beneficial cooperation between the countries and for military interaction.*

***Keywords:*** *Russia, SMO, Ukraine, China, USA, SRV, India, foreign economic relations, export, import, cooperation, foreign economic activity, dicapping, AUKUS, QUAD.*

The SMO, which began in February 2022, led to the fact that the Russian Federation faced a number of difficulties in the economic and technological spheres caused by an unprecedented number of sanctions imposed on the country by the Western community. Currently, Russia is the most sanctioned state – more than 15,000 restrictions [1], and this number is certainly not final. In response to these aggressive actions by certain members of the global community, a list of "unfriendly countries" was published [2], with a total of 43 countries included in this list. This situation, along with other political events that unfolded after the start of

the special military operation in Ukraine, showed the need to change the foreign economic vector of the Russian Federation's policy. One of the actions taken as part of the "change of course" was the accelerated development of cooperation with "friendly countries" in the field of international trade, investment, etc.

Of course, cooperation between Russia and the People's Republic of China as a key, strategic partner deserves special attention. The success of reorienting the system of foreign economic relations to friendly countries depended to a decisive extent on the position of the PRC. Beijing's fundamental refusal to join the sanctions against the Russian Federation has become one of the key factors that has allowed the Russian economy to withstand the sanctions pressure since February 2022. In the new situation, bilateral trade has demonstrated a high degree of stability. This result was achieved both due to the favorable situation for Russian exporters in world prices for energy and industrial goods, and due to an increase in the physical volumes of supplies, as well as the diversification of payment mechanisms, a more balanced policy of mutual development between states in the context of retorts and reprisals, and growing military-technical cooperation in various regions of the world through military-technical cooperation and PMC interaction.

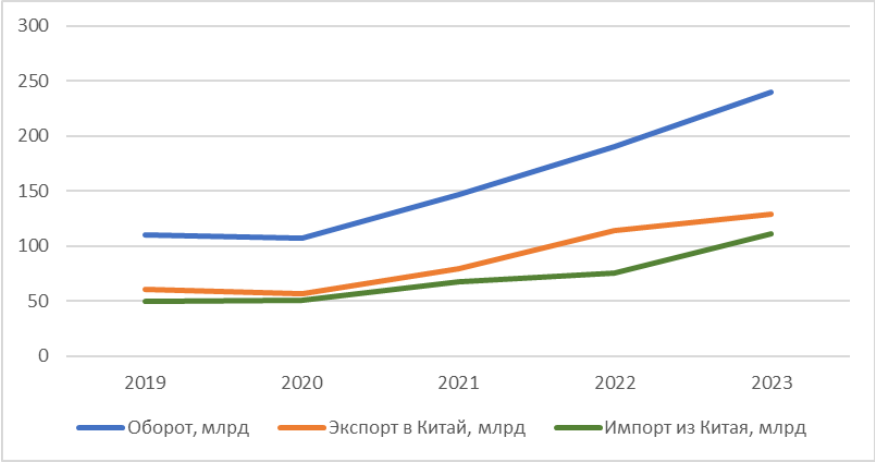


***Figure 1.*** *Indicators of foreign trade between China and Russia*

*Source: compiled by the authors based on data from China's customs statistics for 2019–2023.*

According to the General Administration of Customs of the People's Republic of China, foreign trade turnover between China and Russia in 2023 amounted to 240.11 billion US dollars (+26.3%) [3]. In the period from 2019 to 2022, for-

eign trade turnover amounted to: 110.79 billion (+3.4%), 107.76 billion (-2.9%), 146.89 billion (+35.8%) and 190.27 billion US dollars (+29.3%), respectively [4].

Export figures to China for the same period amounted to 61.05 billion (+3.2%), 57.18 billion (-6.6%), 79.32 billion (+37.5%), 114.15 billion (+43.4%) and 129.14 billion US dollars (12.7%). Imports from China amounted to $49.74 billion (3.7%) in 2019, $50.58 billion (1.7%) in 2020, $67.57 billion (33.8%) in 2021, $76.12 billion (12.8%) in 2022, and $110.97 billion (46.9%) in 2023. In 2023, the volume of bilateral trade continued to grow, primarily due to the active filling of commodity niches with Chinese products that were previously occupied by Western companies in the Russian market. In the first half of the year, Russian purchases of Chinese products increased by a record 78.1%, which was to some extent facilitated by the relatively low calculation base for the corresponding period of 2022. Chinese manufacturers have significantly strengthened their positions in a number of previously poorly developed market segments, including automobile, construction and road machinery, other types of machinery and equipment, spare parts and tools, electronic gadgets, household electrical appliances, etc. According to available data, it can be determined that the average annual growth rate for all three indicators was approximately 120%. The average annual growth rate, respectively, was approximately 20% for all indicators (see Table 1).

***Table 1***

*Growth rates of foreign trade indicators of China and Russia*

| | **Turnover** | **Import** | **Export** |
|---|---|---|---|
| Average annual growth rate, % | 121,33 | 120,60 | 122,22 |
| Average annual growth rate, % | 21,33 | 20,60 | 22,22 |

Source: compiled by the authors based on [WTO, 2024]

The rapid growth of the scale of bilateral cooperation in the economic sphere, the achievement of the goal set by the countries of annual bilateral trade volume of $200 billion by 2024 have put the issue of a program for further development of trade and economic cooperation on the agenda. During the state visit to Russia of the Chairman of the People's Republic of China Xi Jinping in March 2023, the parties adopted a Joint Statement on the plan for developing key areas of Russian-Chinese economic cooperation until 2030 [5]. The document sets out eight areas:

• increasing the scale, optimizing the structure of trade and promoting investment cooperation;

• developing an interconnected logistics system;

• increasing the level of financial cooperation, including by expanding the practice of using national currencies;

• strengthening a comprehensive partnership in the energy sector;
• developing supply chains for basic goods and mineral resources;
• expanding cooperation in the areas of technology and innovation;
• qualitatively improving industrial cooperation, including harmonization of industry standards and technical requirements;
• increasing the level of cooperation in agriculture in order to ensure food security of the two countries.

One of the striking examples of successful cooperation is the Moskvich automobile plant, renamed in June 2022 after the sale of the enterprise by the former owner of Renault. [6] The Unified State Register of Legal Entities indicates that the plant was actually owned by the Moscow City Property Department. It is also known that the Moskvich brand models assembled within the walls of this plant use technologies and developments of Chinese automobile brands. The cars are assembled on the basis of cars of the Chinese concern JAC. By 2025, the plant plans to develop a completely Russian platform for electric vehicles. [7]

Such cooperation with friendly eastern states is multiplying, which allows us to be sure that the Russian Federation has the resources and opportunities to build a favorable model for further economic development.

In conclusion, it should be added that the creation of a common economic mechanism on the basis of existing international organizations is especially important in this situation. The most suitable for this purpose are BRICS and the Shanghai Cooperation Organization (SCO). BRICS seems to be a particularly promising option, as negotiations on the creation of similar mechanisms have been ongoing within this organization for a long time. On May 26, 2023, Deputy Foreign Minister of the Russian Federation Sergei Ryabkov said that the BRICS countries had accelerated the transition to settlements in national currencies, as well as the development of the BRICS Pay system. [8] Preparation of the infrastructure for the creation of the BRICS currency and simplification of settlements in national currencies began back in 2014, when the New Development Bank was created. Later, in 2015, the finance ministers of the BRICS countries began consultations on the creation of a multilateral payment system similar to SWIFT. Additionally, as a measure to accelerate and strengthen currency integration, it is proposed to create a platform for national currency and stock exchanges, which will increase the liquidity and trading volumes of the BRICS currencies and expand the opportunities for hedging currency risks. To solve this problem, since 2019, a single payment system BRICS Pay has been developed, which will operate on the territory of five states and unite the national payment systems of the participating countries. With BRICS Pay, conversion to dollars via American banks will no longer be required, as payments will be made using the national currencies of the BRICS countries.

BRICS Pay will also allow the union members to reduce their dependence on international payment organizations such as SWIFT, Visa, and Mastercard. The

pilot project was launched in South Africa in early April 2019. BRICS Pay is expected to be fully operational by 2025. [9]

Many experts express the opinion that these two organizations will become the key force in countering pro-Western international organizations and structures. [10] At the same time, China did not allow the yuan to be used as the supporting currency of this integration platform at the BRICS summit on August 15, 2023, and in the winter of 2024, Chinese Foreign Minister Wang Yi spoke of respect and recognition of all the institutions of the Bretton Woods system, which speaks of the viability of the US dollar and the clear unwillingness of the Celestial Empire to get even more bogged down in the currency wars that already fill trade relations between America and China [11].

The growing global uncertainty of geopolitical showdowns in the world, especially during the Palestinian crisis, the 3rd Lebanon war, as well as the statement in October 2024 by Xi Jinping that Taiwan would simply be destroyed in the event of a direct conflict, speaks of an irreparable blow to the global ICT industry and the destruction of China's achieved leadership in the ongoing American-Chinese dicapping. This makes us think about platforms for additional fragmentation and glocalization of network telecommunications components in Vietnam and India for all technology players, as well as for AUKUS and KUAD, which receive chips and microcircuits from Taipei companies in their activities [12]. All this can also affect Russia, and given the risk of an escalating war in the Asia-Pacific region, it can further exacerbate our confrontation with the Anglo-Saxons not only in Ukraine. The signed strategic partnership in the area of mutual defense against attack between the Russian Federation and the DPRK may become a prologue to the beginning of World War III and ignite the already blazing Korean Peninsula. The expected creation of a de jure joint military alliance between China and Russia is currently built on multi-vector cooperation in the area of joint military exercises and the expansion of technological cooperation in the military-industrial complex and in space, in innovative interaction and in the growth of cooperation chains that hedge the risks of undersupply of weapons to the SVO zone by Russia. But if we look at the pace of reform of the PLA (People's Liberation Army of China), then de facto we can conclude that the combat coordination of military structures in all three physical environments continues, and the exchange of technologies, cyber specialists and personnel between Russia and China is building a new security configuration already in the Asia-Pacific region. At the same time, it becomes clear that the preconditions are being formed for the rapid clustering of such a model of military cooperation at any point on Earth where the interests of the collective West exceed the limits of reasonable self-restraint and cross the "red lines" of our allied states.

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# MUTUAL INFLUENCE OF INTERBUDGETARY TRANSFERS TO THE BUDGETS OF THE BUDGET SYSTEM OF THE RUSSIAN FEDERATION AND INFLATION (2011:01÷2021:12)

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***Abstract.*** *The priority goal of Russia's macroeconomic policy is to maintain budget sustainability and a stable price level characterized by low inflation. General interbudgetary transfers (IBT) to the budgets of the budget system of the Russian Federation play a significant role in ensuring the growth of income of the subjects of the Russian Federation, contributing to the balance of both subfederal budgets and the entire budget system. The results of the few empirical studies do not yet provide an unambiguous answer about the inflationary consequences of interbudgetary transfers to budgets. The objective of the study is to examine the dynamic causal relationship between inflation and interbudgetary transfers to the budgets of the budget system of the Russian Federation, based on monthly data for the period from January 2011 to December 2021, using wavelet coherence analysis, which allows separating short-term, medium-term and long-term effects in causal relationships between variables. The results of the study indicate that in the long term, on the scale of (70 ÷ 90) months, two regimes have been formed in which the inflationary consequences of fiscal policy, based on the IBT provided to the regions, are different: in the time period (2014:01 ÷ 2015:01), a regime has been formed in which the growth of IBT leads to an increase in inflation, therefore, measures to reduce IBT can be used as measures to reduce inflation; in the time period (2015:01÷2020:06), a regime has been formed in which the growth of the IBT suppresses inflation, this regime is the most effective for developing fiscal policy and fiscal rules that increase fiscal sustainability and do not cause inflation growth. The main conclusions and recommendations of the study are that the results obtained have obvious political implications, since targeted fiscal interbudgetary transfer expenditures can be a powerful redistributive fiscal instrument that stimulates the economy without accelerating price inflation, and*

*can also be used in the design of stabilization fiscal rules that seek to ensure both budget sustainability and reduce the volatility of macroeconomic indicators, primarily inflation.*

***Keywords:*** *interbudgetary transfers to budgets, inflation, wavelet analysis, wavelet coherence, wavelet phase difference.*

The article has been prepared based on the results of research carried out at the expense of budgetary funds under a state assignment to the Financial University.

Introduction. Russia's fiscal policy during the Covid-19 coronavirus pandemic turned out to be very effective, despite the significant scale of anti-crisis measures, which were of a pronounced counter-cyclical nature and had a noticeable impact on the post-crisis recovery of the Russian economy, which, unlike many countries, managed to avoid excessive growth of the budget deficit and public debt during this period (2020-2021) (Akindinova et al., 2022[1]). However, such fiscal stimulus measures were accompanied by an increase in consolidated budget expenditures, including state extra-budgetary funds, in both most developed and developing countries, including Russia, and simultaneously with the economic recovery, according to the IMF, inflation accelerated worldwide (in Russia, it accelerated from 4.9% in December 2020 to 8.4% in December 2021). During the coronavirus pandemic, the growth of inflation correlates with the scale of economic support. At the same time, budgetary and monetary measures of anti-crisis policy, while supporting economic activity and employment, at the same time contributed to the acceleration of inflation (Akindinova et al., 2022[1]).

Fiscal support for the Russian economy during the coronavirus infection in 2020-2021 was carried out in a number of areas, the most important of which were support for small businesses and interbudgetary relations. In particular, in the area of interbudgetary relations, the following was done: the volume of interbudget transfers from the federal budget was increased - their share in regional budget revenues amounted to 25% in 2020 and also included additional subsidies to support measures to ensure the balance of regional budgets; more than 50 regions were provided with preferential budget loans at a rate of 0.1%, with subsequent debt restructuring until 2029; the repayment periods for restructured budget loans were extended, which provide for an exemption from repayment of budget loans in 2020; the term (from 90 to 240 days) and the maximum amount (up to 360 billion rubles) of budget loans to replenish the balance of funds were increased; Individual development programs for dozens of constituent entities of the Russian Federation with a low level of socio-economic development have been approved with an implementation period of five years.

Fiscal transfers and fiscal sustainability. It should be noted that in federal countries (such as the USA, Germany, Russia), fiscal transfers between jurisdictions af-

fect the fiscal sustainability of the federal government and the fiscal sustainability of lower-level governments (regional and municipal), so ignoring fiscal transfers in empirical tests of fiscal sustainability can lead to erroneous conclusions (Potrafke & Reischmann, 2014[2]).

Fiscal transfers, in particular inter-budget transfers from the federal budget, play a significant role in ensuring the growth of revenues of the constituent entities of the Russian Federation (Vasyunina, 2019[3]), contributing to the balance of both subfederal budgets and the entire budget system, which is important for many reasons: to maintain the stability of the socio-economic development of territories; creating conditions for the fulfillment of social obligations; implementation of infrastructure transformations, and promotion of employment.

Fiscal transfers can stimulate both demand and supply in the economy, especially in developing countries, where product markets often operate under conditions of limited demand, which can lead to fiscal transfers being expansionary in nature, without increasing price inflation (Bahal & Shrivastava, 2022[4]). In particular, the results for Mexico (Cunha et al., 2018[5]) and Kenya (Egger et al., 2019[6]) indicate that fiscal transfers in these countries contributed to output growth without increasing inflation. In the work (Bahal & Shrivastava, 2022[4]), based on data on government transfers through social security programs in 17 Indian states over 30 years, the results were obtained that show that budget transfers over 30 years were not inflationary, and moreover, the same budget transfers stimulated output growth. These results have obvious implications for the design of effective fiscal policy and fiscal rules. Targeted transfers through social protection programs can be a powerful redistributive fiscal instrument that stimulates the economy without accelerating price inflation. The absence of a positive relationship between transfer spending and inflation in the above-mentioned countries (Mexico, Kenya, India) can be explained by two possible mechanisms. First, the output in these countries (especially at the regional level) may always have been below potential, and second, it can be assumed that transfer spending not only increased aggregate demand, but also had a positive effect on supply. In particular, the work (Bahal, 2020[7]) provided convincing evidence that budget transfers, such as labor costs and credit subsidies, increase labor productivity, due to the growth of public goods, such as water-related infrastructure.

Analysis of empirical results for Russia does not yet provide convincing evidence that interbudget transfers do not accelerate inflation in Russia, which in turn can affect the balance of the budget system in both the short and long term.

The absence of a positive relationship between interbudgetary transfer expenditures and inflation has obvious implications for the design of effective fiscal policy and fiscal rules, in which targeted interbudgetary transfers can become a powerful redistributive fiscal instrument that stimulates the economy without accelerating price inflation.

The purpose of this study is to analyze the dynamic dependence of inflation and general interbudgetary transfers to the budgets of the budget system of the Russian Federation, (2011:01÷2021:12).

The working hypothesis is that general interbudgetary transfers (IGT) to the budgets of the budget system of the Russian Federation, for the period (2011:01÷2021:12) had a positive effect on inflation in the country.

2. Initial data. To assess the possible impact of interbudgetary transfers (IBT) on inflation in the Russian Federation, monthly data published by the Ministry of Finance of the Russian Federation (Ministry of Finance of the Russian Federation, 2024[8]) and Rosstat (Rosstat, 2024[9]) are used. It should be noted that there are no data on IBT for the period from January 2022.

3. Research method. To identify the causal relationship between interbudgetary transfers (IBT) of a general nature to the budgets of the budget system of the Russian Federation and inflation, the study uses 4 most important tools of wavelet coherence analysis: continuous wavelet transform, wavelet power spectrum, wavelet coherence and wavelet phase difference (Aguiar-Conraria and Soares, 2014[10]; Crowley & Hallett, 2021[11]), which allow us to assess the intensity of the causal relationship and the direction of the relationship between IBT and inflation.

***4. Discussion of results***

Figure 1 shows the dynamics of monthly interbudgetary transfers of a general nature to the budgets of the budget system of the Russian Federation, billion rubles, and Figure 2 shows the dynamics of monthly inflation in the Russian Federation, in %, (2011:01÷2021:12).

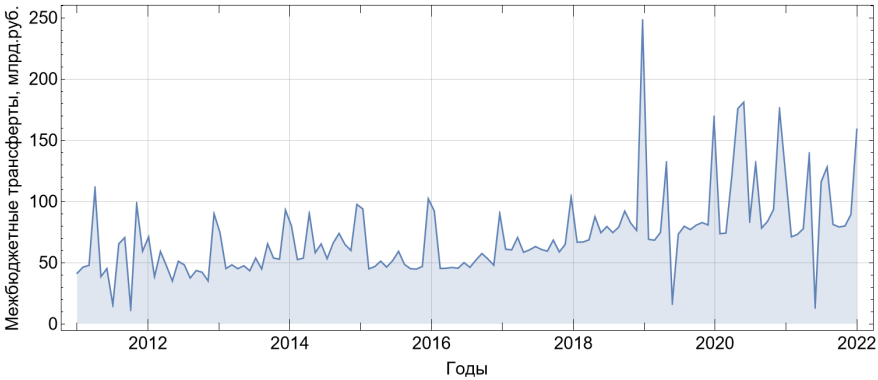


***Figure 1.*** *Dynamics of monthly interbudgetary transfers of a general nature to the budgets of the budget system of the Russian Federation, billion rubles, (2011:01÷2021:12). Source: compiled by the authors.*

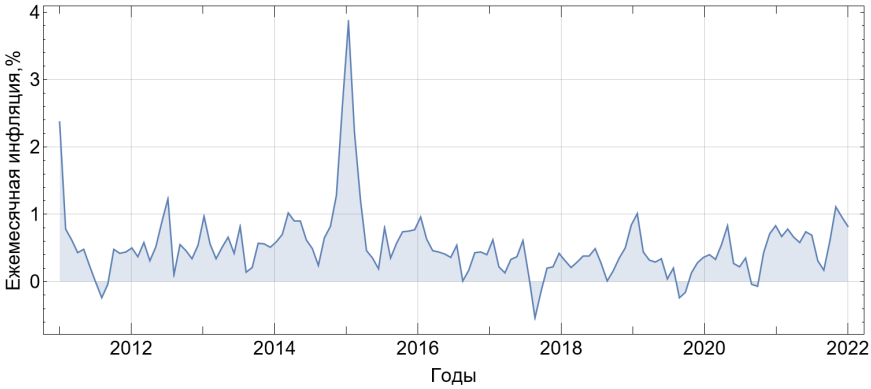


***Figure 2.*** *Dynamics of monthly inflation in the Russian Federation, in %, (2011:01÷2021:12). Source: compiled by the authors.*

The main results of the assessment of the impact of the IBT on inflation in Russia are shown in Figures 3 and 4, where the horizontal axis shows the time expressed in "month/year" (01/2011÷12/2021), and the vertical axis shows the period, or scale of influence, expressed in months, from 1 to 132 quarters. Figure 3 shows the wavelet coherence of the selected variables, which allows us to assess the intensity of the relationships (connections between them) from 0 (no connection) to 1 (completely correlated). Figure 4 shows the difference in the phases of the wavelets of the selected variables, which allows us to assess the direction of the cause-and-effect relationship between the variables. Conventionally, the scale of possible mutual influence of IBT and inflation in Russia can be divided into three levels: short-term, from 1 to 24 months (up to 2 years); medium-term, from 24 to 60 months (up to 5 years); long-term, from 60 to 132 months (up to 11 years).

In all figures 3 and 4, the area in which there are no end effects (Cone of Influence) is highlighted with a white line (Aguiar-Conraria and Soares, 2014[]).

*Short-term effects*. As can be seen from Figure 3, throughout the entire observation period (2011:01÷2021:12) (132 observations), in the frequency band of up to 24 months (*short-term effects*), two small areas with strong (more than 0.9) wavelet coherence of the IBT and inflation in Russia are observed:

on the time intervals (2011:07÷2012:12) and (2014:12÷2015:12), as follows from Figure 4, the direction of the relationship is unidirectional, negative; $\varphi=-2, \varphi \in (-\pi,-\pi/2)$, that is, changes in the MBT and inflation occur in antiphase, but changes in inflation outpace changes in the IBT, and the growth of inflation suppresses the growth of the IBT, therefore, the direction of the negative relationship is from inflation to the IBT.

**Conclusion.** In the short term, on the scale of (1÷24) months, on the time intervals (2011:07÷2012:12) and (2014:12÷2015:12), a regime has been formed in which the growth of inflation suppresses the growth of the IBT.

*Medium-term effects*. As can be seen from Figure 3, in the frequency band from 24 to 60 months (5 years), there is a huge area with reduced (less than 0.3) wavelet coherence of the IBT and inflation, which indicates that changes in inflation and the IBT, neutral - weakly depend on each other.

**Conclusion**. In the medium term, on the time segment (2011:01÷2021:12), on the scales of (24÷60) months, a regime has been formed in which changes in inflation in Russia and the IBT are independent of each other. Thus, the growth of inflation, in the time period (2011:01÷2021:12), on the scales of (24÷60) months is not associated with the growth of the IBT.

*Long-term effects*. As for the long-term effects in the mutual influence of the MBT and inflation in Russia, on the scales from 60 to 132 months, it should be noted that there is a significant area with high wavelet coherence: in the frequency band from 70 to 90 months and the time range (2014:01÷2020:06), two modes are formed:

in the time period (2014:01÷2015:01), the mode in which the phase difference, $\varphi=1,\varphi\in(0,\pi/2)$, that is, changes in the IBT and inflation in Russia are consistent in phase, but the IBT is ahead of inflation, and the growth of the IBT leads to an increase in inflation;

on the time period (2015:01÷2020:06), the mode in which the phase difference is $\varphi=2,\varphi\in(\pi/2,\pi)$, and the direction of the relationship is unidirectional, negative, that is, changes in the IBT and inflation occur in antiphase mode, but changes in the IBT outpace changes in inflation, and the growth of the IBT suppresses the growth of inflation, therefore, the direction of the negative relationship from the IBT to inflation in Russia.

Thus, on the scale of (70÷90) months, two regimes are formed in which the inflationary consequences of fiscal policy, based on the IBT provided to the regions, are different:

on the time period (2014:01÷2015:01), a regime is formed in which the growth of the IBT leads to an increase in inflation, therefore, the main hypothesis of the study is confirmed;

on the time period (2015:01÷2020:06), a regime is formed in which the growth of the IBT suppresses inflation, therefore, the direction of the negative relationship from the IBT to inflation in Russia.

On the scales from 90 to 132 months, a regime with a neutral or weak dependence of inflation on the IBT is mainly manifested.

**Conclusion**. In the long term, on the scale of (90÷132) months, a regime is mainly manifested, which is characterized by a weak dependence of inflation on the IBT (inflation growth is not associated with the growth of the IBT).

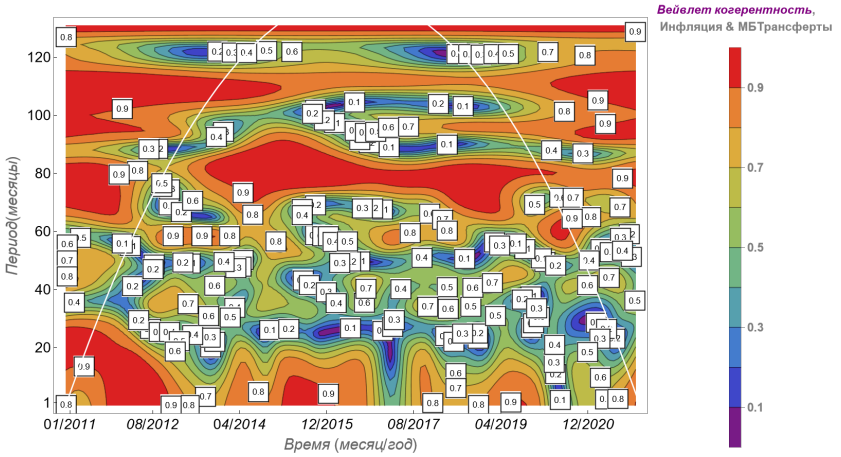


***Figure 3.*** *Wavelet coherence of the growth rates of monthly inflation and interbudgetary transfers of a general nature to the budgets of the budget system of the Russian Federation, (2011:01÷2021:12).*

Source: compiled by the authors

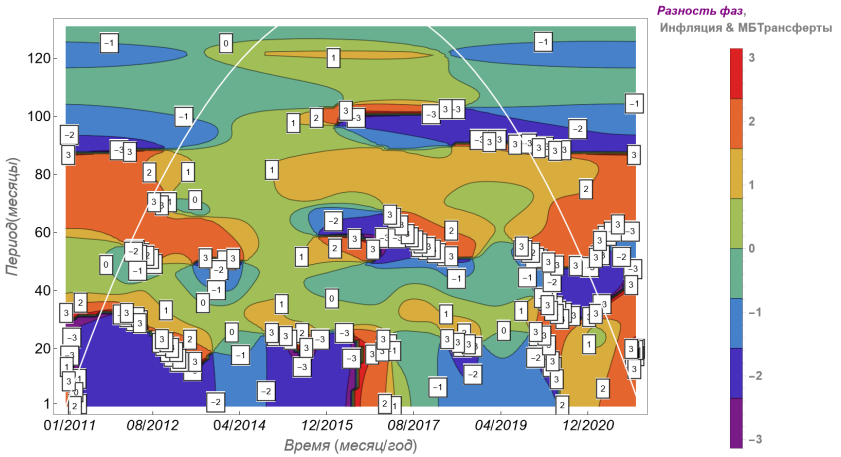


***Figure 4.*** *Difference in the phases of the growth rates of monthly inflation and general interbudgetary transfers to the budgets of the budget system of the Russian Federation, (2011:01÷2021:12).*

Source: compiled by the authors

**Conclusions**

The results of the work indicate that in the medium term, on the scale of (24÷60) months, changes in inflation in Russia and the IBT are independent of each other, therefore, a possible policy for reducing inflation does not depend on the scale of the IBT.

*In the long term*, on the scale of (70÷90) months, two regimes have been formed in which the inflationary consequences of fiscal policy, based on the IBT provided to the regions, are different:

in the time period (2014:01÷2015:01), a regime has been formed in which the growth of the IBT leads to an increase in inflation, therefore, measures to reduce the IBT can be used as measures to reduce inflation;

on the time period (2015:01÷2020:06), a regime was formed in which the growth of the IBT suppresses inflation, this regime is the most effective for developing fiscal policy and fiscal rules that do not cause inflation growth.

**5. Conclusion**

Using the tools of wavelet coherence analysis: wavelet coherence and phase difference, the intensity and direction of the dynamic relationship between monthly interbudgetary transfer expenses of a general nature to the budgets of the budget system of the Russian Federation and inflation over time (2011:01÷2021:12) were studied in the paper.

The time intervals and scales of the regimes in which the inflationary result of fiscal policy, based on the IBT, are different are established, and the time interval of the regimes in which: inflation growth led to the growth of the IBT (these are mainly short-term effects); the growth of the IBT led to inflation growth; inflation growth is neutral in relation to the growth of the IBT (mainly medium-term effects); the growth of the IBT led to a decrease in inflation (mainly long-term effects), and the implementation of such a fiscal policy did not lead to an increase in inflation. These results have obvious political implications, in particular, it has been established that targeted fiscal transfers through interbudgetary transfers to the budgets of the budget system of the Russian Federation can be a powerful redistributive fiscal instrument that stimulates the economy without accelerating price inflation, and can also be used in the construction of stabilization fiscal rules that seek to ensure both budgetary stability and reduce the volatility of macroeconomic indicators, primarily inflation. The two most probable mechanisms for the absence of a positive relationship between interbudgetary transfer expenditures and inflation in Russia (2015:01÷2020:06) are, firstly, the assumption that output could be lower than potential output, and, secondly, the assumption that the growth of interbudgetary transfer expenditures increased not only aggregate demand, but also had a positive effect on productivity growth, i.e. on the growth of the supply side. In further future studies, it is necessary to establish a quantitative

assessment of the results of the influence of interbudgetary transfer expenditures on factor productivity in the Russian economy.

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# RESOURCE-SAVING TECHNOLOGIES AS A FACTOR OF INCREASING CROP YIELDS OF AN AGRICULTURAL ENTERPRISE IN SIBERIAN REGIONS

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***Abstract.*** *The article considers the possibilities of using resource-saving technologies in agricultural enterprises of the region. The purpose of the research was to identify the dependence of a set of resource-saving factors that affect the grain yield of an agricultural enterprise in the region. Methods of statistical data processing based on modeling were used to test the results of the combine harvester at the enterprise of the region. Resource-saving in agriculture allows agricultural enterprises to carry out activities in order to minimize resource costs and ensure environmental friendliness. The factors that help the development of resource-saving technologies in the crop production of Krasnoyarsk Krai of the Russian Federation were determined. The problems and prospects for the development of resource conservation were identified, which make it possible to achieve an increase in efficiency, ecological safety and quality of agricultural products. In order to activate the technological modernization of agriculture, it is necessary to use new types and classes of machinery and equipment in crop production, which are ahead of analogues in developed countries in terms of technical and ecological parameters. It is necessary to develop and master resource-saving, environmentally safe and high-performance technologies adapted to environmental requirements, contributing to a technical breakthrough, ensuring labor productivity growth and resource savings. The Russian production company Rostselmach has launched an innovative combine harvester to increase the level of technical equipment of grain production. The introduction of the proposed resource-saving technology was justified by calculations based on a multiple correlation and regression model. On the basis of the proposed model, the factorial characteristics of seed costs, energy availability, labor intensity that affect the effective feature such as the level of yield were identified.*

***Keywords:*** *resource-saving technologies, crop production, agricultural enterprises.*

**1. Introduction**

The most important strategic priorities for the development of agriculture in modern conditions are continuous renewal of agricultural production, use of resource-saving technologies based on the achievements of science and technology. The share of high-tech products in the agro-industrial complex of Russia does not exceed 0.3% of the total volume, and in developed countries, it is more than 20%. The innovative potential of the agro-industrial complex of the Russian Federation is used by 4%-5%, while in the USA it is 50%.

The departmental target program "Scientific and technical support for the development of branches of the agro-industrial complex" until 2025 [18] clearly outlines the directions of development of scientific and technological progress in crop production, which are related to the specifics of the industry, in particular: activation of technological modernization of agriculture; creation of new types and classes of machinery and equipment that are ahead of analogues in developed countries in terms of technical parameters, to ensure a technical breakthrough and labor productivity growth, saving resources; development and development of resource-saving, environmentally safe and high-performance technologies adapted to the requirements of ecology and competitiveness in the world agro-food market.

The activation of innovation activity is one of the main conditions for the development and improvement of the efficiency of agricultural production in a market economy [12]. The introduction of highly adaptive, resource-saving technologies for the production of agricultural products based on innovative activities with the widespread use of automation and computerization of production, new generation machines and equipment, robotics and electronic technologies, restoration and improvement of the production and technical potential of agricultural enterprises are the determining directions for improving the efficiency of production [15].

Agribusiness industries are complex and peculiar in terms of energy supply, so the problem of energy saving in them is quite relevant and is characterized by:

• 4-6 times higher energy intensity of manufactured products than in developed Western countries;

• a low coefficient of useful use of technical, technological and energy resources (about 20 % average annual energy efficiency of energy-consuming equipment in the country);

• a high consumption share of natural energy resources (diesel fuel – about 30 %, gasoline – 11%-16 %, natural gas – 20 %, electricity and coal – 10%-11 % in the structure of consumption);

• outdated technological equipment and technologies (about 90 % work beyond the amortization period);

• the collapse of the system of operation, maintenance, repair and service;
• reduction of the fleet for agricultural machines [5].

**2. Materials and methods**

The purpose of the research is to substantiate the influence of a combination of factors of resource-saving technology on increasing the yield of the crop production enterprise of the region.

To achieve the purpose of the research, the following tasks were set and solved:

- the factors influencing grain yield are identified;
- the characteristics of resource-saving technologies in grain production are determined;
- the dependence of the influence of a combination of factors and resource-saving technology on grain yield is based.

The theoretical and methodological basis of the research was the works of leading scientists in the field of resource conservation of agricultural enterprises, normative reference materials, recommendations of research institutions [1;3;6; 7;12;16].

The data of the reports of the Russian agricultural enterprise of Krasnoyarsk Krai for the previous 4 years (2019-2023) were used in the work [19]. The methods of statistical data processing and mathematical modeling were used in the study.

The studies were carried out on the production enterprise of Rodnik LLC, located Balakhtinsky district of Krasnoyarsk Krai (the Russian Federation). In the agricultural activity of Rodnik LLC grain farming is the basis of the crop industry. During the analysis for the current state of grain production, changes in the decrease in the efficiency of grain production were determined.

In agriculture, land acts as the main means of production, it is the most important part of the material and technical base. The development of the crop production industry is completely based on the level of security and efficiency of the use of agricultural land resources and soil treatment technology [2]. Updating and modernization of the machine and tractor fleet in order to develop resource-saving technologies is one of the directions of development of the grain production industry for Rodnik LLC.

Resource saving provides savings of material, technical, fuel and energy, labor and financial resources on the basis of resource-saving technologies [7].

High-intensity resource-saving technologies help to obtain grain yields up to 50-60 kg / ha on the most favorable soils of the Russian Federation: the North Caucasus and the European Urals [11]. «The equipment for these technologies provides conservation land use, precise processes management of crop cultivation, harvesting and storage, itself controls the quality of technological operations performed considering changing landscape conditions and optimizes the use of all types of resources» [10, 2-3].

To regulate resource conservation, agricultural organizations must have appropriate technical and economic standards developed by research institutes [8]. The basis should be the standards for the cost of cultivation and harvesting of 1 ha or 1 c of agricultural crops. The influence of the following factors should be taken into account: technologies, crop yields, production volumes, standards for the consumption of certain resources types per 1 ha of agricultural land, arable land or crops [13].

**3. Results**

During the analyzed period, Rodnik LLC the production direction was plant–growing, and the specialization was grain. The specialization coefficient for the entire studied period averages 0.6, which indicates an in-depth specialization.

Currently, the company uses combine harvesters "Don 500", "Vector" and a more modern "Palesse GS12" (KZS-1218), manufactured by Rostov agricultural machines production company Rostselmach (Rostov, the Russian Federation).

One of the innovative combines on the Russian market is the ACROS 585 combine harvester from the Rostselmach manufacturer, which is one of the main competitors of the Palesse GS12 model [17]. Comparative analysis of agricultural machinery has shown that the ACROS 585 combine harvester from the Rostselmach meets the requirements of resource conservation in the conditions of Krasnoyarsk Krai (table 1).

***Table 2.***

*Characteristics of grain harvester models*

| Characteristics | Palesse GS12 | Innovative resource-saving harvester ACROS 585 |
|---|---|---|
| The width of the reaper, m | 6 | 9 |
| Drum diameter, mm | 600 | 800 |
| The speed of the grinding drum rpm. | 875 | 1,050 |
| Grain cleaning (separation) area, sq.m | 3.15 | 4.95 |
| Grain hopper volume, l | 8,000 | 9,000 |
| The speed of emptying the hopper, l/s. | 65 | 90 |
| Type of unloading | completely | by portions |
| Work without refueling, h | 10 | 14 |
| Specific fuel consumption, l/ha | 18 | 13.6 |
| Productivity, ha/hour | 3.1 | 4.15 |

The ACROS 585 combine harvester has the main criteria: innovations of combine, adapters and software. New developments are aimed at reducing losses and crushing of grain at maximum productivity of combines

***Table 3.***

*Economic efficiency of the using resource-saving equipment in grain production*

| Indicators | Reporting period, | Project (ACROS 585 harvester) |
|---|---|---|
| Area of sowing of grain crops, ha | 11,854 | 11,854 |
| Gross collection, ts | 359,033 | 390,234 |
| Yield, c from 1 ha. | 30.3 | 32.92 |
| Implemented, c | 231,805 | 263,006 |
| Marketability level, % | 64.56 | 67.40 |
| Production cost of 1c, rub. | 528.31 | 487.95 |
| Total cost of products sold, thousand rubl. | 150,398 | 160,026 |
| The selling cost of 1c products, rub. | 648.81 | 608.45 |
| including implementation costs | 120.50 | 120.50 |

*Source:* «Compiled by the authors».

To assess the effectiveness of the using resource-saving technologies, it is necessary to pre-predict the prospects for the development of grain production. An increase in crop production can be achieved through a increase in crop yields. The potential yield of varieties and hybrids of agricultural crops used in agriculture is currently used by 40% - 60%. The reason for this is non-compliance with the technology of cultivation, plant care and harvesting, insufficient application of organic and mineral fertilizers, unsatisfactory preparation of seeds and planting material.

Previous studies have considered one of the factors of the use of resource-saving technology in crop production. In order to increase the productivity of agricultural crops, Russian researchers determined the need for the use of precision farming and digital technologies for optimal control of each square meter of the field. The purpose of such management is to maximize profits while optimizing agricultural production, saving economic and natural resources [16].

Resource-saving technologies of soil treatment minimum and no-till allow increasing soil fertility, obtaining high yields of agricultural products. Reducing the burden on the environment, the transition to an environmental regime of land use contributes to the preservation and expansion of the resource potential of agriculture for future generations [1].

The No-till technology is aimed at stabilizing the agrochemical properties of the soil, the content of nitrate nitrogen and the preservation of moisture storage [6]. Prudent and efficient resource use, treatment of wastes and their all round effective utilization contributes to safeguarding environmental sustainability [3].The sustainable development of agriculture is aimed at the efficient use of resources and the preservation of the environment, which are potentially long lasting. It comprises of a farming system suited to the needs of crops and the prevailing conditions of

a locality based on resource-saving technologies: Conservation Agriculture (CA) Sustainable Land Management (SLM) Technological and Behavioral changes [9].

The introduction of organic farming technologies contributes to solving agricultural problems: degradation, depletion and erosion of soils, a decrease in land fertility. The increase in demand for environmentally friendly products motivates agricultural producers to apply technologies of resource saving technologies and organic farming [7].

Further yield improvements pose considerable challenges for researchers because of the unprecedented changes in global warming and its related uncertainty.

The introduction of resource-saving technologies in agricultural production requires significant additional costs, the payback period for innovative agricultural machinery is quite long and does not allow to obtain an economic effect for the first season. At the same time, resource-saving technologies are defined as a key factor in increasing crop yields of enterprises focused on modernization and innovative development.

**4. Conclusion**

The use of resource conservation in crop production determines the sustainable development of agricultural enterprises, the improvement of economic, qualitative and energy-saving indicators of grain production not only for Krasnoyarsk Krai, but also for Russia and other countries as a whole. We used the multiple correlation and regression model in resource saving practice for the first time. The proposed resource-saving technology was justified by the calculation based on a multiple correlation and regression model. The resource-saving technology of a combine harvester with minimal fuel consumption and maximum productivity helps to reduce the cost of producing 1 c of grain by 6.2% and increase the yield by 2.62 c from 1 ha. Resource-saving technologies when used in agricultural enterprises specializing in crop production can increase yields without changing the area of sowing and significantly reduce the cost of tillage and grain harvesting. Obtaining high yields of crop products, preserving and expanding the resource potential of agriculture for future generations should be based on evidence-based conservation methods of agricultural production and resource-saving technologies.

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# ARTIFICIAL INTELLIGENCE AS A TOOL TO REDUCE THE RISK OF FLOOD HAZARDS

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***Abstract.*** *Flooding is a natural hazard. In global climate change, the role of artificial intelligence in making accurate flood forecasts is increasing. In order to analyze in advance, the extent of flooding, carry out preventive measures to protect the population, socially important facilities, buildings and structures, and plan the amount of damage compensation, it is necessary to improve the technological process of flood forecasting. The purpose of this study is to demonstrate the effectiveness of machine learning methods in geophysical research to improve the certainty of flood forecasting. The main investigation method is holistic perspective analysis of applied modern approaches such as neural networks, gradient boosting, and vector regression. The result of the work is the introduction of the main capabilities of machine learning and artificial intelligence focused on digital technologies, to improve the accuracy of natural disaster predictions to reduce damage and flood consequences. Work on flood hazard assessment is the basis for the development of artificial intelligence programs for flood forecasting and prevention. Forecast models are built according to the following stages: collection of necessary information, hydrological calculations, mapping of flooded areas, forecast of economic damage and risk. Based on a preliminary flood risk assessment, areas for which there are potentially significant flood risks are identified. The widespread use of neural networks confirms the relevance of research in this direction. Programs based on artificial intelligence for predicting the scale of floods are using hydrological and hydrodynamic models with machine learning.*

***Keywords:*** *flood, machine learning methods, flood forecasting model, artificial intelligence.*

**Introduction**

Why is it important to develop innovative technologies in flood forecasting? Flooding is one of the most common and severe hazards disrupting people's lives and livelihoods around the world. The impact of natural disasters related to climate change, in particular floods, is increasing. According to the WMO, since 1970 the number of natural disasters in the world has quadrupled; over the past 40 years, they have killed more than 3.3 million people and caused economic damage in the amount of $2.3 trillion. In this regard, the topic of flood-prone area management is being actively explored. In the current time of the development of digital technologies, it is advisable to pay increased attention to the IT sphere, to study, develop and implement the latest technologies.

Some 2.2 billion people, or 29% of the world population, live in locations that are estimated to experience some level of inundation during a 1-in-100-year flood event. Such an event has a 1% chance of occurring in any given year, which translates to a 10% probability in a decade, or 50% in a lifetime (68 years). About 1.47 billion people, or 19% of the world's population, are directly exposed to inundation depths of over 0.15 meters. [1]

Flood risk is a wide threat: populations are not safe in any of countries. Yet, the number of people in harm's way is particularly large in South and East Asia. These regions are home to the majority of flood-exposed people, about 1.36 billion. China and India are alone, accounting for over a third of this. This regional picture is explained by the fact that several large and densely populated areas are in high-risk flood zones, such as coastal areas or low-lying river plains. Over 1.5 million people in England and Wales have a greater than 1.3% annual chance of having their homes flooded by tidal flood event, and perhaps as many again are at risk of flooding caused by the incapacity of drainage systems to cope with heavy rain. [2]

According to a study by the Russian Research Institute for Hydrometeorological Information, the total area of flood-prone areas in Russia is about 400 thousand km2. Floods with catastrophic consequences affect an area of 150 thousand km2, where there are more than 300 cities, tens of thousands of villages, more than seven million hectares of agricultural land. Over the past 20 years, 11 floods with catastrophic consequences have occurred in the Russian Federation. The most frequent floods occur in the south of Primorsky Krai, in the basin of the Oka, Don, on the rivers of the Kuban and Terek, in the Tobol basin, on the tributaries of the Yenisei and Lena. In Russia, 40-70 large floods occur annually. According to Russian Hydro Meteorological Center, about 500 000 km2 are subject to these natural disasters, floods with catastrophic consequences. The average annual damage from floods is estimated at about 40 billion rubles. [3]

According to a study by the All-Russian Scientific Research Institute of hydro meteorological Information - World Data Center, the total number of hazardous

hydrological phenomena (floods and mudflows) in the first decade of the XXI century in Russia increased by 1.5 times compared to the 1990s.

There is evidence that the process of coastal urbanization is accelerating the increase of flood risk. With safe areas already occupied, new settlements and developments are occurring increasingly in high-risk areas. As spatial planning and infrastructure investments (such as drainage systems) struggle to keep up with the pace of urbanization, risks build up and are locked in. In the coming years, land subsidence, rapid coastal urbanization and climate change could further increase flood risks. Large-scale investments in flood protection infrastructure enable to mitigate risks. To balance these risks and opportunities in order to safeguard development prospects, we can use artificial intelligence.

Why the study focuses on the field of IT technologies. The use of artificial intelligence-based programs will help protect critical infrastructure, as well as provide an opportunity to prepare in advance for the onset of a natural disaster, which will minimize negative consequences. The integration of artificial intelligence with hazard science helps predict impacts, identify unpredictable risks of natural disasters, prepare for them and reduce their risk, increasing resilience to unforeseen circumstances.

**Materials and Methods**

The purpose of the study is to prove the effectiveness of introducing machine learning methods in solving the problem of flood prevention and reducing the risk of consequences. To achieve the goal, we solved the following tasks:

- analyze existing machine learning algorithms for building digital models (maps) based on regression analysis and solving the classification problem;
- identify effective flood forecasting methods based on machine learning algorithms for time series of hydrological and meteorological observations;
- explore machine learning algorithms in applied problems of flood prevention.

We explore the main modern approaches to analysis, such as neural networks, gradient boosting, vector regression. Gradient boosting is a machine learning technique for classification and regression problems that builds a prediction model as an ensemble of weak predictive models, decision trees. Vector auto regression (VAR, Vector Auto Regression) is a model of the dynamics of several time series, in which the current values of these series depend on the past values of the same time series.[4]

Artificial intelligence (AI) software is based on machine learning (ML) algorithms, which are responsible for sophisticated automated and autonomous capabilities. Machine learning applications in flood forecast, depending on the tasks performed. However, there are certain key machines learning tasks that help make operations more efficient:

- regression — helps identify correlations between various datasets. You can use regression techniques to predict certain activities, compare them to actual activities, and then detect security anomalies.
- clustering — a technique implemented using unsupervised algorithms, which use common features to group artifacts. We can use clustering to identify distributed threat. [5]

To protect the population and territories periodically exposed to floods, provision is made for a preliminary assessment of the risks of future floods. Forecast models are built according to the following stages: collection of necessary information, hydrological calculations, mapping of flooded areas, forecast of economic damage and risk. To assess flood risk, it is necessary to analyze information on cases of exceeding dangerous water levels on rivers during the historical period; to assess the potential adverse economic consequences of floods. Next, based on a preliminary flood risk assessment area for which there are potentially significant flood risks are identified. For these areas are required to map flood zones and develop programs for rational flood executive.

As an experimental base of research were selected areas, selected by the criterion of the presence of recorded cases of excess of dangerous water levels and the presence of cases of water-logging of settlements. First of all, we analyze the historical values of water levels within the surveyed settlements. Based on the data obtained, the basic calculations of the maximum water levels for the year, bringing the series to the multi-year period, constructing the maximum levels probability curve, determining the water levels and discharges with different percentage probabilities. Based on the determined water levels with varying percent, flood probability is mapped and the area of land at 1% and 10% probability of flooding are determined. Using the cadastral value of land, falling into the flood zone, defined the indicator of probable economic damage at 1% and 10% probability of occurrence. At the final stage, it is necessary to identify the consequences of water level rise, determine indicators of economic and social risk.

The main indicators of flood hazard are: the number of permanent residents in the flooded area; development of flood-prone territory; flooding capacity which is determined by the excess of the highest water levels over the critical level, the frequency of excess of dangerous water levels, the duration of standing water above the critical level per year (in days) and the area of flooding.

Based on these criteria, work on flood hazard assessment is the basis for the development of artificial intelligence programs for flood forecasting and prevention.

The characteristics of flooding which are conventionally believed to determine the severity of the consequent damages are:

- the depth of flooding;
- the duration of flooding;

- the velocity of flooding; and
- the sediment load carried on the flood waters and deposited with the retreat of flooding. [6] The depth of flooding in a property is usually considered having the greatest effect on the severity of the consequent damages. Standard damage tables are usually based on some depth-damage relationship. Duration has a clear effect on indirect losses. The ratio of indirect losses to direct losses may be dramatically different for long duration floods compared to short duration floods.

Assuming that the conceptual basis for estimating damages is the same, the expected damages from flooding might be expected to vary between two countries if the flood characteristics are different and / or the damageability of properties varies between the two countries. [7]

Every disaster is unique. Traditionally, this is not reflected in assessments of hazard risk, which often rely on correlational assumptions or stagnant risk maps that only represent a single event or a single point in time.

The US Federal Emergency Management Agency, in 2000, began developing a standardized methodology that is capable of assessing flood damage as well as economic and social losses. The work was carried out through an integrated Geographic Information System - GIS to provide the user with research in tabular and graphical format. GIS is an invaluable tool for flood assessment. An example is the processing of data on a large-scale flood in 1993 in the region of the Mississippi and Missouri rivers, which covered ten states.

One of the positive aspects has been the improvement in the development of information strategies designed to reduce risk and costs in the event of predicting future floods of potentially greater magnitude. Hydrological modeling and remote sensing were the most efficient tools for the analysis. The Earth Satellite Corporation developed 155 databases, following the operational definition of an aerial flood plan and the use of aerial photography. The combination of four satellite imagery, digital imagery, processing technology, differentiation of water surfaces in adjacent areas of the earth, and synchronization of peak flood ridges and radar data were essential for flood assessment. [8]

Technology of artificial intelligence revolutionizes this process, creating hyper local, dynamic and event-specific visualizations of disaster risk. To do this, new technology is built on a core platform combining natural and hazard sciences: structural and seismic engineering, hydrodynamics, atmospheric and meteorological sciences and remote sensing.

Probabilistic models integrate next-gen AI/ML with human-centric disaster science for a comprehensive, dynamic understanding of disaster risk around us. AI/ML enhances and refines hazard algorithms, creating intelligent, probabilistic models that can learn, develop, and scale from each new piece of data. Innovative

programs synthesize structured and unstructured data from a variety of sources, consolidating data sets from historically silos systems into a common data schema for models to ingest. This data comes from open source providers, private providers, and clients. The volume of empirical data helps to build synthetic datasets, powered by interpolation, inference, and advanced machine learning for globally scalable and relevant analyses. Datasets help users interpret the risk vulnerability of prospective and owned assets, and make effective plans to mitigate or transfer related risks. These analytics are designed to allow users to consider climate change in their calculations by applying the conditions of RCP 4.5 to analyses. [9]

**Results**

Based on hydrological observation data, we conducted a statistical analysis of initial observation data for maximum annual water levels reduced to a multiyear period to determine the distribution parameters. It was possible to obtain parameter values with a probability of exceeding 1% only analytically as a realization of regularities in behavior of the chosen of the chosen statistical hypothesis in the area of small probabilities. As a result of these calculations, a set of water levels of different percentage probability.

Transferring values to a cartographic base and conducting a spatial analysis in conjunction with a digital elevation model in a GIS environment makes it possible to determine objects falling into the zone of probable flooding. Zoning is an important action in the planning of development and effective management of territories and is a division of the territory into zones with determination of types of urban use of established zones and restrictions on their use.

The following tasks have been solved: the analysis of existing machine learning algorithms for building digital models (maps) based on regression analysis and solving the classification problem has been carried out. Algorithms of machine learning in applied problems of flood prevention are analyzed. Efficient methods of flood forecasting based on machine learning algorithms on integrative flood susceptibility prediction models based on multi-time re-sampling approaches, random sub-sampling and bootstrapping algorithms, integrated with machine learning models: generalized additive model, boosted regression tree and multivariate adaptive regression splines [10].

The Neural Network (CNN) allows, by importing the spatial and temporal characteristics of precipitation, applying a digital elevation model and using statistical data as a trend characteristic, to predict the flooding process with high accuracy. Creating a cartographic basis and spatial analysis in combination with a digital elevation model in the GIS environment makes it possible to determine the objects falling into the zone of probable flooding. Zoning is an important measure in the planning of development and effective management of territories and is a division of territory into zones with the definition of types of urban planning use of the established zones and restrictions on their use.

**Discussion**

In modern approaches to data analysis, neural networks, gradient boosting, vector regression are especially relevant. Gradient boosting is a machine learning technique for classification and regression problems that builds a prediction model as an ensemble of weak predictive models, decision trees. A flood forecasting model based on a convolutional neural network with a two-dimensional convolutional operation by One Concern shows the benefits of this approach for improving forecast accuracy. Research by PRC specialists also determines top results of the proposed model for predicting the flood process of a convolutional neural network.

A prominent representative of the use of artificial intelligence in flood monitoring is the company One Concern. The area of coastal flooding modeling is the focus of One Concern's research as part of the development of an advanced large-scale hydrodynamic model with hurricane predictions as input to predict storm tides, a combination of astronomical tide and storm surge, along the US East Coast coastline. Predicted potential affected areas are compared to satellite imagery and predicted peak water levels are compared to NOAA tide gauge observations along the southeastern United States coast. The projected coastal water level shown can be used to drive local flooding patterns to provide a prediction of coastal flooding. Their results are preliminary and for discussion purposes only. [11]

NOAA created each forecast track, which has integrated various atmospheric forecasting models, including the GFS (Global Forecast System). The company chose GFS forecasts as atmospheric inputs because GFS is used as NOAA's flagship weather model.

The Global Forecast System (GFS) is a weather forecast model developed by the National Centers for Environmental Forecasting (NCEP). Mesh Analysis and Display Systems (GrADS) and ImageMagick were used to generate the images.

It is the process of creating hyper local, dynamic, and event-driven visualizations of disaster risk. The technology is built on a core platform that combines natural and hazard sciences: structural and seismic engineering, hydrodynamics, atmospheric and meteorological sciences, and remote sensing.

Research by PRC specialists in the field of flood modeling confirms the highest effect of the introduction of innovative technologies for flood monitoring in order to reduce the catastrophic consequences of emergency situations. Their research presents a flood forecasting model based on a convolutional neural network with a two-dimensional convolutional operation. Precipitation spatial-temporal characteristics were imported through the gridding of the Xixian County River Basin. The authors then processed the digital elevation model data as a geographic feature and used the historical river flow process in the Xixian Basin as a trend characteristic. A lot of experiments have been carried out to determine the optimal

hyper-parameters of the proposed model for predicting the flood process of a convolutional neural network. Numerical results confirmed the model demonstrated the best accuracy for predicting peak and onset of flood. [12]

The economic aspect of introducing neural networks into the process of forecasting and monitoring floods includes a significant increase in the effectiveness of management decisions to reduce the risk of natural disasters; reduction of compensation and damage recovery costs. Climate change means flood events are on the rise. Population growth, economic development, and urbanization are situating more people and more assets in areas that are at greater risk of flooding. Despite being one of the most common and destructive natural hazards, flood risk is systematically underestimated. This contributes to inadequate insurance, underinvestment in flood resilience, and poor policy decisions, resulting in avoidable costs and suffering. A country that is regularly experiencing floods is expending money on recovery instead of growth and development. Frequent flooding, resulting in loss of livelihoods, production and other prolonged economic impacts and types of suffering, can trigger mass migration or population displacement. Increasing the country's resilience to floods should include mutually reinforcing elements, such as the development of modern flood forecasting models, investments in flood protection and flood resilience, increased access to flood risk data and smarter land use planning. The advantages of neural networks over statically programmable forms of analysis are as follows: accuracy; automation; speed; the ability to customize; scalability. [13]

Conclusion

The purpose of the study was to prove the effectiveness of machine learning methods in solving the problem of flood prevention and reducing the risk of consequences. Analysis of the major studies in flood modeling confirms the highest effect of introducing of innovative technologies for flood monitoring in order to reduce the catastrophic consequences of emergency situations. Transferring values to a cartographic base and conducting a spatial analysis with a digital elevation model in a GIS environment makes it possible to determine objects falling into the zone of probable flooding. Important is our conclusion that zoning is an important action in the planning of development and effective management of territories and is a division of the territory into zones with determination of types of urban use of established zones and restrictions on their use. [14]

Improving the accuracy of forecasts with the help of modern information systems will make it possible to determine the feasibility and social significance of economic activities for territories regularly exposed to floods. The conduct of various economic activities under these conditions follows from the understanding of the inevitability of economic damage from floods and the ability to ensure the accuracy of forecasts and ensure preventive measures in flooded areas. We also

need to improve both damage estimations and the quality of damage data since a good documentation and standardized collection and management of damage data are a prerequisite for the development of reliable damage models. [15]

The World Bank has conservatively estimated the value of economic activity exposed to significant flood risk at $5.3 trillion globally. Losses from business interruption can approach, or even exceed, those from damage to property and assets, as data from several recent large-scale flood events reveals. The main factors affecting the amount of damage (degree of destruction) are:

– flood resistance group;
– existing physical wear and tear;
– flooding level.

A flood risk management strategy identifies and implements measures that reduce the overall risk and what remains is the residual risk. In developing the strategy, those responsible judge the costs and benefits of each measure taken and their overall impact in reducing the risk. In many parts of the world, such financial risks will increase due to climate change and continued building on floodplains. Many governments intervene in insurance markets to help extend cover to households in high-risk areas and avoid a spiral of increasing inequality. [16]

The wide-ranging and complex nature of these affects shows national flood risk strategies must be broad in scope, ensuring alignment across a variety of factors such as national governments, local authorities, businesses, financial regulators, and insurers. This requires coherent policies and regulations, aligned incentives, and accessible, robust flood risk data.

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# ECONOMIC MODELS AND INCENTIVES FOR THE DEVELOPMENT OF THE RECYCLING SECTOR IN THE CONTEXT OF A GREEN ECONOMY: ANALYSIS AND PROSPECTS

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***Abstract.*** *The green economy is aimed at reducing the negative impact of economic activity on the environment and promoting sustainable development. One of the key tasks in this context is to create an effective waste recycling system. The development of recycling contributes to a closed cycle of resources, reducing emissions and reducing the burden on the environment, which ultimately benefits both the environment and the economy. This article examines the economic models that stimulate the development of recycling, as well as various tools that can contribute to the activation of recycling in society.*

***Keywords:*** *green economy.*

Waste recycling is not just a fashion trend, but a key element of a circular economy that seeks to change the very paradigm of resource consumption. Instead of the linear "extraction-production-utilization" model, where resources are rapidly depleted, the circular model offers a closed cycle in which resources retain their value for as long as possible.

The linear model that dominated in the past turned out to be extremely inefficient and environmentally destructive. It leads to huge waste disposal costs, pollutes the environment and depletes natural resources that are not renewable on the required scale. Dependence on non-renewable resources such as oil, gas, and ores poses serious risks for future generations.

In contrast to the linear model, the circular economy focuses on three key principles:

- Recycling of materials: maximum possible reuse of materials, extraction of valuable resources from waste and creation of new products from recycled materials.

• Waste minimization: development of products that are easily recyclable, reduction of packaging and optimization of production processes.

• Product reuse: restoration and repair of existing products, resale or adaptation for new purposes.

The circular model not only reduces pressure on natural resources and reduces waste, but also creates new business opportunities:

• Creation of new jobs in the field of recycling, restoration and design of products for reuse.

• Reducing the cost of raw materials and recycling.

• Increasing competitiveness through the use of more environmentally friendly and sustainable technologies.

One of the popular approaches within the circular model is extended producer responsibility (EPR). Under the EPR, manufacturers are directly responsible for the disposal and recycling of their products, including the collection, sorting and recycling of materials.

EPR stimulates manufacturers:

• Develop more environmentally friendly products, taking into account their life cycle and the possibility of recycling.

• Use fewer primary resources and switch to secondary raw materials.

• Improve the design of products to facilitate their disassembly and recycling.

• Invest in innovative technologies to improve recycling efficiency.

The transition to a circular economy requires comprehensive actions from all participants – from producers and consumers to governments and international organizations. The introduction of EPR, the development of infrastructure for waste collection and recycling, and the improvement of environmental literacy of consumers – all these measures are necessary to create a sustainable system.

The circular economy is not just a trend, but a necessity for the survival of mankind. It ensures a more equitable and sustainable future, where resources are used as efficiently as possible, and natural ecosystems are restored and preserved for future generations.

In order to make recycling economically profitable, various incentive measures are required. These measures are aimed at increasing the attractiveness of recycling for both businesses and consumers.

Government subsidies and tax incentives are among the main tools that governments use to encourage recycling. Governments provide subsidies for the de-

velopment of processing enterprises and the introduction of innovative technologies. In addition, tax incentives are provided to companies using secondary raw materials, which reduces their production costs.

Fiscal instruments and fines also play an important role in stimulating recycling. For example, the introduction of taxes on waste disposal motivates companies to minimize the amount of waste produced and look for cost-effective ways to recycle it. Fines for violations of environmental standards contribute to the introduction of separate waste collection and recycling practices.

Encouraging innovation in recycling is also an important aspect. Government programs can support the development of new recycling technologies, such as the use of artificial intelligence to optimize waste sorting and treatment processes. These technologies help to increase the efficiency of processing and reduce its cost.

One of the key elements of recycling is the secondary raw materials market. It is important that there are economically advantageous conditions for the sale and use of materials obtained during the processing process.

The pricing of secondary raw materials largely depends on the demand for products made from recycled materials, as well as on government support measures. For example, government subsidies for purchases of recycled plastic or paper products can stimulate demand and make this market more sustainable. This is especially important because unstable prices for secondary raw materials can scare off potential investors.

Government regulation plays a key role in setting standards for products made from recycled materials. For example, in many countries, regulations have been introduced requiring manufacturers to include a certain percentage of recycled materials in products, which creates a steady demand for recycled materials and contributes to market development.

The development of recycling brings significant economic and social benefits.

For businesses, recycling can be a source of savings. Reducing production costs through the use of recycled materials helps companies reduce their dependence on primary resources, the prices of which can fluctuate greatly. Moreover, companies implementing environmental practices improve their image, which attracts environmentally conscious consumers and helps increase sales.

Social effects include the creation of new jobs, especially in the field of waste collection, sorting and recycling. Moreover, increasing public awareness of waste issues contributes to the development of a culture of separate collection and recycling, which ultimately leads to a reduction in the burden on the environment and an improvement in the quality of life.

The prospects for the development of the processing sector are related to the further implementation of the principles of circular economy and innovation. The

development of new recycling technologies, such as methods of using waste in construction or the creation of biodegradable materials, will further reduce the burden on the environment.

The circular economy opens up wide opportunities for the recycling sector:

1. Development of new processing technologies: The creation of biodegradable materials, the recycling of waste into raw materials for construction, the use of secondary resources in production – all this allows you to reduce the consumption of primary resources and reduce the burden on the environment.

2. Improving the efficiency of existing technologies: Optimizing the processes of sorting, processing and using recycled materials, developing new methods for separating and cleaning waste – all this will increase efficiency and reduce recycling costs.

3. Development of new products and services: The circular economy opens up opportunities for the creation of new products from secondary resources, as well as for the development of repair, restoration and recycling services.

4. Participation in international environmental agreements: Agreements to reduce greenhouse gas emissions, limit the use of harmful substances and reduce waste disposal stimulate the development of the recycling sector.

Overall, the prospects for the development of the recycling sector are very positive. Circular economy, innovation and international cooperation will create a more sustainable and efficient waste management system, contributing to the conservation of natural resources and improving the environmental situation.

The development of the recycling sector in the context of a green economy is an important step towards sustainable development. To do this, it is necessary to apply various economic models and incentives aimed at supporting business and attracting the public. Government subsidies, tax incentives and innovative approaches can play a key role in this process. However, joint efforts of the state, business and society are necessary to achieve significant results.

It is only through an integrated approach, including both economic measures and social initiatives, that it is possible to ensure the successful development of the processing sector and the transition to a green economy.

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# INFORMATION BASE FOR INDIA'S ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT: CHALLENGES AND OPPORTUNITIES

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***Abstract.*** *The article is devoted to the analysis of the information basis necessary for the environmentally sustainable development of India. The article examines the key environmental challenges faced by India and emphasizes the need for comprehensive and accessible information support for making effective decisions in the field of environmental protection. The existing information systems and databases are analyzed, as well as new ideas and solutions for optimizing the information base for achieving environmentally sustainable development in India are proposed.*

***Keywords:*** *India, environmentally sustainable development, information base, data, monitoring, information systems, digital technologies.*

India, being one of the fastest growing economies in the world, is facing serious environmental challenges due to intensive industrial development, population growth and urbanization. To achieve environmentally sustainable development, it is necessary to create a solid information base that will allow assessing the state of the environment, controlling environmental risks, developing effective measures to reduce them and stimulate the transition to a green economy

India faces a number of key environmental challenges:

• Air pollution: Industry, transport and agriculture are the main sources of air pollution, which leads to public health problems and climate change.

• Water scarcity: Uneven precipitation distribution, overpopulation and intensive use of water resources lead to water scarcity in many regions of India.

• Water pollution: The discharge of industrial and domestic wastewater into rivers and lakes pollutes water resources and threatens biodiversity.

• Soil degradation: Intensive farming, soil erosion and improper use of fertilizers lead to soil degradation and a decrease in its fertility.

• Climate change: India is feeling the effects of climate change, including rising temperatures, changing precipitation patterns, and an increase in the frequency of extreme weather events.

In order to effectively manage environmental risks and achieve sustainable development, India needs a solid information base, which includes:

• Environmental monitoring systems: Monitoring systems allow you to monitor the state of the environment, identify trends in changes and evaluate the effectiveness of environmental protection measures taken.

• Databases on environmental data: Databases should contain information on the state of the environment, on emissions of pollutants, on resource consumption, and on the impact of anthropogenic activities on ecosystems.

• Information systems for decision-making: Information systems should provide analytical materials, forecasts and scenarios for the development of the environmental situation in order to support informed decision-making.

**New solutions and ideas**

• Development of digital technologies for environmental monitoring: The use of unmanned aerial vehicles, sensors, and the Internet of Things makes it possible to create more efficient and accurate environmental monitoring systems.

• Creation of open platforms for data exchange: Open platforms will allow you to combine a variety of environmental data, which will improve analytics and speed up decision-making.

• Development of environmental education and awareness programs: Raising public awareness of environmental issues and the importance of sustainable development is an important factor in changing behavior and stimulating environmentally responsible consumption.

The information base plays a key role in achieving environmentally sustainable development in India. The development of environmental monitoring systems, databases and information systems, combined with the use of digital technologies, will allow for more effective management of environmental risks and ensure India's transition to a green economy.

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# RUSSIANARCTIC OIL FOR INDIA

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***Abstract.*** *The article is devoted to the issues of logistics design of marine transportation of Russian Arctic oil to Indian ports along the Northern Sea Transport Corridor. The SMTC project is proposed to create a new logistics service on the international market for the delivery of goods via the Northern Sea Route. The prospects of creating oil hubs are considered. The possibilities of increasing the oil tanker fleet with the help of a "shadow segment" to counter Western sanctions have been identified.*

***Keywords:*** *marine logistics, hydrocarbons, oil, SMTC, sanctions, hubs, ports of India.*

## Introduction

The sanctions of Western countries have led to the redirection of Russian exports to the East, to the countries of Southeast and South Asia, as well as Africa, i.e., the Global South. They have contributed to the active use of Arctic Sea routes via the Northern Sea Route. Further development has contributed to the expansion of the Arctic route to Arkhangelsk, Murmansk, Vladivostok and the creation of the Northern Sea Transit Corridor (NSTC).

The Northern Sea Route is a shipping route that runs along the northern shores dividing the Arctic and Pacific Oceans, encompassing their seas: the Barents, Laptev, Kara, East Siberian, Chukchi and Bering Seas. There are about 70 ports and transshipment points along the Northern Sea Route. Fig. 1 showsmajor ports along the Northern Sea Route.


***Figure 1.*** *Northern Sea Route*

The average duration of navigation on ice-free seas is 80-90 days a year (from May to October). There are two periods of navigation: traditional, lasting 5 months - from June to October, and extended, including two periods of time: January - May and November - December - a total of 7 months.

The Arctic has significant hydrocarbon reserves. Hydrocarbon raw materials include oil, natural gas and coal. The Arctic currently contains about a quarter of the world's oil and gas reserves. Russia owns about 60% of these natural resources.

Russia has consistently maintained its position among the leading countries in oil production. This industry accounts for 9.1% of the Russian economy. At the beginning of 2022, Russia moved up to 2nd place, overtaking Saudi Arabia [1].

**The aim of the study**, presented in the article, is an analysis of the prospects for oil transportation in the current conditions of international sanctions against Russia and the redirection of Arctic oil exports to the East, to India, in the context of the current geopolitical situation and the development of logistics hubs for the shipment and transshipment of oil.

The objectives were logistical design and forecasting research of two transport and technological schemes for delivering Arctic oil to Indian ports:

1) extracted from the sea shelf using the offshore ice-resistant fixed platform (OIRFP) "Prirazlomnaya";

2) extracted from coastal oil fields and shipped using a stationary vessel located in the waters of the Varandey portoffshore ice-resistant loading terminal (OIRLT).

The subject of the study is the developed theoretical and methodological foundations for assessing the efficiency of the designed logistics schemes for the delivery of crude oil, taking into account the actual operating oil tankers and escort icebreakers.

All calculations for crude oil transportation are performed using the proprietary methodology developed by the Department of Water Transport Management of the Admiral S. O. Makarov State University of Maritime and River Fleet (Admiral S. O. Makarov State University of Maritime and River Fleet). The methodology has been significantly improved in terms of additional calculations:

- taking into account the specifics of the ice conditions of Arctic Sea transport;
- taking into account the requirement for icebreaker assistance for vessels without an ice class and vessels with different ice strengthening;
- taking into account the specifics of the western and eastern sectors of the Northern Sea Route;
- taking into account two periods of navigation (traditional and extended);
- taking into account the depths at different sections of the Arctic routes, etc.

**Methods and materials**

The following methods were used in this study:

- logistics design of transportation with graphic construction of lines;
- multifactor analysis for the selection of optimal vessels on designed lines;
- multi-criteria analysis of the choice of the optimal line and the optimal vessel;
- graphical construction of the results of tactical and strategic competitiveness of ships on the lines.

**Sanctions**

In total, Western countries have adopted 14 sanctions packages, the new 15th package will be developed in January 2025 and is entirely dedicated to liquefied natural gas. Since December 5, 2022, a ban on seaborne deliveries of Russian oil to Europe has been in effect. An embargo is imposed for any technical assistance, financing and insurance services for transactions on the sale of Russian oil and oil products to third countries. The EU has approved a “ceiling” for prices of Russian oil at $ 60 per barrel. The decision of the Russian Federation was immediate - to stop oil supplies to countries that joined this pricing mechanism. Previously, Russia exported about 90% of hydrocarbons to Western countries. In 2022, sanctions (Sovcomflot was also affected) from the US and the EU intensified, so Russian companies began to redirect sales to Asian countries. Russia’s own official tanker fleet is small, and ensuring stable transportation has come to the fore, difficulties have grown. The US and UK banned ships sailing under the Russian flag from entering their ports and blocked the insurance system, stopped supporting electronic map services necessary for safe navigation. As a result, Russian ships began calling more often at Turkey, India and China, and 10 times less at EU ports, and stopped calling at all at the US and UK. There was a sharp redirection of hydrocarbon export flows.

Sovcomflot was forced to sell a third of its tankers to reduce its debt burden due to Western sanctions. Volga Shipping Company and smaller companies fol-

lowed suit. Many used Russian tankers with a service life of more than 15 years were bought by the UAE, Iran, China, India, Singapore and other countries.

Thus, Russia has formed a “shadow” tanker fleet that exports Russian oil. The exact number of vessels cannot be determined, but currently there are about 800 units. Automatic identification systems AIS or transponders, which are used to track the location of vessels, are disabled on “shadow tankers”. Because of this, it is impossible to determine the route of movement and assess the load. There are two types of “shadow” fleet. “Black tankers” - belong to Iran and Venezuela. “Grey tankers” - European vessels sold to Eastern and Asian companies.[2]

**The Importance of Oil Hubs**

An oil hub is a center for the accumulation and distribution of oil. It is located in the center of the infrastructure that facilitates the transshipment and transportation of hydrocarbons. The emergence of oil hubs is primarily associated with economic growth and increased trade in the energy sector. An oil hub can now be called a large port that transships a large number of raw materials, has storage facilities or actively developed wells.

For example, Singapore is the central oil hub of Asia. In December 2022, about 3.5 million barrels of crude oil entered the country. Stable policies and a favorable location have contributed to the development of this region. The state maintains trade relations regardless of the political situation in the world. It does not impose trade restrictions on oil supplies and does not enter into conflicts. Singapore’s oil depots are located on islands, storage facilities can hold 14.25 million barrels.

In Singapore, Russian oil is resold mixed with other grades to circumvent Western sanctions. It is as if Russian oil is being re-exported to countries that fear Western sanctions. Near the Strait of Johor, oil is transferred from tanker to tanker. In addition, Singapore is a manufacturer of advanced floating storage and offloading units, as well as autonomous offshore drilling rigs.

Turkey is also an active source of energy resources. The country buys oil, gas and other raw materials, reselling them to other countries. In South Korea, in the city of Yeosu, there is an underground oil storage tank. It holds up to 20 million barrels. Large oil storage facilities are also located in Japan.

In Russia, a large oil terminal, Port Bukhta Sever, is being built on the eastern shore of the Yenisei Gulf. Rosneft is managing the project. The purpose of the construction is to transship raw materials onto tankers that will carry cargo along the Northern Sea Route to ports in Russia, Asia and Europe. Oil will be delivered to the terminal via pipelines from the Payakhskoye and Vankorskoye fields.[3]

The port of Murmansk is a major logistics hub for the Northern Sea Route. Oil transshipment is actively organized here. Since June 2022, the volume of oil received has increased to 3.6 million barrels per day. Since 2016, the storage tanker Umba with a cargo capacity of about 30 thousand tons has been moored in the

port waters. Oil is delivered to this floating storage with 17 tanks from the Novoportovskoye and Prirazlomnoye fields. The maximum cargo turnover of the transshipment complex is up to 15 million tons per year. The operator, the Murmansk company RPK Nord, which is engaged in storage and warehousing as its main activity, monitors the operation of the vessel. Umba was specially re-equipped for use in the climatic conditions of the Arctic. [4, 5]

**Results research and its discussion**

This article presents a number of calculation results and analysis of key economic indicators for three lines Arctic oil transportation from Russia to India (table 1 - 5):

- Line 1: Port of Varandey (Russian Federation) – (via the Suez Canal) – port of Mundra (India);
- Line 2: Prirazlomnaya MLSP (RF) – (via the NSR) – Chennai port (India);
- Line 3: Prirazlomnaya MLSP (RF) – (via NSR) – Mumbai port (India).

Operating tankers of various Arctic classes were selected to operate the lines: “Mikhail Ulyanov”, “Timofey Guzhenko”, “Vasily Dinkov”, “SCF BALTICA”, “ADYGEYA”, “Kirill Lavrov”, “Shturman Skuratov”, “Shturman Koshelev”, “Shturman Shcherbinin”. The project involved oil exports to major Indian ports with equipped berths for oil transshipment.

The rules of navigation along the NSR were studied: the characteristics of vessels of different ice classes, the criteria for admitting vessels during summer and winter navigation were studied. The current state of the tanker and icebreaker fleet of Russia was analyzed, the pricing and rules of icebreaker assistance were studied, ensuring safe navigation of vessels along the NSR.

The legal framework for activities in the Arctic and on the Northern Sea Route is characterized by a number of regulations not only at the level of the Russian government, but also at the level of international communities.

Calculations of the performance indicators of the projected lines were performed using the original methodology of the Department of Water Transport Management of the Adm. S. O. Makarov State University of Maritime and Inland Shipping, which allowed taking into account the specifics of navigation in the Arctic zone. An economic analysis of the vessels’ performance, their strategic and tactical competitiveness was conducted. Using multifactor analysis and graphic material, the optimal vessels were selected for each line. Three projected lines were compared using several criteria. As a result, an effective line was selected that ensures a high level of oil carrying capacity, low costs and high profitability.

***Table 1***

*Calculation of specific currency indicators, income and expenses for a round trip along line 1: Port of Varandey (RF) – (via the Suez Canal) – port of Mundra (India)*

| Indicator | Traditional navigation | | | Extended navigation | | |
|---|---|---|---|---|---|---|
| | Types of vessels | | | Types of vessels | | |
| | Mikhail Ulyanov | Navigator Skuratov | Vasily Dinkov | Mikhail Ulyanov | Navigator Skuratov | Vasily Dinkov |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Currency consumption per 1 ton of cargo (currency cost price), S, USD/t | 45.13 | 72.17 | 45.28 | 45.13 | 72.17 | 45.28 |
| Cost of vessel maintenance (including fuel costs), SV, USD/day. | 46927,18 | 44002.89 | 45767,42 | 46927,18 | 44002.89 | 45767,42 |
| Estimated freight rate, fp USD/t | 55,51 | 88.76 | 55.69 | 55,51 | 88.76 | 55.69 |
| Income per round trip, Dkr, USD | 2605452,33 | 2602260,28 | 2586143,14 | 2605452,33 | 2602260,28 | 2586143,14 |
| Round trip costs, Ekr, USD | 2118250,11 | 2115803,56 | 2102544,20 | 2118250,11 | 2115803,56 | 2102544,20 |

***Table 2***

*Calculation of specific currency indicators, income and expenses for a round trip along line 2: MLSP Prirazlomnaya (RF) – (via NSR) – Chennai port (India)*

| Indicator | Traditional navigation | | | Extended navigation | | |
|---|---|---|---|---|---|---|
| | Types of vessels | | | Types of vessels | | |
| | SCF BALTICA | ADYGEYA | Kirill Lavrov | SCF BALTICA | ADYGEYA | Kirill Lavrov |
| Currency consumption per 1 ton of cargo (currency cost price), S, USD/t | 16.65 | 16.42 | 30.79 | 23.42 | 23,24 | 42.30 |
| Cost of vessel maintenance (including fuel costs), SV, USD/day. | 17537,92 | 19073,84 | 21534,58 | 22126,66 | 21058,72 | 22657,71 |
| Estimated freight rate, fp USD/t | 20.81 | 20.53 | 38,49 | 29,27 | 29.05 | 52.88 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Income per round trip, Dkr, USD | 1728522,09 | 1564293,30 | 1661393,16 | 2431227,37 | 2214061,17 | 2282764,48 |
| Round trip costs, Ekr, USD | 1382983,80 | 1251339,96 | 1329141,18 | 1945314,15 | 1771080,43 | 1826004.29 |

***Table 3***

*Calculation of specific currency indicators, income and expenses for a round trip along line 3:*
*MLSP Prirazlomnaya (RF) – (via NSR) – Mumbai port (India)*

| Indicator | Traditional navigation | | | Extended navigation | | |
|---|---|---|---|---|---|---|
| | Types of vessels | | | Types of vessels | | |
| | **Timofey Guzhenko** | **Navigator Koshelev** | **Navigator Shcherbinin** | **Timofey Guzhenko** | **Navigator Koshelev** | **Navigator Shcherbinin** |
| Currency consumption per 1 ton of cargo (currency cost price), S, USD/t | 26.17 | 41.96 | 41.96 | 40.76 | 64.93 | 64.93 |
| Cost of vessel maintenance (including fuel costs), SV, USD/ day. | 21068,49 | 20340,81 | 20340,81 | 23458,98 | 23011,93 | 23011,93 |
| Estimated freight rate, fp USD/t | 32.19 | 51,61 | 51,61 | 50.14 | 79.87 | 79.87 |
| Income per round trip, Dkr, USD | 1577759,37 | 1596975,54 | 1596975,54 | 2457559,95 | 2471563,78 | 2471563,78 |
| Round trip costs, Ekr, USD | 1282695,33 | 1298479,89 | 1298479,89 | 1997809,01 | 2009301,70 | 2009301,70 |

***Table 4***

*Multi-criteria selection of optimal vessels*

| No. | Indicator | LINE 1 | LINE 2 | LINE 3 |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 1 | min Average round trip time, tcr sr, days. | Mikhail Ulyanov | Kirill Lavrov | Timofey Guzhenko |
| 2 | max Carrying capacity of the vessel, G, t | Mikhail Ulyanov | ADYGEYA | Timofey Guzhenko |
| 3 | min Average cost per round trip, Ekr avg, USD | Vasily Dinkov | ADYGEYA | Timofey Guzhenko |
| 4 | min. Currency consumption per 1 ton of cargo (currency cost price), S, USD/t | Mikhail Ulyanov | ADYGEYA | Timofey Guzhenko |
| 5 | min Cost of vessel maintenance (including fuel costs), Sv, USD/day. | Navigator Skuratov | SCF BALTICA | Navigator Koshelev and Navigator Shcherbinin |

| | | | | |
|---|---|---|---|---|
| 6 | min Estimated freight rate, fr USD/t | Mikhail Ulyanov | ADYGEYA | Timofey Guzhenko |
| 7 | max Gross profit, Pv, USD | Mikhail Ulyanov | Kirill Lavrov | Timofey Guzhenko |
| 8 | max Transportation profitability, R, % | Mikhail Ulyanov | ADYGEYA and Kirill Lavrov | Timofey Guzhenko |
| 9 | max Integral indicator of the vessel's tactical competitiveness | Mikhail Ulyanov | ADYGEYA | Timofey Guzhenko |
| 10 | max Integral indicator of the vessel's strategic competitiveness | Mikhail Ulyanov | ADYGEYA | Timofey Guzhenko |
| 11 | Optimal vessel on the line: | Mikhail Ulyanov | ADYGEYA | Timofey Guzhenko |

So, the optimal courts are:

- for line 1 – Mikhail Ulyanov;
- for line 2 – ADYGEYA;
- for line 3 – Timofey Guzhenko.

**Selecting the optimal line**

The optimal line should provide high carrying capacity, have low costs (especially port charges and service fees) and be profitable.

If we look only at the length of the round trip, then Line 1, passing through the Suez Canal, will be more advantageous, since this route is shorter by 5,675.84 km than going along the Northern Sea Route to distant India along the route of Line 2. But we should not forget about a number of significant factors:

1. Shipping fees and charges for passage through the Suez Canal are high, moreover, the canal administration increases tariff every year due to the difficult maintenance of the route (in order for the canal to be navigable, it is necessary to constantly clean out sand blown in from the desert).

2. There have been cases of ships being robbed by Somali pirates.

3. Frequent cases of congestion due to ships running aground, long queues of ships and long waiting times.

***Table 5***

*Multi-criteria selection of the optimal line*

| No. | Indicator | LINE NO. |
|---|---|---|
| 1 | min Length of the route, Ltr, km | 1 |
| 2 | min Average round trip time, tcr sr, days. | 1 |
| 3 | max Carrying capacity of the vessel, G, t | 2 |
| 4 | min Average cost per round trip, Ekr avg, USD | 2 |
| 5 | min. Currency consumption per 1 ton of cargo (currency cost price), S, USD/t | 2 |

| | | |
|---|---|---|
| 6 | min Cost of vessel maintenance (including fuel costs), Sv, USD/day. | 2 |
| 7 | min Estimated freight rate, fr USD/t | 2 |
| 8 | max Annual income, D, USD | 1 |
| 9 | min Annual expenses, E, USD | 3 |
| 10 | max Gross profit, Pv, USD | 1 |
| 11 | max Transportation profitability, R, % | 2 |
| 12 | max Integral indicator of the vessel's tactical competitiveness | 1 |
| 13 | max Integral indicator of the vessel's strategic competitiveness | 2 |
| 14 | Optimal line: | 2 |

The line that wins by the largest number of indicators is optimal. This is line 2: MLSP Prirazlomnaya (RF) - (via NSR) - Chennai port (India).

**Conclusion**

This article shows some results of the development of transport and technological logistics schemes for the transportation of crude oil from the Arctic to the ports of India. The issues raised suggest further development of mutually beneficial trade relations between our countries, as well as increasing the competitiveness of the SMTC in the global maritime transportation market. By 2035, it is planned to transport up to 160 million tons of various cargo and make the SMTC regular, year-round and uninterrupted in accordance with the strategic plans for the development of the Arctic and the Northern Sea Route.

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# CURRENT TRENDS IN THE DEVELOPMENT OF CROSS-BORDER PRIVATE LEGAL RELATIONS IN INTEGRATION ASSOCIATIONS

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***Annotation.*** *Strategies within integration associations are aimed at developing economic principles, digitalization, concluding new regional agreements, as well as the possibility of introducing changes to the current legislation of member states of integration associations in the context of the development of innovation.*

***Keyword:*** *integration associations, modern vectors of development, economic transformation, new Strategies.*

The Strategic Directions for the Development of Eurasian Economic Integration until 2025" (SEEC Order No. 12 dated December 11, 2020) stipulates:

- improving customs regulation in the EAEU, which involves expanding the use of digital technologies;

– improvement of the EAEU Customs Code taking into account practice

its application and introduction of appropriate amendments to the acts of the EAEU bodies;

ensuring a uniform standard for performing customs operations

and carrying out customs control;

– unification of electronic document flow between customs authorities and participants in foreign trade activities, formation of priority tools for implementing the "single window" mechanism in the system of regulation of foreign economic activity[1].

Article 35 of "Treaty on the Eurasian Economic Union" (Signed in Astana on May 29, 2014) (as amended on May 25, 2023) (as amended and supplemented, entered into force on June 24, 2024) states:

The regime of free trade in goods in the understanding of GATT 1994 is established in trade with a third party on the basis of an international treaty of the

[1] Decision of the Supreme Eurasian Economic Council: "On the Strategic Directions for the Development of Eurasian Economic Integration until 2025." // https://docs.eaeunion.org/docs/ru-ru/01428320/scd_12012021_12 (date of last access: 21.10.2024).

Union with such a third party, taking into account the provisions of Article 102 of this Treaty.

An international agreement between the Union and a third party establishing a free trade regime may include other provisions related to foreign trade activities. Article 65 states: « The Member States shall pursue a coordinated policy in the field of consumer protection aimed at creating equal conditions for citizens of the Member States to protect their interests from unfair activities of business entities.

The implementation of a coordinated policy in the field of consumer protection is ensured in accordance with this Agreement and the legislation of the Member States on the protection of consumer rights based on the principles in accordance with Appendix No. 13 to this Agreement.

Member States coordinate trade in services with third parties.

The implementation of coordination does not mean the supranational competence of the Union in this area»[2].

Order of the Council of the Eurasian Economic Commission «On the list of services and digital infrastructure implemented in order to form an ecosystem of digital transport corridors of the Eurasian Economic Union» 2020 regulate: «digital map and database of main roads and infrastructure facilities of international transport corridors passing through the territories of the Member States; 2. service for booking roadside infrastructure facilities; 3. service for booking a queue at a vehicle checkpoint of a Member State; 4. service for conducting a medical examination of drivers of vehicles remotely (including the prevention and prevention of coronavirus infection COVID-19); 5. service for the application of an electronic international waybill (for railway transport)»[3]. EAEU Decision No. 7 of May 27, 2022 "On the main guidelines for the macroeconomic policy of the EAEU member states for 2022-2023" (hereinafter referred to as EAEU Decision No. 7 of 05.27.2022). stated: Improving transport and logistics infrastructure, eliminating obstacles in mutual trade and preventing the creation of new cross-border barriers, developing promising forms of trade and creating new export opportunities;

- conclusion of new trade agreements and memorandums of cooperation;
- intensification of business dialogue with business circles of third countries through the EAEU Business Council[4].

[2] "Treaty on the Eurasian Economic Union" (Signed in Astana on May 29, 2014) (as amended on May 25, 2023) (as amended and supplemented, entered into force on June 24, 2024). //https://www.economy.gov.ru/material/file/2bbbbf9ae33443d533d855bf2225707e/Dogovor_ees.pdf(date of last access: 06.13.2024).

[3] Order of the Council of the Eurasian Economic Commission dated «On the list of services and digital infrastructure implemented in order to form an ecosystem of digital transport corridors of the Eurasian Economic Union». November 23, 2020. № 29. // https://eec.eaeunion.org/en/news/v-2022-godu-v-eaes-budet-sozdana-informatsionno-kommunikatsionnaya-vitrina-natsionalnykh-servisov-ek/. (date of last access: 21.10.2024).

[4] EAEU Decision No. 7 of May 27, 2022 "On the main guidelines for the macroeconomic policy of the EAEU member states for 2022-2023." // https://www.alta.ru/tamdoc/22vr0007/ (date of last access: 21.10.2024).

In 2022, the "Declaration on Allied Cooperation between the Russian Federation and the Republic of Azerbaijan" was concluded, which stated that the parties would develop cooperation in the field of healthcare, the implementation of joint projects in the field of ensuring the sanitary and epidemiological well-being of the population, including countering infectious diseases, and will also explore opportunities for cooperation in the field of biological safety[5].

Agreement on the mechanism for the traceability of goods imported into the customs territory of the EAEU dated May 29, 2019: "the agreement is aimed at creating a traceability system for foreign goods in the Union, the main task of which will be to confirm the legality of their circulation when moving from the territory of one member state to the territory of another country Union, as well as creating conditions excluding the use of various schemes for evading customs and tax payments, ensuring state control over operations related to the circulation of such goods"[6].

The 2018 Declaration on the further development of integration processes within the framework of the Eurasian Economic Union states:

-increase in passenger and freight traffic in order to realize the transit and logistics potential of the EAEU;

Improving tools for interaction with the business community;

Formation of territory-innovation[7].

About the Program of Joint Actions of the Member States of the Eurasian Economic Union in the field of protection of conusmer rights. The Commission, with the assistance of the Member States, develops recommendations aimed at bringing national approaches closer together in the main areas defined in paragraph 3 of the Protocol on the implementation of a coordinated policy in the field of consumer protection (Appendix No. 13 to the Treaty), including:

general approaches to protecting consumer rights in electronic commerce;

general approaches to conducting reviews of legislation of Member States in the field of consumer protection[8].

Memorandum on deeing interaction between the EAEU and the CIS Executive Committee 2023 issues covered: «consumer right protection, digital economy, dooperation in the field of foreign trade»[9].

[5] "Declaration on allied interaction between the Russian Federation and the Republic of Azerbaijan." 22.02.2022. // https://president.az/en/articles/view/55498.(date of last access: 21.10.2024).

[6] Agreement on the mechanism for the traceability of goods imported into the customs territory of the EAEU. 2.12.2019. // "Collection of Legislation of the Russian Federation", 03.15.2021, N 11, art. 1714.(date of last access: 21.10.2024).

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In «Concept of information policy of the judicial system for 2020 - 2030" (approved by the Council of Judges of the Russian Federation on December 5, 2019):

«ensuring citizens' access to justice and ensuring its maximum openness and transparency, implementing the principle of independence and objectivity when making court decisions are the main directions for the further development of the judicial system»[10].

Development strategy of the Shanghai Cooperation Organization until 2025: «Member States will promote the development mutually beneficial cooperation in the innovation sphere.

The SCO member states will develop mutually beneficial diversified cooperation in the energy sector, including in the field of the use of renewable and alternative energy sources»[11].

Thus, the latest changes in the legislation of the member states of integration associations will lead to the transformation of the institutions of modern international private law.

[10] «Concept of information policy of the judicial system for 2020 - 2030" (approved by the Council of Judges of the Russian Federation on December 5, 2019):// https://www.consultant.ru/document/cons_doc_LAW_339776/(date of last access: 21.10.2024).

[11] Development strategy of the Shanghai Cooperation Organization until 2025. // https://rus.sectsco.org/documents/ (date of last access: 21.10.2024).

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# THE LAWS AND CUSTOMS OF WARFARE IN EUROPE OF THE FIRST MILLENNIUM

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***Abstract.*** *The article studies the formation of laws and customs of warfare in Europe in the first millennium, in the Middle Ages. It is emphasized that the establishment of a certain tradition of moral and religious regulation of the course of armed conflicts was an important step in securing universal norms of the laws of warfare and increasing their effectiveness, despite the irreconcilability of various religious and ideological factors. In the Middle Ages, elements of the internal obligation of a warrior-knight were established, the effectiveness of which depended on understanding and following the moral duty of honor. They formed the internal basis of the laws and customs of war.*

***Keywords:*** *laws and customs of war, armed struggle, combat morale, knight's code, humanity.*

In the context of the study of the history of the formation of laws and customs of warfare, the Crusades constituted a special period where various legal concepts of armed struggle collided. As a way of theoretical and practical comprehension of international legal life, the concept is a step towards the creation of a doctrine of law.

Despite the widespread opinion regarding the conflict between the Christian and Muslim worlds, the relations were not only violent: there were cultural and economic relations, contracts and agreements were concluded, including in the area of regulating armed struggle, that is, international law acquired a broader meaning. E. David briefly noted the significance of Vigayat in his work [11].

The literature often emphasizes the "initiative" role of Christian campaigns in religious wars [6], and less attention is paid to Arab raids. However, the Koran states: "And fight them until there is no more temptation, and the religion belongs to Allah. And if they hold out, then there is no hostility except against the unrighteous!" [5].

Different humanitarian approaches were compared – Islamic (Muslim law) and knightly-Christian codes of combat conduct to the Rules of Conduct of Armed

Warfare. The knightly approach was dominated by the honor and morality of the venerable knight, who carried the true faith and civilization. If a sin is committed in war, the knight believed, it will be atoned for by the Church. One example of neglect of personal responsibility for inhumane behavior was the sack of Constantinople by the Crusaders in 1204, in which the victims and victors were Christians. The papal legate Peter of Saint-Marseille, without the knowledge of the Pope, released the knights from their vow, and the massacre continued for three days [3]. During the capture of Jerusalem in 1099, eyewitness Raymond d'Agilles wrote: "So much blood was spilled in the ancient Temple of Solomon, where 10,000 Muslims had taken refuge, that bodies floated in the flood in the courtyard next to severed hands." Another eyewitness said that the blood was knee-deep [8]. But oblivion of personal responsibility can hardly explain these displays of brutal violence.

In order to increase the effectiveness of regulating armed struggle, it was necessary to move on to establishing the rules of warfare. The first agreements were signed between the caliphs and Byzantium. According to them, prisoners were provided with humane treatment and the possibility of ransom. Muslims considered it necessary to fulfill the agreements, because the Holy Quran stated: "They give food, although they themselves are in need of it, to the poor who cannot earn their bread, to the orphan who has lost his father, and to the captive who has nothing" [1]. But among Christian warriors at that time there was still confidence that agreements with non-Christians could be broken unilaterally. In contrast to the behavior of the Crusaders during the capture of Jerusalem in 1099 were the actions of the troops of Saladin (Salah ad Din) in 1187. His soldiers behaved peacefully towards the locals, special patrols monitored discipline and order. Rich prisoners were released for ransom, and the poor were released.

Written and unwritten agreements were drawn up as a transitional phase from moral rules to legal norms between the warring parties. Almost simultaneously with the establishment of the "Truce of God" in Islam, Viqayat (1280) as a real code of laws of war extended the protection of the elderly, women, children, the mentally ill, parliamentarians, the disabled, and prohibited the damage of water sources and fountains.

Thus, the establishment of a certain tradition of moral and religious regulation of the course of armed conflicts was an important step in securing universal norms of the laws of warfare and increasing their effectiveness, despite the irreconcilability of various religious and ideological factors, as was the case between the Muslim and Christian worlds during the Crusades. However, these steps were not enough to move from moral rules to elements of legal regulation.

Turning to the state of combat morale. In those distant times, the fate of a soldier, an isolated weapon of war, was of little interest to anyone. Often, a warrior

performed bloody work, in which plunder was, as it were, partial payment for his labor. Wounded, he could not count on mercy, even the doors of monastery hospitals were closed to him. There was no medical service in the armies, their own were left to die in agony, and wounded enemies were usually killed, as were prisoners, if there was no one willing to pay ransom for them. The fate of the civilian population of captured cities was no better.

But it would be wrong to note only the negative aspects of the general state of military morale in the first centuries. The main asset of this period was the strengthening of the humanistic content of the moral and religious codes of the professional warrior. The attitude to military activity as a component of ethnonational culture required a set of ethical norms that would be a special indicator, in addition to the purely military achievements of warriors, a measure of honor in the performance of their duties. The importance of the synthesis of state duty with the norms of noble morality for the law of war was noted by I. Huizinga. "Thus," he wrote, "the system of international law arose and grew on an ancient and Christian basis. And these two ideas - chivalry and international law - became fertile ground for the idea of pure humanity" [10]. The medieval knightly code was based on the ideas of statehood, nobility, established rules and the warrior's own interest, which confirms the tendency we have noted of the transition from moral codes of militaristic behavior to the ideas of law and order in armed struggle.

Considering some of the moral codes of the Middle Ages. The moral code of Japanese warriors Bushido received impetus for development in the 12th century in Japan and China and imposed on warriors-Bushido, in addition to purely official duties, also humanitarian duties. The researcher of the Asian concept of the laws and customs of war Sumio Adashi believed that the code of Bushido enjoyed wider recognition among warriors in the East than the knightly code in the West [9, p. 31]. Seven dogmas were proclaimed: honesty, moral courage, humanity, love, straightforwardness, sincerity, honor, obedience and loyalty to higher levels of society. Honor as part of the honor of the emperor acquired special significance for warriors-Bushido, and the manifestation of humanity to the weak, wounded, defeated was considered its virtue. Adashi believed that before Henri Dunant's "Memories of Solferino" there was a novel by Japanese writer Takizawa, which glorified helping a defeated enemy. In the Middle Ages, prisoners in Japan were often freed, allowed to settle in certain areas, and most foreigners assimilated.

Contribution to the formation of the laws of war was made by strategists, military leaders of Japan. Yamaga Soko (1622-1685), the founder of Japanese military science, believed that the goal of strategy is to ensure humanity, peace, and the prevention of senseless victims. Commander Ogyu Sorai (1666-1728) wrote that humanity is the core of military operations, because an army without a sense of humanity loses unity. Since the main law of war, they believed, is to punish

evil, restore justice, then it was strictly forbidden to use unjustified violence, harm children, women, the elderly, destroy graves, set fire to houses, poison water and food. A more meaningful rule was formulated by Sato Nobuhiro (1769-1850), who developed the rules for the treatment of prisoners and came to the conclusion that the law of war should be passed on from generation to generation, and strategists should teach it. Let us take into account that the modern doctrine of the International Committee of the Red Cross emphasizes the teaching of basic humane norms by the military [4].

The transfer of knowledge and rules of humane behavior of a warrior in war from generation to new generation, as advised by the Bushi code, familiarization of personnel with the peculiarities of traditions, customs, and national approaches to humanism remains an important task in increasing the effectiveness of the norms of international humanitarian law.

The rules of humane behavior of Bushi warriors did not always correspond to the combat behavior of the Japanese soldier already in the 20th century, who was fanatical in defense, stubborn in the attack, and often treated prisoners with disdain. In the documentary memoirs of P. P. Vladimirov "Special Region of China. 1942-1945" there are facts when prisoners were cut and stabbed with bayonets, and the civilian population was abused [2, p. 87].

The knight's moral and combat code became a component of the training of secular feudal warriors, which began before armed trials. The complex of positive traits that constituted the knight's honor had to be demonstrated publicly, and when honor was in danger, it also had to be defended publicly. And in the late Middle Ages, the custom of organizing a knightly duel was established, and monarchs often participated in it. Perseverance in observing the rules of the game duel, and the apparent seriousness indicate the great moral content of this way of maintaining knightly honor.

In medieval legal proceedings, a significant place was occupied by the "trial duel". This was a form of resolving controversial and complicated cases, when it was impossible to determine unequivocally which of the litigants was right. Despite a certain formalism inherent in the "trial duel", the rules for choosing weapons, various complications for equalizing the chances of opponents with unequal forces, indicated the priority of the honor and dignity of knights. The last trial due to a duel in a civil case took place in 1571 in Westminster [7]. The fight could last from sunrise to the first stars. Knightly duels reflected the importance of observing established (oral) rules in a case that concerned power, law, morality, and military affairs. According to these unwritten rules, a victory is significant only when the prestige of the knight rises even higher. This was achieved through restraint and noble behavior with the enemy.

The consecration of the law of war through religious teachings of various schools created a theoretical basis for determining the admissibility of waging

war and moral restrictions in its conduct. Being an integral part of traditions and beliefs, these teachings formed a general idea of the legality, admissibility and ethical standards of conducting military actions and left a significant mark on the development of international humanitarian law. The first successes of such consecration in Christianity are recorded in the works of Blessed Aurelius Augustine. In his work "The City of God" he points out that "by the law of war" the victors could kill the vanquished. And if they left them alive, they became slaves.

Thus, summing up the brief overview of the formation of the rules and humanitarian traditions of warfare, which have not yet been completely separated from the norms of combat morality, it can be seen that play and struggle, morality and law, humanism and cruelty went hand in hand. The humane elements of combat morality did not provide a sufficient level of protection of the human right to life. From the point of view of the state and the church, moral and legal state regulation should be introduced into military relations. In the Middle Ages, elements of the internal obligation of a warrior-knight were established, the effectiveness of which depended on understanding and following the moral duty of honor. They constituted the internal basis of the laws and customs of war. Although in subsequent history the emphasis was placed on the development and consolidation of international legal norms that determine proper humane behavior, a sense of honor and morality in the conduct of military operations, the humanistic ethics of victory and resistance is of utmost importance. "The old knightly rules should be rehabilitated in a modern form and introduced into combatant training programs," E. David rightly believes [11, p. 654].

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# THE XVI BRICS SUMMIT AND THE COLLECTIVE WEST'S ATTEMPT TO NEUTRALIZE THE EVOLUTION OF EURASIAN INTEGRATION PROCESSES

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***Abstract.*** *the authors examine the current agenda of the BRICS summit in Kazan under the chairmanship of Russia, which is building a polycentric world of new opportunities in the field of integration and development of mechanisms to counter the neocolonial hegemony of the Anglo-Saxons.*

***Keywords:*** *BRICS, Russia, Brazil, India, China, Eurasia, neocolonialism, Anglo-Saxons, conscious wars, AI, Big Data, AUKUS, NATO, QUAD.*

The 16th BRICS summit, chaired by Russia and held at the end of October 2024, once again demonstrated the interest of the states of the global South participating in the construction of an alternative world order with a fairer distribution of technologies and resources, food and opportunities for a successful and dignified life. [1] As part of the panel of meetings in Kazan, a meeting was held between Russian President Vladimir Putin and President of the BRICS New Development Bank Dilma Rousseff, former President of Brazil and top manager of the largest oil company Petrobras before her election as the head of the country. It was noted by the parties that since 2018, 100 projects have been financed for a total of 33 billion US dollars and they have become part of the infrastructure of the BRICS countries being formed and built. This trend allows for targeted use of partner countries' technologies and relatively cheap investments in mutual logistics and transport chains, which ensures more successful and secure interaction, which yields its independent results in self-sufficiency of the countries of the previously

formed business club in the field of food and energy security. The results of such a financial institution were not only highly appreciated by other leaders of the BRICS countries, but also allowed for continued dialogue on the creation of the currency of the association itself, which was previously planned to be the Chinese yuan, but during the Johannesburg Declaration it did not become this instrument due to the objections of representatives of the Celestial Empire, fearing currency risks and insufficient hedging of their national currency with its uncontrolled spread across many countries and projects. [2] At a meeting with Narendra Modi, Vladimir Putin stated that Russian-Indian relations are developing as a particularly privileged, strategic partnership aimed at further diversification of economies and mutual trade, as well as energy cooperation. He noted the stable trade turnover and announced the upcoming meeting of the intergovernmental commission on November 12 in New Delhi. The Russian President supported the idea of opening a Consulate General of India in Kazan, as a closer point to the countries of the Asia-Pacific region and Siberia.

South African President Cyril Ramaphosa said that Russia has been a valuable ally and friend of the country since the fight against apartheid and the construction of transport infrastructure within Southern Africa, where transport companies from Russia have a significant share of their participation. The head of the Russian state noted that trade turnover between the Russian Federation and South Africa has grown by 3% in 8 months and emphasized the need to work on diversifying trade and increasing the inflow of mutual investments. The very attempts of the collective West to destroy the increasingly dynamically developing format through the provocative agenda of the SVO look like conscious influences, which in the form of fakes and doctrines of destruction and chaos are increasingly being introduced into the agendas of both NATO and the KUAD and are being implemented in the military arena within the framework of AUKUS, as a "forge of aggressive plans" of the Anglo-Saxons in all regions of the world. At the same time, the growing tension in the Taiwan issue or the developing 3rd Lebanon war together with the Palestinian issue make efforts in the field of peacekeeping or the task of forming a new security framework dependent on the ambitions of the future US president and the policy of the neocons, who want to crush the modern foundations of civilization with conscious provocations and the introduction of the ideas of transhumanism and the LGBT agenda (banned in Russia), as means of dehumanization and further pumping of resources into the possession of the countries of the "golden billion" according to the old principle of "gold for beads". [3]

The new "beads" today are the products of generative AI, which shapes foreign trade and singles out particularly tasty morsels in global markets in the process of post-covid recessionary seething of highly volatile markets and gives illusions of their infallibility and invulnerability, as a class of former exploiters of the

historical realities of the world of colonies and countries with an uncertain status of existence as pasture for metropolises, and now corporatocratic elites, solving issues of maintaining their power through the mechanisms of global governance institutions. At the same time, it is precisely the conscious technologies that lead humanity itself into a dead end and replace vital needs with the standards of the "consumer economy" of Daniel Kahneman and Richard Thaler that speak of the far-fetchedness and insolubility of many geopolitical intrigues, uncontrollably and irresponsibly launched by the West to maintain the hegemony of the dollar and its position as the only master of planet Earth. [4]

The ability to be the best, safe, high-quality and inexpensive in the right place and to reflect the market conditions of the ongoing changes in society, on exchanges, in payment systems and on marketplaces is becoming the handicap that American big tech and Chinese "unicorns" with "gazelles" can afford when growing "black swans" of geopolitical processes of global goal-setting, bringing their wishes to their own success, and most importantly, infallibility. The impossibility of checking the total spectrum of all actions they perform speaks only of the fact that their "brains", formed technologically, impose on the world those pictures and dreams that contribute to their victory over other players on planet Earth. And this depressing knowledge gives rise to even greater sorrow, because no one has yet realized the scale of the activity even within the ongoing American-Chinese decoupling, all studies are technocratic and fragmentary in nature, which is more about the world of technology than about the world of elusive meanings, universal tools and possibilities of hidden control, which was previously discussed at the level of Chinese stratagems, and was described in the works of Alvin Toffler (actions aimed at the cumulative result of selective influence on the perception of a selected focus group under the onslaught of mass media information tools and under the influence of shocks of growing environmental challenges (environmental approach within the framework of the "green agenda") and Johann Gottlieb Fichte, the continuer of the ideas of Immanuel Kant, as a visionary of the emerging systems of "global governance of humanity" from a single, in the case of its overdevelopment, center for setting tasks and monitoring the decisions executed after that or unity in the face of a common misfortune (covid waves, man-made disasters, famine, neocon-prepared migration of peoples and the victory of machines over the very nature of the human personality, losing self-identity and a set of rights and obligations guaranteed by national independence, dissolving in the system of Thomas Hobbes "war of all against all and each") from the position of finding spiritual imperatives and harmony with the "starry sky above" for each of their contemporaries. [5] Therefore, BRICS and Russia, as a hospitable host, must be able to implement mechanisms to counter the conscious technologies of the decomposition of real business efforts to turn the countries of the integration

platform into an ordinary set of states and create both an army to protect the interests of BRICS, and currency and credit instruments for development to consolidate their interests and keep the world on the brink of a catastrophe of nuclear madness and the death of humanity as a whole.

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# INNOVATIONS IN BRICS AND SANCTION RESTRICTIONS: STR OR NEOCOLONIAL DEPRESSION OF WORLD TRADE?

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***Abstract.*** *The authors describe current trends in world trade from the standpoint of WTO expansion and the introduction of sanctions against Russia in connection with the beginning of the SMO. They provide specific examples of the construction of national currency systems alternative to dollar settlements, which are increasingly used in BRICS and in energy settlements.*

***Keywords:*** *NWO, BRICS, WTO, free trading, innovation, sanctions, Russia, USA, China, India, global South, alter-globalization, fragmentation, glocalization.*

Scientific and technological revolution and innovation require constant improvement of national economies. The emerging new world order of mutual settlements, which intensified in its emergence after the Ukrainian events of February 2022, has become the center for concretizing global geoeconomic trends in the world of changing geopolitics of a multipolar and polycentric future [1].

The Kazan BRICS summit in October 2024 shows the world the futility of the sanctions policy of the collective West against Russia and the countries of the global South, which expect more just solutions and additional opportunities to strengthen national sovereignty and protect their sovereign interests in the era of growing neocolonialism from integration with leading non-Anglo-Saxon economies. At the same time, the special operation carried out by Russia in Ukraine to denazify and demilitarize the Nazi regime has encountered an unprecedented barrage of all existing restrictions from Western countries: from sectoral, corporate and personal sanctions to the introduction of retorts and reprisals against the

leaders of a number of Russian executive, legislative and business structures. This sanctions hysteria and the Warsaw, and now Washington, summit NATO association on the principles of total Russophobia have made Russia's vital interests dependent on an adequate and timely reaction to create and introduce a system of measures to counter the bacchanalia against the "civilized West", [2] ready to punish the Russian state for its unwillingness to focus more on its semi-colonial existence. These conclusions were clearly and uncompromisingly formulated in the introductions of various representatives of the authorities and business of Russia, summarized by the President of Russia V.V. Putin, as the beginning of trade in Russian gas for Russian rubles with all unfriendly states and the implementation of a further policy of national revival in the financial sector through the sovereignty of mechanisms for mutual settlements with the SCO and EAEU countries. [3]

In particular, the relevant proposals have already begun to form during the negotiations of our strategic partners, the Chinese comrades, with representatives of the leading Saudi Arabian company Saudi Aramco in planning to abandon settlements for oil in US dollars, which has been the basic and unchanged since 1974, and are preparing to switch to the yuan. These agreements have been in preparation for about 6 years and will help strengthen the yuan itself, without devaluing the Saudi riyal too much. [4]

This step has also pushed the SCO and EAEU countries towards a more global ideology of creating a single international currency and developing proposals and mechanisms for updating and personalizing interstate settlements within the framework of the declared international monetary and financial system. The cost of the new international means of payment being developed will be based on the correlation of the index of national currencies of the participating countries and the prices of exchange commodities. This decision should be adjusted and presented by the beginning of April 2022 to all member countries of the EAEU and China, as a basic document for further financial integration and reform of the SCO itself, which for more than 20 years has been dealing with issues of Chinese business development in the post-Soviet space and the harmonization of various kinds of standards and regulations in countries that have approved and entered politically and technologically into the implementation of the Chinese global initiative "One Belt, One Road". [5]

The decision on a single international currency in the Central Asian region and in the Eurasian space will support all countries interested in more nationally oriented breakthroughs, will strengthen the Chinese economy itself, which "was the first in the world to achieve national recovery from post-COVID shocks and pandemic lockdown," as noted by the Minister for Integration and Macroeconomics of the EEC Glazyev S.Yu. [6]

Moreover, as our strategic partner in BRISK and the SCO, India also plans to simplify and diversify currency risks in international trade with Russia. In this

regard, Chinese-Indian cooperation will extend not only to the ruble-rupee coverage of the existing trade turnover, but will also be built with a peg to the yuan as the base currency. And such steps will immediately diversify possible problems with dollarization and with settlements in euros, directing financial flows in rupees to national Indian producers. At the same time, mutual opening of accounts to support export-import operations will be carried out in Russian and Indian banks responsible for the financial implementation of transactions on the part of both countries. This trend is already unfolding, primarily due to the growing discount on the planned purchase of Russian oil by Indian companies at reduced prices. The same calculations were previously practiced when Russia purchased Indian tea, and today medical and pharmaceutical products, agricultural products may be added to these supplies, and India itself plans to further increase its defense potential and purchase goods from the military-industrial complex and space industry of Russia for more active participation in the industrialization processes of the 6th and 7th scientific and technological structures. Another driver of this ruble-rupee currency transition are sanctions on Russian purchases, when more than half a billion US dollars cannot be transferred from Russia to India. The State Bank of India (SBI), the largest bank in India, is not ready to take risks and expose itself in transactions with Russia due to its global presence and in anticipation of punitive measures for non-compliance with sanctions against Russian companies that were previously serviced in it in the pre-sanction period. At the same time, the sanctions themselves, despite the unprecedented pressure from Great Britain and the United States, on the Indian economy have not been imposed on Russian companies and banks. [7]

The construction of this international configuration and the increasing involvement of China and India in the development of mechanisms for financial interaction with Russia and the EAEU countries, starting from the creation of a credit rating agency independent of the "golden billion" countries based on the Chinese Dagond Global Credit Rating, assessing the possibilities of various global projects between states in addition to the big three (Fitch, Moody's and Standard and Poor's) to the adoption of the yuan as a reserve and base currency in settlements of all BRICS and SCO countries.

Therefore, mass exits from dollar agreements have already forced IMF officials to predict the coming and widespread refusal to use it and will certainly lead to a slide in the positions of countries to rethink the place of this reserve currency in the gold and foreign exchange reserves of the world's central banks, - said Gita Gopinath, Deputy Managing Director of the IMF, on March 22, 2022. [8] South Africa is also planning to facilitate Russia's return to the African continent in anticipation of the consequences of the post-Ukrainian crisis, which threatens real famine for 1.4 billion people on the African continent. One of these non-linear

responses is being developed within the framework of Russian-African cooperation cooperation of the Afrocom Foundation, which participates in the work of the Coordinating Committee for Economic Cooperation with African Countries. The task of future trade deals is not only to increase barter and foreign trade operations, but also to apply structural mechanisms of banking and investment cooperation, capable of building new food and cooperative extractive international chains, aimed at Russia's strategic return to the African market. And the issues of food, its delivery for humanitarian purposes and from the standpoint of integration interaction from BRICS to the level of Russian personalized involvement with business structures of South Africa and all countries pro-Russian oriented towards our cooperation, should receive a new meaning in the near future in the form of doctrinal and conceptual strategies, become economically filled in content and implementation within the emerging banking structures of the international and military-political alignment.[9]

At the same time, the growing pressure from unfriendly countries is forcing Russia to articulate a new agenda for partial temporary blocking or possible nationalization of assets of unfriendly companies that support negative pressure or seek to chaotically and unreasonably exit existing assets of our hydrocarbon and innovation sectors. These actions were initially extremely beneficial to them, as a way to maximize profits and involvement in the process of setting up and strengthening the assets of Russia's national production base. Their activity during the implementation of programs to reduce state participation in the Russian economy for its further effective development and global digital transformation was also beneficial to all parties in terms of intensification and growth of productivity of Russian industries, annually privatized by global TNCs at a level of 10% compared to the previous year, for 6 years, according to the program that was previously adopted under the name "Main directions of activity of the Russian government for 2019-2024". In the absence of the "black swans" of COVID and the Ukrainian crisis, Rosimushchestvo should have prepared approximately 1,500 companies with various market organizational and legal forms of ownership (PJSC, OJSC, LLC) for the implementation of this program and should have achieved the effect of reducing assets with state participation by 47%, to 797 companies, by the end of 2024. [10] Therefore, the political aspect of admitting companies from leading sectors to the Russian market for state privatization, with the exception of the force majeure that has occurred and the complete nationalization of assets in all industries, will be able to monitor and audit all potential friends and strategic partners from the BRICS, SCO and EAEU countries, creating a truly nationally oriented system of not only payments, investments and mutual settlements themselves, but, truly, on a market basis, capable of identifying those startups and greenfields of our real allies that would contribute to bringing Russia to the leading position of the superpower of Industry 4.0. [11]

The probability of such a forecast is not yet high, since the ongoing wave of sanctions and incomplete provision of financial tasks for trade and commercial operations of the state and corporate sectors require a new paradigm for all Russian business, however, the coming patriotic consolidation based on the integration diversification of future shocks and risks will allow Russia to correctly place emphasis on its national interests and build a polycentric world where all today's partners will receive both reciprocal support and a new geopolitical breath - from geo-economic integration zones to military blocs of national self-sufficiency and industrial prosperity. [12]

Innovations, as the engine of modern development and reflection of the leading trends of the scientific and technological revolution, allow accelerating the processes of creating higher quality and cheaper products, which in the period of post-covid recession become drivers of growth in the processes of alter-globalization: fragmentation and glocalization of chains of national economies in their regional and bloc development. [13] The unwillingness of the collective West to move to secondary positions in the global economy and the degradation of supply chains in the countries of the "golden billion" is fraught not only with the loss of income of the "gentlemen of the pirate past", but also threatens the beginning of global cataclysms with the aim of preventing the latter from changing the existing geopolitical status quo: by inciting the Palestinian issue, the 3rd Lebanon War and conflicts around Taiwan and on the Korean Peninsula.

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# OBJECTIVES, PROBLEMS AND PROSPECTS FOR THE DEVELOPMENT OF INNOVATIVE EDUCATIONAL TECHNOLOGIES IN THE PROCESS OF INTERCULTURAL PROFESSIONAL COMMUNICATIONS IN THE COGNITIVE-COMMUNICATIVE SPACE

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***Abstract.*** *In the context of global digitalization and the growing dynamics of international cooperation, the problems of the development of innovative educational technologies in the process of intercultural professional communications in order to optimize the management of cross-cultural processes, the formation of special competencies for global cooperation and the improvement of the system of personnel training for global interaction in the modern information society are of significant importance.*

***Keywords:*** *intercultural professional communications, cognitive linguistics, digital linguistics, intercultural communication skills, intelligent technologies, digital educational technologies, generative AI, digital linguodidactics.*

In the modern education system, the fundamental and promising approach is the competence-based project-oriented approach to training specialists, the most important integral function of which is the formation of professional competencies, as well as the competence of intercultural communications, which creates conditions for the development of international business intercultural relations.

With the modern development of digital tools and services, it is important to note the trend towards digital transformation of all spheres of human life.

The phenomenon of transforming the education system for the transformation of society has emerged. At the same time, digitalization of any processes of human activity, “big data” technologies, artificial intelligence, network architectures create real opportunities, firstly, for the implementation of effective educational technologies and systems of continuous training of personnel, and secondly, for the training of a new generation of specialists with a high level of communicative

competencies in the process of professional intercultural communications, as well as cultural characteristics of business communication partners.

Knowledge of the history and culture of a foreign country gives additional confidence in the process of intercultural communication. Therefore, it is important to note that comprehensive training for business intercultural communications is a necessary tool for developing a business communication strategy, human and professional understanding in the communication process.

This fact confirms that in the modern education system, the formation of intercultural communicative competence in the new generation of specialists is very relevant.

Possession of intercultural communicative competence in the process of professional communications, including professional linguistic and discursive competence, creates confidence in the effectiveness of professional interaction and the achievement of the goals of professional activity.

Of particular interest are innovations related to changes in the goals, content and methods of educational technologies aimed at solving the problem of intercultural competence of students. The successful formation and development of this educational strategy is facilitated, first of all, by information technologies and active teaching methods [2,3].

To more effectively achieve the goals of developing intercultural communicative competence, we can identify the most promising comprehensive solutions for creating innovative digital educational technologies and creating educational products based on them, including:

- development and promotion of an innovative system of distance learning of additional professional education and infrastructure cloud solutions for digital education using innovative digital technologies such as: virtual (VR) and augmented reality (AR), artificial intelligence, machine learning, gamification and visualization, interactive simulators - trainers;
- implementation of innovative educational technologies and modern robotic network platforms aimed at various target audiences and which provide comprehensive education according to individual curricula and personalized educational trajectories at the location of the students;
- production of educational products - methodological and technological support, creation of educational content using educational interactive technologies (digital simulators, training devices, “situational cases”, role-playing game models, etc.) based on a competency-based approach;
- creation of subject-oriented libraries of electronic educational resources, providing remote access to them for all participants in the educational process.

A promising vector for the development of educational technologies for the formation of intercultural communicative competence is the use of interactive

intelligent cases that provide opportunities for meaningful dialogue in a given subject area. At the same time, it is possible to conduct group trainings with the participation of intelligent digital assistants.

Educational technologies based on role-playing and business games allow simulating a real problem situation that involves appropriate professional communications, as well as methods of situational analysis.

The study of practices and methods based on the principles of cognitive psychology and cognitive linguistics allows us to make the following statements:

1. By immersing themselves in the study of a particular culture, in the process of real intercultural communication, the student begins to automatically compare what they read or heard with the realities of their native language community, resulting in the development of mutual understanding of cultures, rapprochement and the formation of intercultural communicative competence.
2. The introduction of innovative digital interactive educational technologies and active teaching methods (virtual (VR) and augmented reality (AR), artificial intelligence, machine learning, digital simulators, training devices, "situational cases", role-playing game models, etc.), which create qualitatively new opportunities for modeling the socio-cultural space and intercultural interaction, are the basis for the formation of intercultural communicative competence of students.
3. The level of intercultural communicative competence determines the level of knowledge in a given subject area, a person's preparedness to manage communications, empathy and tolerance, the ability to maintain a healthy and friendly level of relationships, and the ability to choose a situationally correct model of behavior.

**Basic mechanisms and characteristics digital linguistics in the context of the presentation socio-cultural communicative code.**

In modern linguistics, much attention is paid to the cognitive aspects of communicative interactions. In this aspect, the most pressing issues are the interrelationships between language, thinking and cognitive processes, methods of knowledge representation used by communication participants, mechanisms of organization and conceptualization of information in the processes of understanding and constructing speech statements, mental representations and models that act as a necessary component of our consciousness and the entire cognitive structure reflecting the social and cultural experience of a person.

Cognitive linguistics deals with issues of knowledge representation and its structuring in language in the communication process [4,5,6].

Cognitive linguistics aims to model the picture of the world, to model the structure of linguistic consciousness.

The main object of cognitive linguistics is the concept. Concepts are mental entities that have a name in language and reflect a person's cultural and national understanding of the world. A concept can be imagined as a concentrated model of the cultural environment in a person's consciousness.

Cognitive linguistics adopts the concept of conceptual and cognitive models from cognitive psychology. Indeed, language is an external manifestation of human intelligence and is based on psychological mechanisms.

Innovative development mechanisms Digital technologies have become a major force in professional communications, the emergence of which was made possible by digital linguistics, a field of artificial intelligence that deals with the description of natural languages using mathematical models. Digital linguistics solves problems related to Natural Language Processing (NLP).

Digital linguistics of intercultural professional communications faces the challenges of linguistic support for the processes of collecting, accumulating, processing and searching for information. The most important of them are:

- Speech recognition and synthesis.
- Text generation.
- Automatic translation of texts.
- Creation and use of electronic text corpora.
- Extracting information from text.
- Self-referencing.
- Automatically detect and correct errors as you type on your computer.
- Creation of question-answer systems.
- Creation of electronic dictionaries, thesauri, ontologies.

Digital linguistics is a powerful tool for extracting knowledge (relevant information) from huge volumes of texts.

Before automation Natural language processing (NLP) has two major tasks - Natural Language Generation (NLG) and Natural Language Understanding (NLU). Understanding natural language allows you to receive commands and requests from a person in a form convenient for him, as well as sort information, highlight the main thing, analyze the content of the text and its emotional coloring.

Thus, the methodological foundations for the formation of professionally oriented communicative competence using the tools of digital linguistics are gradually being built.

Due to the promising possibilities of digital linguistics as a method of artificial intelligence (AI), the methodology of generative AI is becoming an effective mechanism for the development of a new generation of educational technologies for intercultural professional communications [8-13]. This is a machine learning method where neural networks study content or objects, collect data and use them to create new artifacts, generate new knowledge. Generative AI allows creating

new forms of content in different modalities: for example, generating a video based on an object description, forming subject concepts [7].

The generative AI method enhances the didactic potential of digital technologies, accelerates cycles of learning, research, immersion in the specifics of a particular business and development of joint projects in a variety of fields, from medicine to industry and marketing, which is very important in the processes of intercultural professional communications in a multicultural society.

**Benefits of using AI in online education:**

**Personalization of the educational process.**

Generative AI mechanisms create personalized educational programs and materials based on intelligent analysis of the learner's characteristics, their learning pace, and their preferences. Thus, a personalized learning model is created, optimized for a specific learner. At the same time, it is possible to build a comprehensive personalized online educational system focused on the full educational cycle of a given stage of learning.

**Adaptive methodology for personalized customization of online tools.**

Thanks to generative AI algorithms, students have the opportunity to work with educational material on any digital platform with a personalized interface, educational scenario, and adapted educational programs.

**Intelligent digital environment for managing educational content.** Generative AI, using algorithms for intelligent analysis of the current level and preferences of the student, enables adaptive management of the formation of content corresponding to the current educational scenario.

**Improving cognitive functions.**

Generative AI tools can be configured to perform cognitive training tasks within a personalized educational scenario, which improves memory and attention indicators, leading to an increase in the quality of current cognitive activity. Thus, an adaptive digital environment for improving cognitive functions and, accordingly, improving the quality of the process is createdonline education.

**Generative AI in the Development of Online Education**

Generative AI will improve the learning process itself in online education through the use of various personalization tools, such as gamification of the process, microlearning and adaptive learning, which will make online learning even more attractive and effective compared to conservative education.

Generative AI is being actively integrated into modern online learning platforms, which creates competitive advantages.

For example, Duolingo, a popular language learning platform, uses Generative AI to personalize its learning materials and assessments. Similarly, Coursera uses Generative AI to create personalized course recommendations based on students' interests and goals.

Generative AI has great potential to transform online learning into next-generation platforms that enable the creation of virtual teachers and tutors that are tailored to personalized learning scenarios, as well as intelligent educational content management services.

Generative Pre-trained Transformers, commonly known as GPT (Generative Pre-trained Transformers), are used to learn neural networks, such as neural networks, neural networks, and neural networks. -Trained Transformers (GPTs) are a family of neural network models that use the Transformer architecture and are a key advancement in artificial intelligence that powers generative AI applications like ChatGPT. GPT models enable applications to generate human-like text and content (images, music, and more) and answer questions in a conversational manner. Organizations across industries use GPT models and generative AI for Q&A bots, text summarization, content generation, and search.

GPT models are transformer neural networks. The transformer neural network architecture uses self-supervision mechanisms to focus on different parts of the input text during each processing step. The transformer model captures more context and improves performance on natural language processing (NLP) tasks.

Generative text models such as ChatGPT and GPT-4 have revolutionized the field of artificial intelligence [14]. GPT models have significantly lowered the barrier to entry into the field of AI, making it accessible even to those who are far removed from computer technology. Anyone can simply start asking the model about everything under the sun and get accurate answers.

When a model fails to produce the correct answer, it doesn't mean it can't do it. Often, all you need to do is change the task, or "prompt," to guide the model toward the correct answer. This is often called "prompt engineering."

Many industrial engineering techniques are based on attempts to imitate how human thinking works. Great examples of simulating human thinking are asking models to "think aloud" or telling them " think step by step."

Such analogies between GPT models and human psychology are important because they help us understand how we can improve the performance of such models. The analogies point us to capabilities that the models may lack.

Intelligent assistants created with Chat GPT can be so effective that they can handle tasks that could previously only be performed by experienced teachers. They can be customized to work with students of all levels and are capable of providing personalized assistance based on the individual needs of each student [15].

One of the major problems that students face in online courses and distance learning is the lack of feedback from teachers. Intelligent assistants created with Chat GPT can solve this problem by providing students with the help and feedback they need. One of the potential applications of Chat GPT is the creation of educational materials. With the use of this amazing technology, teachers can create

articles, lectures, and presentations with incredible speed and quality. With Chat GPT, teachers can create tests and assignments based on specific topics and also offer students personalized test options based on their level of knowledge. This can help students learn more effectively and quickly.

Chat GPT can be used to create different types of tests, including multiple choice tests, open-ended tests, and more. The technology allows you to create tests that are based on specific topics and intended for a specific audience.

In addition, Chat GPT can create high-quality tests and assignments. The technology can provide students with tests and assignments that are based on relevant and interesting topics, which can make the learning process more fun and interesting.

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Chat GPT can be used to create interactive learning materials such as textbooks that can include animations, videos, and other interactive elements. This can make learning more interesting and engaging for students.

Chat GPT is a powerful technology that can help improve learning and education processes. Its use can reduce the time spent on preparing learning materials and delivering lessons, as well as improve the quality of feedback for students. Using Chat GPT in online courses and distance learning can increase the accessibility of learning and make learning materials more interactive. Overall, Chat GPT has great potential to improve education and learning in general, and its use will only increase in the future.

**GPT Innovations: Creating the Classroom of Tomorrow**

With GPT, we can create personalized learning programs that match each student's learning style, allowing them to reach their full potential. With GPT, we can create personalized learning programs that match each student's learning style, allowing them to reach their full potential.

GPT can create interactive games and simulations to help them better understand the subject matter. Visuals can be customized to accommodate students with color blindness, dyslexia, or other visual impairments.

With GPT, students can participate in online classes and connect with their peers and teachers.

The most important innovation that GPT brings to the classroom is augmented reality (AR) and virtual reality (VR). With AR and VR, students can explore places they never thought possible, making learning not only informative but also fun and interactive.

Digital linguodidactics is a new method of working with information of various natures and new forms of communication in the context of globally changing technologies of the information society, allowing to prepare specialists with excellent knowledge of economics, business and finance and who are able to competently formulate key values and business strategies [13].

A pilot project for the implementation of innovative The mechanism for the development of a new generation of educational technologies for intercultural professional communications is the International Educational Program MBA - Young Generation Program" School for training the country's personnel reserve from the school bench of the new generation" educational Consortium AURORA. The international educational program is aimed at high school students from Russia and friendly countries (China – India – Turkey – Iran, etc.)

The main goal of the international educational program straining of the country's personnel reserve of a new generation from the school bench and development of the innovative creative potential of the state based on the development of personal and professional communications with like-minded people from friendly countries.

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# THE RESOURCE POTENTIAL OF THE HUNTING ECONOMY OF THE TRANS-BAIKAL TERRITORY OF THE RUSSIAN FEDERATION

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***Annotation.*** *The natural and climatic conditions of the Trans-Baikal Territory are unique and determine the richness of the flora and fauna of the region. More than 75% of the total area of the region is forest lands, which are the main habitats of game animals. The fauna of the forests is richly represented both in the number of species and in the number of population groups of animals. The article provides a description of the forest fund and hunting grounds of the Trans-Baikal Territory. Hunting in the Trans-Baikal Territory is considered a traditional occupation, it is the most ancient branch of industrial activity of the population of the region and the basis of the way of life of indigenous ethnic groups, especially in the northern regions, since it serves as the main source of income, providing employment for the population.*

***Keywords:*** *Transbaikal region, forest fund, hunting grounds.*

The priority areas of the state policy of the Russian Federation in the field of hunting and conservation of hunting resources are reflected in the Strategy for the Development of Hunting in the Russian Federation until 2030 [3]. The number of hunters in the Russian Federation has increased by almost 2 million people since

2012 and amounted to 4,702,858 in 2020. At the same time, the area of land covered by forest vegetation from 2012 to 2022 decreased by 463.6 thousand hectares [5].

In the Federal Law "On Hunting..." hunting industry is defined as a sphere of activity for the conservation and use of hunting resources and their habitat, the creation of hunting infrastructure, the provision of services in this area, as well as the purchase, production and sale of hunting products [1].

Zabaikalsky Krai is a constituent entity of the Russian Federation, located in the eastern part of Zabaikalsky Krai, and is part of the Far Eastern Federal District. The administrative center is the city of Chita. Zabaikalsky Krai borders on the Sakha Republic (Yakutia) and Irkutsk Oblast to the north; on the Amur Oblast to the east; on the south, there is a state border with China and Mongolia; and on the west, with the Republic of Buryatia. The total area of the territory of the region is 431,892 km², which is 2.52% of the area of Russia. According to this indicator, the region ranks 12th in the country. The population of the region, according to estimates for 2024, was 984,395 people.

The Zabaikalsky Krai has great resource potential for the development of hunting. The natural, climatic and physical-geographical features of the region determine the diversity of the hunting fauna. The large extent of the region from north to south (about 1000 km) determined the presence of taiga, forest-steppe and steppe latitudinal natural zones.

The hunting grounds fund may include lands of various categories included in the Land Fund of the Russian Federation [6].

Forest lands in the Trans-Baikal Territory occupy more than 75% of the total area of the region [7]. The composition of forest fund lands is presented in Table 1.

***Table 1***

*Composition of forest fund lands of the Trans-Baikal Territory*

| No. | Name of the land | Occupied area, thousand hectares |
|---|---|---|
| 1 | Forest fund lands | 32617 |
| 2 | Lands of Defense and Security | 1118,5 |
| 3 | Lands of populated areas where forests are located | 8.5 |
| 4 | Lands of specially protected natural areas | 324 |
| 5 | Lands of other categories | - |
| | **Total** | **34068,0** |

Currently, the Ministry of Natural Resources of the Zabaikalsky Krai has developed a plan for forest restoration on an area of more than 400 thousand hectares by 2027. In terms of the volume of forest restoration work, the Zabaikalsky Krai is one of the three subjects in the Far Eastern Federal District with the largest area

of forest restoration work [5]. According to the Ministry of Natural Resources, as of 11.10.2024, artificial forest restoration in the forest fund has been completed on an area of more than 3.3 thousand hectares, which is 114 percent of the plan for 2024 [7].

Game animals are an important part of the natural capital of the Russian Federation and ensure the formation of ecosystem services of a consumer and environment-forming nature [3]. More than 80 species of mammals live in the Zabaikalsky Krai, about 30 of which are considered game animals. The most popular objects of game hunting are ungulates, among which the Siberian roe deer (Capreolus pygargus) is especially popular. In addition to roe deer, the following ungulates are hunted: red deer (Cervus elaphus xanthopygus), elk (Alces alces), less often - wild boar (Sus scrofa) and musk deer (Moschus moschiferus). Among fur animals, sable (Martes zibellina) is in particular demand.

According to the Federal Law of 24.07.2009 No. 209-FZ "On Hunting and the Conservation of Hunting Resources and on Amendments to Certain Legislative Acts of the Russian Federation" [1], hunting grounds are divided into two types - assigned hunting grounds, which are used by legal entities and individual entrepreneurs on the grounds provided by law; and publicly accessible hunting grounds, in which individuals have the right to freely reside for hunting purposes.

As of 01.01.24, the total area of hunting grounds in the Zabaikalsky Krai is 38,393.14 thousand hectares, of which 22,350.12 (58%) are publicly accessible lands (Table 2). The hunting industry of the Krai is represented by 123 hunting grounds assigned to various organizations. The largest hunting user in the Krai is the Zabaikalsky Krai Public Organization of Hunters and Fishermen (ZabKPOHF). The organization carries out hunting activities, including issuing permits for the extraction of wildlife, on the territory of 20 districts of the Krai (there are 31 districts in the Krai in total).

***Table 2***

*Area of hunting grounds in the Transbaikal Territory*

| Item No. | Form of ownership | Area, thousand hectares |
|---|---|---|
| 1 | Public hunting grounds | 22350,12 |
| 2 | Hunting grounds assigned to ZabKPOHF | 5141.7 |
| 3 | Hunting grounds registered to limited liability companies (LLC), joint stock companies (JSC) | 6347,42 |
| 4 | Hunting grounds assigned to individual entrepreneurs | 1594.03 |
| 5 | Cooperatives | 768.95 |
| 6 | Municipal unitary enterprises (MUP) | 396.81 |
| 7 | Hunting grounds assigned to military hunting societies (MHS) | 221.53 |

| | | |
|---|---|---|
| 8 | Reserves | 1121.8 |
| 9 | Scientific stationary facilities | 72.88 |
| | **TOTAL:** | **38393,14** |

The largest part of the hunting grounds is concentrated in the north of the region. In these areas, forests occupy up to 90% of the entire territory. The hunting grounds located in the north (Kalarsky municipal district, Tungiro-Olekminsky and Tungokochensky municipal districts) are the most productive. Large areas of slightly disturbed ecosystems are preserved here, which is due to the significant remoteness of the districts from the regional capital, weak industrial development, low population density (from 0.03 to 0.19 people / km2). The lack of developed infrastructure and linear objects excludes significant fragmentation of the territory, which contributes to an increase in the number of the main species of game animals. These areas are classified as territories with preserved elements of traditional nature management [4].

Currently, due to a number of reasons, commercial hunting is becoming an unprofitable occupation. Poaching has a negative impact on the development of hunting in the region. Thus, during the 2022-2023 hunting season, 18 cases of poaching were registered in the Zabaikalsky Krai, the damage amounted to about 4.4 million rubles.

As noted above, hunting resources constitute a significant part of the natural capital of the Russian Federation as a whole and the Zabaikalsky Krai in particular. The tasks of preserving and maintaining biodiversity and the tasks of hunting management (increasing the most important hunting objects) are very close and require an integrated management approach. Hunting management should be sustainable, which, according to the Strategy for the Conservation of Rare and Endangered Species of Animals and Plants [2] in the context of preserving biodiversity, can be formulated as ensuring the maximum income of the present and future generations while maintaining the optimal population structure of the exploited animal species and their habitat. The Zabaikalsky Krai has all the necessary conditions for the development of a modern hunting industry.

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# PRIMARY MORBIDITY OF THE ADULT POPULATION FROM DISEASES OF THE CIRCULATORY SYSTEM: MODERN ASPECTS

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***Abstract.*** *The article discusses modern aspects of primary morbidity of the adult population from diseases of the circulatory system using the example of the city of regional subordination of the Samara Region - Novokuibyshevsk. The dynamics of the level of primary morbidity for 2019-2023, its structure, as well as features among the adult population of working age and older than working age are determined.*

***Keywords:*** *primary morbidity, adult population, diseases of the circulatory system.*

Primary morbidity of the population gives an idea of the registration of new cases of diseases. It should be noted that the primary morbidity of the adult population (18 years and older) of Novokuibyshevsk for 2019-2023 increased from 634.9 to 785.8 per 1000 residents, or by 23.8%. The average annual value of the primary incidence rate of adults in the city was 713.9 and exceeds the similar indicator for the Samara region as a whole (676.6 per 1000 adults) by 5.5%. The excess of the primary incidence rate in the city over the average regional level is explained by the lower availability of medical care and lower appeals of the population in the region as a whole, the territory of which includes rural areas. The increase in primary incidence is also characteristic of the adult population of the Samara

region, but to a lesser extent (613.1 per 1000 adults in 2019 and 694.4 in 2023, an increase of 13.3%). In recent years, in the city of Novokuibyshevsk, an average of about 3 thousand new cases of diseases of the class of diseases of the circulatory system (DCS) with codes according to the ICD 10th revision - I00-I99 have been registered. In 2019, the share of DCS was 5.3% of the total number of diseases diagnosed for the first time in life, and in 2023 - 5.7%, accounting for approximately every seventeenth case of all pathology registered for the first time in life among the adult population. Considering the dynamics of the primary incidence of DCS in the adult population in 2019-2023, it should be noted that it increased from 32.7 cases to 41.3 per 1000 adult population, that is, by 26.3%. This growth outpaces the growth of the primary incidence of the adult population of the city as a whole for all classes (23.8%). In 2020 and 2021, negative growth rates of the primary incidence of DCS were noted in general (- 19.0% and - 28.1%, respectively, relative to the 2019 level), which is explained by the spread of COVID-19. Furthermore, in 2022, the primary incidence rate of DCS increased and almost equaled the 2019 level (32.6 cases per 1000 adults), and in 2023 it exceeded it by 26.3%.

In the class of diseases of the circulatory system, we identified five main groups of diseases, which account for more than 90% of all cardiovascular pathology.

In 2019-2023, the primary incidence rate of diseases characterized by high blood pressure increased to the maximum, from 7.1 to 14.2 per 1000 persons aged 18 and older, by 100.0%, or exactly twice as much. This growth significantly exceeds both the growth in the primary incidence of DCS (by 26.3%) and the growth in the primary incidence of adult population for all classes of pathology (by 23.8%) (Table 1)

***Table 1.***

*Primary incidence of adult population with diseases of the circulatory system in 2019-2023 (per 1000 persons aged 18 years and older)*

| Name of diseases | 2019 | 2020 | 2021 | 2022 | 2023 | 2023 / 2019, % |
|---|---|---|---|---|---|---|
| Diseases of the circulatory system in total | 32,7 | 26,5 | 23,5 | 32,6 | 41,3 | 126,3 |
| Including: | | | | | | |
| diseases characterized by high blood pressure | 7,1 | 6,6 | 3,7 | 7,6 | 14,2 | 200,0 |
| ischemic heart disease | 7,0 | 5,5 | 6,2 | 6,7 | 8,2 | 117,1 |
| cerebrovascular disease | 11,5 | 9,4 | 9,3 | 14,5 | 14,1 | 122,6 |
| endarteritis, thromboangiitis obliterans | 0,8 | 0,4 | 0,2 | 0,3 | 0,3 | 37,5 |
| diseases of veins, lymphatic vessels and lymph nodes | 3,6 | 2,4 | 1,8 | 1,8 | 1,9 | 52,8 |
| other diseases | 2,7 | 2,2 | 2,3 | 1,7 | 2,6 | 96,3 |

The primary incidence of cerebrovascular diseases in the adult population also increased, from 11.5 per 1000 adults in 2019 to 14.1 per 1000 in 2023, or by 22.6%. The value of the primary incidence of ischemic heart diseases from 2019 to 2023 increased to a lesser extent, by 17.1%, from 7.0 to 8.2 cases per 1000 adults.

At the same time, there is a decrease in the primary incidence of vascular pathology: endarteritis, obliterating endarteritis from 0.8 to 0.3 per 1000 adults (by 62.5%) and diseases of the veins, lymphatic vessels and lymph nodes from 3.6 to 1.9 per 1000 adults (by 47.2%). A decrease in the primary incidence of other diseases was also noted (by 3.7%), from 2.7 to 4.6 per 1000 adults over the period under review, but their share in the pathology of DCS is not high and averages 6-8%.

In 2023, in the structure of primary morbidity of DCS in the adult population of Novokuibyshevsk, diseases characterized by high blood pressure were in first place, amounting to 34.4%. In this group of diseases, the main pathology is hypertension (86.2%).

In 2019, the first place in the structure of primary morbidity was occupied by cerebrovascular diseases (35.2%), while diseases characterized by high blood pressure, with a share of 21.7%, were in second place. Thus, there is an increase in the proportion of this pathology over five years by 12.7%.

In second place in the structure of primary morbidity of DCS in 2023 were cerebrovascular diseases, the share of which did not change significantly over the studied period of time (35.2% in 2019 and 34.1% in 2023), while in 2019 this group of diseases was in first place in the structure of primary morbidity.

Third place, both in 2019 and in 2023, is occupied by ischemic heart diseases, the proportion of which slightly decreased from 21.4% to 19.9%. Ischemic heart diseases are represented by two leading groups of diseases - chronic ischemic heart disease, the share of which in 2023 was 43.5%, and angina pectoris with a specific gravity of 32.0%. Vascular diseases occupy the fourth place in the structure of primary morbidity of DCS, and their share has significantly decreased from 13.5% in 2019 to 5.3% in 2023). This pathology is represented by diseases of the veins, lymphatic vessels and lymph nodes, the share of which in 2023 was 81.8% of all vascular diseases, and the second group - endarteritis and obliterating thromboangiitis with a share of 18.2%.

The share of other diseases of the circulatory system, which are in fifth place, is small with a downward trend (8.2% in 2019 and 6.3% in 2023).

Thus, in the dynamics of the structure of primary morbidity of DCS over five years, one can note a significant increase in the share of diseases characterized by high blood pressure due to a significant decrease in the share of vascular diseases, some decrease in the share of ischemic heart diseases and other diseases of the circulatory system.

**Peculiarities of primary morbidity of the adult population over working age from diseases of the circulatory system.** On average, almost 2/3 of cases of

first-time registered diseases of the circulatory system among the adult population of Novokuibyshevsk are among people over working age.

The level of primary morbidity of the population over working age from DCS in 2019 was 64.2 per 1000 residents and by 2023 increased to 80.6 per 1000, an increase of 25.5%. This increase is comparable with the rate of increase in primary morbidity among the entire adult population (26.3%). The rates of primary morbidity from DCS among people over working age were significantly higher than among the adult population as a whole (2.0 times in 2019 and 2.5 times in 2023) (Table 2).

***Table 2.***

*Level (per 1000 persons) and structure (in %) of primary incidence of diseases of the circulatory system in the adult population over working age in 2019 and 2023*

| Name of diseases | 2019 | | 2023 | | Level 2023 / 2019, % |
|---|---|---|---|---|---|
| | Level | B % | Level | B % | |
| Diseases of the circulatory system in total | 64,2 | 100,0 | 80,6 | 100,0 | 125,5 |
| Including: | | | | | |
| diseases characterized by high blood pressure | 9,9 | 15,4 | 19,0 | 23,6 | 191,9 |
| ischemic heart disease | 15,6 | 24,3 | 19,3 | 23,9 | 123,7 |
| cerebrovascular disease | 26,3 | 41,0 | 33,3 | 41,3 | 126,6 |
| endarteritis, thromboangiitis obliterans | 1,6 | 2,5 | 0,9 | 1,1 | 56,3 |
| diseases of veins, lymphatic vessels and lymph nodes | 5,5 | 8,6 | 2,4 | 3,0 | 43,6 |
| other diseases | 5,3 | 8,2 | 5,7 | 7,1 | 107,5 |

In the structure of primary morbidity of the population over the working age in 2023, cerebrovascular diseases were in the first place (41.3%), their share compared to 2019 remained virtually unchanged (41.0%), while the incidence rate increased from 26.3 to 33.3 per 1000 people over the working age, or by 26.6%. At the same time, the primary morbidity rates exceeded the corresponding values among the adult population as a whole in 2019 by 2.3 times, in 2023 - by 2.4 times. Ischemic heart diseases rank second in the structure of primary morbidity from DCS, accounting for 24.3% in 2019 and 23.9% in 2023 among people over the working age. At the same time, the incidence rate of this pathology increased by 23.7%, from 15.6 to 19.3 per 1000 people over the working age, exceeding similar indicators of general incidence among the adult population by 2.2 times in 2019 and 2.4 times in 2023.

In third place in 2023 were diseases characterized by high blood pressure (23.6%), while their share increased from 15.4% in 2019, and the incidence rate

increased from 9.9 to 19.0 per 1000 people, or by 91.9%. At the same time, the primary incidence rates exceeded the corresponding values among the adult population as a whole in 2019 by 1.4 times, in 2023 - by 1.3 times.

Primary incidence of vascular diseases (endarteritis, obliterating thromboangiitis, diseases of the veins, lymphatic vessels, etc.) among the population of retirement age has decreased both in structure (11.1% in 2019 and 4.1% in 2023) and in level (7.1 and 3.3 cases per 1000 persons of the corresponding age). At the same time, the values of the primary incidence rate among persons of retirement age exceeded those among the adult population as a whole in 2019 by 1.6 times, in 2023 - by 1.5 times. Thus, among the adult population of retirement age, the rates of primary incidence from DCS are on average more than twice as high as similar values among the adult population, both for the entire class and for individual diseases, and the rate of increase in incidence corresponds to the rate of increase among the adult population as a whole. The structure of primary morbidity from DCS among people of retirement age differs from the similar structure of morbidity among the adult population in favor of the predominance of cerebrovascular diseases, a higher proportion of ischemic heart diseases and a lower proportion of diseases characterized by high blood pressure.

**Features of primary morbidity of the adult population of working age from diseases of the circulatory system.** Among the adult population of Novokuibyshevsk, the ratio of people of retirement age to people of working age is on average one to two, while the ratio of cases of registered diseases of the circulatory system in these groups is, on the contrary, two to one, which ensures relatively low values of primary morbidity among the adult population of working age from DCS (Table 3).

The level of primary morbidity among the adult population of working age in 2019 was 14.9, and in 2023 - 22.2 per 1000 working-age persons, an increase of 49.0%. This increase significantly exceeds the growth rate of primary morbidity in the entire adult population (26.3%). It is characteristic that the rates of primary morbidity from DCS among people of working age were significantly lower than among the adult population as a whole (2.2 times in 2019 and 1.9 times in 2023).

Considering the structure of primary morbidity among the adult working-age population, it should be noted that in 2023, diseases characterized by high blood pressure (53.2%) are in first place, and their share has increased from 36.9% compared to 2019, and the incidence rate has sharply increased from 5.5 to 11.8 per 1000 people of the corresponding age, by 114.5%, or 2.1 times. At the same time, the primary morbidity rates in this group of pathologies among people of working age are lower than the corresponding values among the adult population as a whole (in 2019, by 1.3 times, in 2023 - by 1.2 times.

***Table 3.***

*Level (per 1000 people) and structure (in %) of primary morbidity of the adult working-age population with diseases of the circulatory system in 2019 and 2023*

| Name of diseases | 2019 | | 2023 | | Level 2023 / 2019, % |
|---|---|---|---|---|---|
| | Level | B % | Level | B % | |
| Diseases of the circulatory system in total | 14,9 | 100,0 | 22,2 | 100,0 | 149,0 |
| Including: | | | | | |
| diseases characterized by high blood pressure | 5,5 | 36,9 | 11,8 | 53,2 | 214,5 |
| ischemic heart disease | 2,2 | 14,8 | 2,8 | 12,6 | 127,3 |
| cerebrovascular disease | 3,2 | 21,5 | 4,8 | 21,6 | 150,0 |
| endarteritis, thromboangiitis obliterans | 0,3 | 2,0 | 0,1 | 0,5 | 33,3 |
| diseases of veins, lymphatic vessels and lymph nodes | 2,6 | 17,4 | 1,7 | 7,7 | 65,4 |
| other diseases | 1,1 | 7,4 | 1,0 | 4,4 | 90,9 |

The second place in the structure of primary morbidity among persons of working age is occupied by cerebrovascular diseases, the proportion of which remains virtually unchanged (21.5% in 2019 and 21.6% in 2023), while the incidence rates are growing, respectively, from 3.2 to 4.8 per 1000 persons of the corresponding age, an increase of 50.0%. The primary incidence of cerebrovascular diseases among adults of working age is significantly lower than similar values of the indicator among the adult population as a whole (in 2019, by 3.6 times, in 2023 - by 2.9 times). The third place in the structure is occupied by ischemic heart diseases, accounting for 14.8% in 2019 and 12.6% in 2023 among adults of working age. At the same time, the values of the primary incidence rate of this pathology increased by more than a quarter (by 27.3%), from 2.2 to 2.8 cases per 1000 of the corresponding population, but they are much lower than similar indicators of primary incidence among the adult population by 3.2 times in 2019 and 2.9 times in 2023.

The primary incidence of vascular diseases (endarteritis, obliterating thromboangiitis, diseases of the veins, lymphatic vessels, etc.) of the adult population of working age has significantly decreased, both in structure (19.4% in 2019 and 8.2% in 2023) and in level (2.9 and 1.8 cases per 1000 people of working age). At the same time, the values of the primary incidence rates of this population group were lower than similar rates among the adult population as a whole (in 2019 by 1.5 times, in 2023 - by 1.2 times).

**Conclusion**. Thus, among the adult population of working age, the rates of primary incidence of DCS are on average two times lower than those of the adult population as a whole. At the same time, the rate of increase in incidence is almost twice as high as the rate of increase among the adult population as a whole.

In the structure of primary incidence of DCS among adults of working age, compared with the structure of morbidity among the adult population, there is a significantly higher proportion of diseases characterized by high blood pressure and vascular pathology, as well as a lower proportion of cerebrovascular diseases and ischemic heart diseases.

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# ANALYSIS OF THE CAUSES OF RELAPSES WHEN USING SYNTHETIC MATERIALS IN GENITAL PROLAPSE SURGERY

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***Resume.*** *The main problem that arises when using surgical methods for treating pelvic organ prolapse using native tissues is the large number of relapses, reaching 45% of cases. This is determined by the fact that these surgical technologies do not eliminate the cause of the disease, which is due to the failure of the patient's own connective tissue structures. Technologies, based on duplicating insolvent fascial-ligamentary structures with synthetic materials, due to the use of the etiological principle, they have higher efficiency and better long-term results. However, they also do not exclude the possibility of relapse.*

*The aim of the study was to analyze the causes of relapses of the disease based on a follow-up examination of 165 patients within 18 months to 4 years after surgical treatment.*

*Evaluation of remote results showed that the number of relapses after laparoscopic promontofixation was 12.1%, and after extraperitoneal MESH-fascial reconstruction - 10.8%. The causes of relapses of genital prolapse after laparoscopic promontofixation are most often associated with the presence of*

*fascial defects that were not diagnosed before the operation and, therefore, not eliminated, or with the appearance of new ones, which can be regarded as a continuation of the disease. The causes of relapses after fascial reconstruction are most often insufficient sizes of the prosthesis, not taking into account its retraction during the formation of fibrosis, or incorrect fixation of the prosthesis, leading to its displacement at points located within the boundaries of fascial defects.*

***Keywords:*** *recurrence of pelvic organ prolapse, synthetic materials.*

Pelvic organ prolapse is one of the most common pathological conditions of the female reproductive system.[1]. Its incidence in the Russian Federation fluctuates within fairly wide limits and in certain years reaches 28 per 1000 female population [2].

The maintenance of the pelvic organs in a normal position is ensured by their active support by the complex of muscles that make up the pelvic floor, and passive support by their own ligamentous-fascial structures. The cause of pelvic organ prolapse is the excess of intra-abdominal pressure over the ability of the system responsible for their retention to resist it. In most cases, this circumstance is due to the failure of these structures, associated with their traumatic injury, dystrophic disorders or manifestations of systemic connective tissue dysplasia [3].

Treatment of the disease consists of strengthening support and restoration of the normal position of the pelvic organs, which are carried out mainly by surgical means. Many different surgical methods of treating genital prolapse are known, most of which, due to their insufficient effectiveness, are of interest rather in the historical aspect. At present, a certain set of surgical interventions aimed at restoring the levels of support of the pelvic organs in accordance with the concept of De Lancey JO (1993) [4] and using their own connective tissue structures to correct vaginal anatomy disorders.

The main problem that arises when using the above methods is the high rate of relapses, reaching 45% of cases [5]. This is due to the fact that these technologies allow restore the normal position of the pelvic organs and eliminate the etiological factor of a traumatic nature. At the same time, they in no way contribute to the elimination of dystrophic disorders and do not affect the insolvency of connective tissue associated with its dysplasia. Consequently, in a number of cases they do not eliminate the cause of the disease.

In recent decades, technologies have been developed based on duplication of insolvent connective tissue structures with synthetic materials. Due to the use of the etiological principle, these surgical methods have higher efficiency and better long-term results. However, they also do not exclude the possibility of relapse [6].

**The goal** The purpose of this study was to analyze the causes of disease recurrence after surgical treatment using synthetic materials.

**Material and methods.** The study was conducted on the basis of a control examination of 165 patients at periods from 18 months to 4 years after surgical treatment of pelvic organ prolapse using synthetic materials. For the purpose of endoprosthetics, the surgical mesh ULTRAPRO ETHICON was used. Given the variety of anatomical disorders of pelvic organ support, various combinations of surgical procedures were used in all patients. Nevertheless, two groups of patients were identified based on the methods of using synthetic materials. In 91 cases (the first group), laparoscopic promontofixation was performed, in 74 cases (the second group) - extraperitoneal MESH-fascial reconstruction via vaginal access.

In some cases, patients of the first group had concomitant gynecological pathology requiring simultaneous operations, namely: ovarian cysts in 7 cases, uterine fibroids in 12, severe cervical dysplasia in 4. In this connection, laparoscopic access was used to perform 7 cystectomies, 8 supracervical hysterectomies and 4 myomectomies, 4 total hysterectomies. For the purpose of apical fixation with non-absorbable suture material, cervicosacropexy was performed in 79 women of the first group, in 12 cases (after 4 hysterectomies performed simultaneously and in 8 cases in the presence of posthysterectomy prolapse) - colposacropexy. In addition, all patients in the first group underwent levatorplasty, the purpose of which was to strengthen the active support of the pelvic organs, and 73 with cystocele underwent anterior colporrhaphy. In this case, absorbable suture material was used.

In the second group, 40 women underwent anterior reconstruction of the pubocervical fascia using four sleeves to fix the prosthesis through the obturator foramina, and 4 women underwent posterior reconstruction of the rectovaginal septum using two sleeves to fix the prosthesis through the sacrospinal ligament. Both anterior and posterior (total) reconstruction were performed in 30 patients. Fixation of the prostheses to the cervix or to the vaginal dome was performed with non-absorbable suture material. It should be noted that the use of the sacrospinal ligament in posterior and total reconstruction, in addition to correcting the rectocele, contributed to apical fixation at the level of the interspinous line. In addition to fascial reconstruction, 40 women in the second group underwent hysterectomy through the vagina for apical fixation, cervical amputation with transposition of the fornices was performed in 6 women, and bilateral sacrospinal colpofixation was performed in 7 women.

The results of surgical treatment were assessed prospectively based on a gynecological examination with the Valsalva maneuver, which determined location of nine control points on the walls of the vagina and cervix or vaginal fornix relative to the plane of the hymenal ring using the quantitative classification POP-Q [7]. In this case, a vaginal profile was described, characterized by the absence or presence of disorders of various parts of the vaginal anatomy. In diagnosing disorders corresponding to stage II and higher of genital prolapse, the term “relapse of the disease” was used. In

patients with diagnosed relapses, in order to determine the causes of their occurrence, an analysis of the compliance of the surgical treatment methods used with the existing anatomical defects was performed. In addition, for the same purpose, an ultrasound examination of the pelvic organs and structures was performed using the Sono Scape S 20 Exp ultrasound device. Vaginal and perineal scanning was performed using a 4-11 MHz/R10mm micro convex rectovaginal sensor. The study was performed with the patient in a supine position at rest and with the Valsalva maneuver with a filled bladder of 150-200 ml. The position of the posterior wall of the bladder relative to the pubis, the position of the cervix relative to the pubis and the entrance to the vagina, deformations and structural changes in the anterior wall of the rectum, the topography and linear dimensions of the muscles that make up the pelvic diaphragm, the height and degree of expression of the tendinous center of the perineum were assessed.[8].

**Results.** Evaluation of the remote results of the studied surgical technologies showed the following. Within 6 months after the surgical treatment, postoperative complications specific to the techniques used developed in a number of cases. In the first group, 2 (16.7±10.8%) patients after colposacropexy developed ligature fistulas with granulation polyps. They recovered after removing the ligatures. No such complications were observed in women after cervicosacropexy. In the second group, 9 cases (12.2±3.8%) developed vaginal erosions above the prosthesis. Conservative treatment of these complications, regardless of the size of the erosions, was unsuccessful, which required excision of a part of the prosthesis and application of secondary sutures. It should be noted that the elimination of the complications that arose in both groups of patients did not entail a relapse of prolapse in any case.

When determining the vaginal profile of patients in both groups based on a gynecological examination using the Valsalva maneuver, the absence of vaginal anatomy disorders was found in 80 women in the first group and in 66 in the second, and the number of relapses was 11 (12.1±3.4%) and 8 (10.8±3.6%), respectively.

In the first group, the following sections of vaginal anatomy were disrupted: all sections (total) – 1 case, posterior – 3, anterior – 5, combination of anterior and posterior – 2. The disruptions corresponded to grade 2 prolapse in 4 cases, grade 3 – in 7.

Analysis of possible causes of vaginal anatomy defects showed the following. Apical section abnormalities were observed in one case of total prolapse after colposacropexy (8.3% of all cases of this intervention). Most likely, this was caused by cutting through the ligature fixing the vaginal dome to the prosthesis. It should be noted that attaching the vaginal dome to the endoprosthesis is one of the most vulnerable stages of these surgeries, due to the need for a sufficiently deep suture

to prevent its cutting through, while avoiding through suturing to avoid the formation of ligature fistulas. In this regard, for the most durable fixation, it is advisable to preserve the cervix even in the presence of elongation or dysplasia, limiting itself, if necessary, to amputation of its vaginal part.

Defects of the anterior segment were present in only 8 cases: 1 with total violation, 5 with isolated anterior and 2 with a combination of anterior and posterior. Of these 8 women, 5 did not undergo anterior plastic surgery due to the absence of anterior segment violations before the surgery. Ultrasound examination revealed displacement of the posterior wall of the bladder below the level of the lower edge of the pubic symphysis at rest or during straining in the form of an acute-angled triangle, which is a diagnostic marker of the central defect of the pubocervical fascia. That is, in 5 of 18 (27.8%) patients without anterior plastic surgery, anatomical violations appeared after the surgery and can be regarded as a continuation of the disease in the form of new fascial defects. In 3 women out of those who underwent anterior colporrhaphy, ultrasound examination also revealed displacement of the posterior wall of the bladder below the level of the pubic symphysis. However, unlike previous cases, when straining it had an asymmetrical oval shape, which we assessed as a manifestation of paravaginal fascial defects that were not diagnosed before the first operation. Consequently, the previously performed anterior colporrhaphy did not contribute to the restoration of the fascia detachment from the tendinous arch and was not pathogenetically justified.

Posterior defects were present in only 6 cases: 1 with total impairment, 3 with isolated posterior defects, and 2 with a combination of anterior and posterior defects. Ultrasound examination of the pelvic organs and structures, performed to clarify the location and nature of defects, revealed the following. Three patients had a “sac-like” protrusion of the anterior wall of the rectum and posterior wall of the vagina, the lower border of which was at the level of the dentate line of the anal canal and was significantly higher than the upper edge of the levators. Consequently, previously performed levatoroplasty did not create prerequisites for eliminating the existing defect. In the other 3 patients, during the Valsalva maneuver, wedging of small intestinal loops into the Douglas space was noted, i.e., enterocele was present. Thus, all patients had previously undiagnosed proximal defects of the posterior vaginal support, the elimination of which using native tissues was not possible. In addition, all patients had diastasis of the levators in the area of the tendon center. Consequently, plication of the levators with absorbable suture material did not result in the formation of a scar that would provide full active support of the pelvic organs.

In the second group, 4 anterior and 4 posterior vaginal disorders were noted. Recurrences of the anterior segment occurred in two cases after total fascial reconstruction and in two cases after the anterior one. Ultrasound examination revealed

incomplete lateral coverage of the fascial defect in three patients, apparently due to the insufficient size of the prosthesis without taking into account its subsequent retraction. In one patient, the level of fixation of the upper edge of the mesh was below the level of the upper edge of the anatomical defect of the fascia. As a result, with an increase in intra-abdominal pressure, there was a displacement of the urethrovesical segment and the posterior wall of the bladder together with the prosthesis, which contributed to the recurrence of cystocele.

Relapses of the posterior section were noted in 3 cases after total fascial reconstruction and in 1 case after the anterior one. This case can be considered as a continuation of the disease, since the echographic picture showed diastasis of the levators in the area of the tendon center. In the other three cases, fixation of the lower edge of the prolene mesh above the lower edge of the fascial defect was noted. The level of formation of the rectovaginal septum defect coincided with the anatomical level of the dentate line of the anal canal. Fixation of the prosthesis above this anatomical mark led to the fact that with an increase in intra-abdominal pressure, an area of prolapse of the anterior wall of the rectum and the posterior wall of the vagina was formed between the upper edge of the levators and the lower edge of the prosthesis.

Thus, in fascial reconstruction with synthetic materials, the causes of relapses are mainly insufficient sizes of the prosthesis, which do not take into account its retraction during the formation of fibrosis, or incorrect fixation of the prosthesis, or its absence, leading to its displacement at points located within the boundaries of fascial defects.

**Conclusions:**

1. The use of surgical technologies using synthetic materials allows for effective correction of disorders of both the first and second levels of vaginal anatomy support in pelvic organ prolapse.
2. Recurrences of genital prolapse after laparoscopic promontofixation are most often associated with the presence of fascial defects that were not diagnosed before surgery and, therefore, not corrected, or with the appearance of new ones, which can be regarded as a continuation of the disease.
3. The most common causes of relapses after fascial reconstruction with synthetic materials are insufficient sizes of the prosthesis, which do not take into account its retraction during the formation of fibrosis, or incorrect fixation of the prosthesis, leading to its displacement at points located within the boundaries of fascial defects.

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# ABOUT ORGANIZATION OF MEDICAL AND SOCIAL ASSISTANCE TO THE ELDERLY PEOPLE

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***Annotation.*** *Today one of the most serious, medical, social and economic problems is the aging of the population. The growth of life longevity is not only positive one because for many elderly people it means life without joy, help and low quality of existence. In Russia the quality of life still remains low. In this case the definition of life quality for such category of population is in-time medical help, care and organization of other types of palliative help.*

***Keywords:*** *elderly people, population, life quality, medical help, palliative help.*

Palliative care implies comprehensive support for patients and their caregivers. It includes rendering practical help and consulting in the case of the loss of relatives. At the same time, the support system is provided to help patients to be in active life as possible before death. Modern hospices, being medical institutions with their own specifics, put forward work aimed at solving the social and family problems of their patients as one of their priority tasks. This is the fundamental difference in the provision of assistance in a regular hospital and a hospice

In different countries of the world, the level of development of hospice care varies significantly. The World Atlas of Palliative Care presents a scale according to which 80 countries of the world were divided by the World Health Organiza-

tion into four groups depending on the level reflecting the quality of palliative and hospice care. The top ten leaders include, for example, such countries as Great Britain and the USA, where palliative care is integrated into the healthcare system. The list of key quality indicators presents the level of education and competence of doctors in palliative care, the availability of pain relief, the number of hospices per capita and the degree of government support for this area. At the same time, there is a need for strategic integration of palliative care with programs aimed at the prevention, timely detection and treatment of oncological diseases in children and adults [10]. In the presented scale, Russia is only on the 48th place, occupying a place in the penultimate third group of countries in which separate palliative care centers operate [1]. Significant organizational, economic and political obstacles prevent raising hospice care to the required level and transforming it into one of the most important parts of the modern healthcare system [5].

The need for long-term care in appropriate institutions potentially represents the fastest growing segment of the Medicare hospice market (Medicare is a national health insurance program in the United States for people aged 65 and over, also provided to a certain category of people under 65). This category includes, for example, disabled people and patients suffering from permanent renal failure or amyotrophic lateral sclerosis (Charcot's disease) [7]. This phenomenon is directly due to such a factor as the state's approach to this type of activity, which is reflected in the definition of the very concept of "hospice". "In the United States, the term "hospice" is understood as to mean government-controlled organizations or programs for helping dying patients and their family members..." [4]. Another determining factor in the active development of hospice services in America and some other countries is economic benefit, i.e. the opening of hospices can be considered to be a competative business. "Hospices bring economic benefit to any state. And not a small one. Americans estimate the economic feasibility of hospices by the size of the gross national product produced by relatives freed from caring for a terminally ill person" [3]. The fact that the United States recognizes the need to search for innovative, cost-effective and community-oriented approaches to improving hospice care contributes to the emergence of new terms, for example, "TeleHospice" [6]. At the same time, the country notes inequality in the provision of hospice care, consisting of limited access to hospice services for patients without cancer; representatives of ethnic minorities; those living in rural areas and disadvantaged areas; elderly citizens; the homeless; patients suffering from diabetes and cystic fibrosis; as well as HIV-infected and suffering from AIDS [8]. In the process of active development of the hospice industry, cultural and religious traditions play a significant role. In Western countries, "living out" old age in various hospice-type institutions is considered the norm, which also affects the wide variety of vocabulary in the area of activity under study. In Muslim

countries, with their cultural and social preferences for dying at home, there is a tendency to focus on the development of home hospices. And this determines the limited saturation of the analyzed layer of vocabulary. Religion can also influence the choice of lexical units to denote the concept of "hospice". For example, the fact that in China and Taiwan the majority of the population adheres to Buddhism (often in combination with the philosophy of Confucianism and/or Taoism), this contributes to the identification of the following linguistic factors.

One of the fundamental factors influencing the quality of services at the end of life is an appropriate environment that can help to overcome the physical, social, spiritual and psychological needs of both patients and caregivers. [9]. In order to create access to maximum comfort in the analyzed area of services, the National Palliative and End of Life Care Partnership published a six-year plan in 2021 [10]. In the United States, a criterion was developed (the only one to date), with the help of which an attempt was made to assess the attitude of health workers to care at the end of life. Based on the principles of hospice philosophy, this criterion is called the Hospice Philosophy Scale (HPS) [11]. In many other countries, and in Russia, in particular, the concept of "care at the end of life" will most likely be included in the general term "palliative care". In our country, hospices are traditionally associated with a certain type of institution providing palliative care to patients suffering from severe oncological diseases. "Modern Russian hospices operate almost the same as regular oncology clinics, but specialize in helping patients in particularly difficult cases" [12]. This circumstance is reflected in the Order of the Ministry of Health and Social Development of Russia "On Approval of the Procedure for Providing Medical Care to the Population with Oncological Diseases" No. 944n dated 03.12.2009 // SPS "Garant". At the same time, according to paragraph 2 of the Appendix to this document, hospices provide assistance primarily to incurable oncological patients in the terminal stage of the disease. This category is in much greater need of medical care, social care and drug provision than others.

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# ASSESSMENT OF CELLULAR ADAPTIVE IMMUNITY IN PATIENTS WITH MULTIPLE SCLEROSIS INFECTED WITH JOHN CUNNINGHAM VIRUS

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***Abstract.*** *After discontinuation of Natalizumab, some patients with multiple sclerosis (MS) may experience reactivation of the John Cunningham virus (JCV), which may manifest as a life-threatening complication - a picture of progressive multifocal leukoencephalopathy (PML). The risk management strategy for treating patients with MS with Natalizumab involves discontinuing the drug if the likelihood of developing PML increases, in particular, after an increase in the titer of antibodies to JCV, transferring patients to Ocrelizumab and searching for criteria to assess the possibility of exacerbations in such patients. Patients with MS underwent an assessment of the parameters of T-, B-, NK-cell immunity using the method of multicolor flow cytometry depending on the presence / absence of serum AT to the John Cunningham virus, and based on the results obtained, immunological criteria for the development of an exacerbation of the disease were developed. Patients were divided into 3 groups: Group 1 - "naive" untreated patients with rapidly progressive MS (RPMS) seronegative to JCV; in 10 patients (group 2), after the cancellation of Natalizumab, a high titer of AT to JCV was detected and an exacerbation of the disease was confirmed clinically and neuroimaging; in 7 patients (group 3), despite seropositivity to JCV, no signs of MS exacerbation were detected. Group 4 (control) consisted of 12 practically healthy individuals comparable in gender and age. Immunological criteria (predictors) of MS exacerbation after Natalizumab discontinuation due to JCV infection may include:*

*1. A decrease in the content of effector T-lymphocyte subpopulations: cytotoxic (CD3+CD8+) and NKT subpopulation (CD3+CD16+CD56+) in peripheral blood (PB);*

*2. A decrease in the content of B1-lymphocyte subpopulation (CD5+CD19+) in PB.*

*An increase in the content of CD38 and CD25 activated B-lymphocytes in circulation in "naive" untreated patients with BPMS and MS patients without clinical signs of exacerbation, but seropositive for JCV, may indicate the presence of a pool of B-lymphocytes with a high activation potential and a significant risk of disease exacerbation.*

***Keywords:*** *multiple sclerosis, natalizumab, John Cunningham virus, cellular adaptive immunity, flow cytometry.*

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Introduction. Multiple sclerosis (MS) is a multifactorial immune-mediated disease involving both T- and B-lymphocytes in the pathogenesis, migrating to the central nervous system and triggering the process of autoimmune antibody formation by plasma cells against myelin antigens. The main goal of MS therapy is to prevent disease progression and increasing disability. According to the latest data, B-cells are considered to be the central component of MS pathogenesis. They present antigens to T-lymphocytes, produce cytokines that act as inflammatory mediators and are the main antibody-producing cells to the specific protein myelin, which leads to demyelination of CNS cells. On the other hand, this process is aggravated by the reactivation of the John Cunningham virus (JCV), which can manifest itself as a picture of progressive multifocal leukoencephalopathy (PML). Natalizumab is a selective inhibitor of the adhesion molecule α4-integrin. The drug prevents the adhesion of lymphocytes to the endothelium and their subsequent penetration into the CNS. After the cancellation of Natalizumab, there is an increase in the number of patients with MS who experience reactivation of JCV, which is an indication for their transfer to Ocrelizumab (a drug of monoclonal antibodies against CD20), which leads to the rapid removal of B cells from the blood, but the degree of B cell depletion and the kinetics of their restoration in various immune compartments are poorly understood. During the use of Natalizumab in domestic clinical practice, its safety profile and adverse events have been studied quite well. However, discontinuation of Natalizumab therapy is accompanied by the development of an exacerbation of MS in approximately 38% of cases, which is explained by immune reconstitution inflammatory syndrome (IRIS), and in some cases by the development of a rebound phenomenon (worsening of existing and the appearance of new symptoms of MS, often of the acute disseminated encephalomyelitis type) [1–3].

The literature data on the study of the parameters of cellular immunity during Natalizumab therapy are quite contradictory due to the variety of clinical manifestations of MS itself. Thus, researchers claimed that Natalizumab therapy was

accompanied by a decrease in the content of CD4+ and CD8+ T-lymphocytes, B-lymphocytes (CD19+) and plasma cells in the cerebrospinal fluid as a result of the suppression of their penetration into the cerebrospinal fluid from the circulation, while in clinically manifested exacerbations after the discontinuation of Natalizumab therapy, a high content of T-helper (CD4+) and T-cytotoxic (CD8+) lymphocytes was detected, which was regarded as IRIS [4, 5].

John Cunningham virus (JCV) was isolated from cell cultures of glial cells from a patient who died of progressive multifocal leukoencephalopathy in 1971. In 1984, the JCV genome was sequenced. It is a DNA-containing virus from the papovaviridae family. Primary infection with the John Cunningham virus occurs through the respiratory system or gastrointestinal tract and is asymptomatic. Subsequently, the virus persists in the urinary system, bone marrow, tonsils and spleen [6]. B-lymphocytes, CD34+ progenitor cells are a reservoir for JCV in MS and play a significant role in activation, viremia and the development of PML. PML is caused by the reactivation of latent JCV in immunodeficiency states. The main target of JCV in MS is oligodendrocytes and, partially, astrocytes; their lysis causes massive demyelination of nerve fibers. The presence of PML DNA in the cerebrospinal fluid (PCR method) and MRI is critical for the diagnosis of PML [7].

The risk management strategy for treating MS patients with Natalizumab involves discontinuing the drug if the likelihood of developing PML increases, in particular, after an increase in the titer of antibodies to JCV, which is an indication for their transfer to Ocrelizumab and searching for criteria to assess the possibility of exacerbations in such patients.

In MS, a high prevalence of antibodies against JCV has been revealed - 85.9%. High-risk groups for PML include patients receiving Natalizumab therapy for more than 24 months and having an antibody index to JCV $\geq$1.5 without a history of immunosuppressive therapy (IST), as well as patients who previously received IST, receiving Natalizumab for more than 2 years, and a seropositive status of antibodies to JCV. It is necessary to maintain alertness regarding this pathological condition in all patients receiving Natalizumab, as well as for 6 months after completion of therapy [8].

In this regard, it seems particularly relevant to study the initial parameters of cellular immunity in patients with MS who previously received Natalizumab courses, with developed reactivation of JCV and are candidates for Ocrelizumab therapy.

Objective of the study: Identification of the features of adaptive cellular immunity in patients with MS who discontinued Natalizumab therapy due to an increased risk of developing PML.

Materials and methods: The study was an open prospective observational study. An examination of 23 patients observed in the MO MS center in 2019-2023

was performed. Group 1 consisted of 6 patients with BPMS who had not previously received DMT therapy and were seronegative to JCV.

Treatment adjustment was required in 20 patients with MS, 17 of whom had a high titer of antibodies to JCV, treatment duration of more than 24 months and a high risk of PML. In 10 patients (group 2), disease exacerbation was confirmed clinically and neuroimaging, in 7 patients (group 3) no signs of MS exacerbation were detected. Group 4 (control) - 12 practically healthy individuals matched for gender and age. Patients underwent assessment of cellular immunity parameters by flow cytometry (6-color flow cytometer Becton Dickinson, USA). The population and subpopulation composition of peripheral blood lymphocytes (PC) within CD45+ lymphocytes was studied: the content of CD3+, CD19+, CD20+, CD3-CD16+CD56+, CD3+CD4+, CD3+CD8+, CD3+HLA-DR+ cells was determined.

The subpopulation composition of B-lymphocytes (B1 cells, memory B-cells), expression of costimulatory and activation antigens (CD40, CD25, CD38, CD95) were determined within the gate of CD19+ cells.

Statistical processing of the material was carried out using the software package "StatPlus Pro v.7.6.5.0" Quantitative data are presented as the mean and standard deviation (M+-SD) using the Mann-Whitney tests with Bonferroni correction, Kruskal-Wallis.

The indicators of the population and subpopulation composition of PC lymphocytes are presented in Table 1.

***Table 1.***

*Indicators of cellular immunity in patients with MS during JCV infection (% of cells within CD45+ lymphocytes)*

| Indicator | "Naive" patients with RPMS AT to JCV (-) n=6 | MS patients with exacerbation of AT to JCV (+) n=10 | MS patients without exacerbation of AT to JCV (+) n=7 | Almost healthy faces n=12 | P |
|---|---|---|---|---|---|
| CD3+ | 76,9+-6,07 | 71,9+-16,8 | 69,9 +-11,3 | 74,3 +-7,8 | 0,117 |
| CD3+CD4+ | 40,5+-5,6 | 48,0+-12,0 | 42,8+-10,3 | 41,0+-5,01 | 0,525 |
| CD3+CD8+ | 34,3+-7,0 | 22,9+-6,7 | 25,4+-7,2 | 33,00 +-4,2 | P2-4 <0,001 |
| CD3-CD16+CD56+ | 11,3+-2,4 | 16,6+-18,5 | 13,0+-6,0 | 12,47+-2,99 | 0,831 |
| CD3+CD16+CD56+ | 6,13+-1,98 | 4,8 +- 3,3 | 2,5+-2,2 | 10,50+-4,51 | P2-4 = 0,003<br>P3-4 = 0,003 |
| CD3+HLA-DR+ | 11,8+-0,5 | 6,6+-3,2 | 8,3+-2,9 | 13,30+-5,35 | P2-4 = 0,002<br>P3-4 = 0,012 |
| CD19+ | 11,2+-2,8 | 12,0+-5,6 | 14,2+-7,4 | 11,79+-2,31 | 0,417 |
| CD20+ | 10,24 +- 2,2 | 10,70 +- 6,1 | 12,8+- 6,59 | 11,19+-1,41 | 0,219 |
| CD19+HLA-DR+ | 9,80 +- 1,34 | 11,75 +-5,57 | 13,10 +- 6,80 | 10,3+- 1,41 | 0,348 |

The content of T-B, NK, T-helper, T-cytotoxic and NKT subpopulations in "naive" patients with BPMS, who did not have reactivation of the JC virus, did not differ from the control values, despite the severity of clinical manifestations of MS.

In patients with MS in the phase of clinically expressed exacerbation, having AT to the JC virus, a significant decrease in the content of cytotoxic and NKT lymphocytes, as well as a marked decrease in the level of activated T lymphocytes compared to normal values was revealed.

In the group of patients with MS outside of exacerbation, but also having high titers of AT to the JC virus, a significant decrease in the content of the NKT lymphocyte subpopulation and the level of activated T lymphocytes was revealed compared to practically healthy individuals. The proportion of B-lymphocytes in all groups of patients by two B-cell markers (CD19, CD20), as the proportion of B-cells expressing the HLA-DR molecule, reflecting the antigen-presenting ability of B-lymphocytes, did not differ in all groups compared to the control values.

Thus, when infected with the JCV virus, there is an increase in the release of specific effector cells - killers, as well as activated T-lymphocytes from the circulation into the CNS.

Data on the subpopulation composition of B-lymphocytes of PC in patients with MS depending on infection with the JC virus are presented in Table 2.

***Table 2.***

*Indicators of B-cell immunity in patients with MS with infection with JCV (% of positive cells within the CD19+ gate)*

| **Indicator** | **"Naive" patients with RPMS AT to JCV (-) n=6** | **MS patients with exacerbation of AT to JCV (+) n=10** | **MS patients without exacerbation of AT to JCV (+) n=7** | **Almost healthy faces n=10** | **P** |
|---|---|---|---|---|---|
| CD40+ | 51,13 +- 8,3 | 39, 7+- 27,13 | 55,9 +- 27,6 | 49,20 +-3,69 | 0,168 |
| CD5+ | 19,3+- 6,4 | 9,63+- 3,3 | 19,1+-16,3 | 17,29 +- 4,5 | P2-4 < 0,001 |
| CD27+ | 26, 0+-5,2 | 32,1+-18,3 | 30,5+- 14,2 | 28,30 +- 2,28 | 0,441 |
| CD95+ | 19,3 +- 1,67 | 18, 9+- 10,8 | 33,3 +- 22,3 | 19,89 +- 1,41 | 0,094 |
| CD38+ | 26,43+- 6,96 | 20,8 +- 9,56 | 44,13 +- 18,20 | 16,10 +- 4,47 | P1-4 < 0,001<br>P3-4 < 0,001 |
| CD25+ | 21,93 +- 5,51 | 16,4 +- 7,54 | 27, 65 +- 8, 10 | 13,79 +- 3,69 | P1-4 = 0,004<br>P3-4 = 0,016 |

The group of naive patients with RPMS was characterized by a significant increase in the content of B-lymphocytes expressing the activation markers CD38 and CD25. In patients of group 3 (without exacerbation of MS), a significant in-

crease in the content of B-lymphocytes expressing the activation markers CD38 and CD25 was also revealed.

In patients of group 2, with a combination of pronounced clinical exacerbation of the disease and reactivation of the JC virus, a significant decrease in the content of the B1-lymphocyte subpopulation (cells associated with the production of autoantibodies in autoimmune pathology) was revealed, both in comparison with patients without treatment and with control values.

**Conclusion.**

In patients with MS who are candidates for switching to Ocrelizumab therapy, no decrease was found, but the number of CD20+ B-lymphocytes was preserved after long-term therapy with Natalizumab. Immunological criteria (predictors) of MS exacerbation after Natalizumab discontinuation due to JCV infection may include:

1. A decrease in the content of effector T-lymphocyte subpopulations in the MC: cytotoxic and NKT (CD3+CD8+ and CD3+CD16+CD56+, respectively);

2. A decrease in the content of the B1-lymphocyte subpopulation in the MC.

Probably, when infected with the JCV virus in MS patients, there is an increased release of specific effector cells - killers, as well as activated T-lymphocytes from the circulation into the CNS.

An increase in the content of B-lymphocytes activated by CD38 and CD25 in circulation in patients with BPMS and MS patients in the absence of clinical signs of exacerbation, but seropositive for JCV, may indicate the presence of a pool of B-lymphocytes with a high activation potential and a pronounced risk of disease exacerbation.

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# THE PATIENT-ORIENTED MODEL OF MANAGEMENT OF PATIENTS WITH HAEMOPHILIAIN DENTAL PRACTICE

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***Abstract.*** *This article considers the peculiarities of preparing and managing of patients with haemophilia before dental interventions with a patient-oriented approach. It's imperative to provide dental care to patients suffering from haemophilia after consultation with haematologist and other doctors. It's important to use individually developed algorithms of prevention and treatment of dental diseases. The priority is to minimize the risk of hemorrhaging by joint work of doctors and taking into account individual characteristics of patients with haemophilia, dental health and rational hemostatic support before dental interventions.*

*The main bioethical problems, that arise, when working with children at the dental clinic, are described.*

*We concluded that it is necessary to develop timely modern prevention of dental diseases and sanitary education work for patients with haemophilia.*

***Keywords:*** *haemophilia, dental health, patient-oriented approach, dental interventions, patients with haemophilia, bioethical problems, children.*

**Introduction.** When providing dental care to such a group of the population as children, difficulties arise related to the peculiarities of the psyche of the small patient and their parents or legal representatives. The severity of various mental reactions often prevails in patients suffering from hemophilia. In order to ensure the safety, quality and comfort of dental care for such patients, a pediatric dentist must be able to apply methods of minor psychotherapy in combination with professionalism and clinical thinking [5, 6].

It is important to use not only practical competencies, but also a patient-oriented approach during dental appointments with patients with hemophilia.

The patient-oriented model includes: elements of minor psychotherapy (eye contact, sitting communication, nodding, open posture of the doctor), elements of a problem interview (collection of the disease history is carried out using a combination of open and closed questions). Open questions allow you to collect information about the patient's "pain" and begin to talk about the problem. Closed questions are of a clarifying nature to form a hypothesis of the patient's disease. Taking into account the psychoemotional characteristics of patients with hemophilia, especially children, this tactic allows you to create a comfortable environment for the patient.

A dentist must be patient-oriented, namely, know about different types of teeth cleaning and their features, items and means of personal oral hygiene. The ability to find an individual approach to a patient suffering from hemophilia during an initial consultation at a dental appointment, identifying the patient's needs, as well as forming motivation to receive appropriate treatment and maintain contact with the dentist is the basis for forming a patient-oriented approach in modern medicine. In a patient-oriented model, the dentist acts as an expert, the patient makes a request for knowledge, and whether to use it is up to the patient, not the dentist. Therefore, an important component of a consultation with a dentist is the correct establishment of communication with a patient suffering from hemophilia and increasing patient compliance; in our studies, low compliance of patients with hemophilia was revealed for the first time. Increasing compliance of patients with hemophilia is an important task of a dentist and helps to maintain the dental health of this population group.

Hemophilia is a hereditary hemorrhagic disease, predominantly affecting males, which is based on a disorder of blood clotting, namely its first phase with a deficiency of factor VIII or IX and manifested by frequent, long-term bleeding and hemarthrosis. Hemophilia A is most common in patients, and B is less common. The incidence of hemophilia in the world ranges from 10 to 14 males per 100 thousand men examined. [1].

The disease is transmitted linked to the X-recessive chromosome, so only males get sick. Women are carriers of the gene - hemophilia conductors.

It is generally accepted to divide hemophilia into 3 degrees of disease severity, based on the activity of a certain coagulation factor in the blood plasma. The division is as follows: mild severity - factor activity is more than 5% and less than 40%; moderate - factor activity is 1-5% and severe severity - factor activity is less than 1% [2].

For patients with hemophilia, it remains important to ensure the effectiveness and safety of dental interventions [3].

For this purpose, before treatment by a dentist, a consultation with a hematologist is necessary to prescribe the correct hemostatic support. In this way, a multidisciplinary approach to complex dental treatment is implemented. Joint work of a dentist with doctors of other specialties (pediatrician, endocrinologist, etc.) will reduce or minimize the risks of bleeding and infection [4].

A pediatric dentist can inevitably face emotional anxiety of a small patient, therefore, to prevent negative perception, it is necessary to take into account the psychological and physiological characteristics of different periods of childhood, namely, that children of preschool and primary school age during daytime sleep may refuse to build a dialogue with the doctor and fulfill his requests, this happens, among other things, due to reduced concentration. Therefore, the time of the visit should be chosen, excluding the hours of the child's usual daytime sleep. It is also necessary to take into account the duration of treatment and choose a method based on the emotional status, lability of each child with hemophilia.

During long procedures, there is a very high probability of moodiness and changes in mood, which can directly affect the quality of dental care provided.

The appearance of a pediatric dentist affects the emotional background only indirectly, but as an additional effect of reducing the emotional background, you can use medical clothing not of the standard white color, but of light colors with bright patterns.

And the leading place is given to the communication skills of the dentist. The right conversation, an individual approach will form a trusting relationship with the child, which is important for providing dental care to patients with hemophilia. Such relationships are formed through non-verbal interaction. It is important to understand that the success of treatment and the patient's peace of mind will depend on the well-coordinated interaction of not only the medical staff (pediatric dentist, assistant, nurse), but also the involvement of the child himself, his parent or guardian. Non-verbal communication consists of behavior and emotions. Maintaining visual contact, genuine interest, a pleasant smile, the absence of sharp and quick hand movements, a positive confident attitude of the doctor will ensure half the success. The style of communication with the patient is chosen taking into account the characteristics of each age. An important aspect is also a friendly and polite tone of voice, because not every patient understands what the dentist is saying due to his age.

It is important to remember that our patient is not a combination of his illnesses that the doctor must detect and cure, but, first of all, a personality. Therefore, when working with patients with hemophilia, it is necessary to be guided by humanitarian principles, using a natural-scientific approach, this is the only way to avoid ineffective treatment and sometimes cruel treatment of patients.

The pediatric dentist must remember that prevention of dental diseases plays a key role in ensuring the dental health of children with hemophilia.

Patients with hemophilia are more often motivated to achieve quick results, rather than to maintain their own health in the long term. Maintaining one's health is important today, which implies a conscious choice of health care. Involving patients with hemophilia in a healthy lifestyle should begin with the formation of their motivation to comply with preventive measures. Therefore, the formation of motivation to care for children and adolescents with hemophilia requires significant efforts not only from the patients themselves, but also from dentists in achieving a common goal.

Before any dental intervention, it is necessary to explain in a form accessible to the patient why and for what purpose it is necessary to use such a method of treatment and what the consequences of further refusal of treatment may be. Thus, the dentist is guided by the principle of respect for human dignity and ensures the patient's right to health protection and its preservation.

A special role is given to filling out the patient's informed consent for dental intervention. Detailed, correct informed consent solves the problem of many bioethical issues.

It is important to remember that the formation of a positive attitude and motivation of parents or guardians is as important a task for a pediatric dentist as high-quality dental care for patients with hemophilia. It is important to remember that a child can copy the behavior of parents, so first you need to calm down "anxious" parents, and then establish communication with the little patient.

An important aspect of the success of treatment is the initial preparatory appointment - to determine the child's psychotype, the level of anxiety that arises when seeing a pediatric dentist. The area and invasiveness of the intervention are also determined, based on this, an appointment and the number of visits are made.

A pediatric dentist should remember that prevention of dental diseases plays a key role in ensuring dental health of the population. This is especially important to remember when working with patients with hemophilia.

**Conclusion.** Formation of a systematized approach to creation of algorithms of preparation for dental intervention, based not only on taking into account the severity of hemophilia, but also on individual features of dental status, results of salivary diagnostics will help patients and doctors in increasing safety and effectiveness of subsequent treatment. The combination of a health questionnaire and a problem interview forms a new vector of development of communication skills of a dentist in a patient-oriented model of interaction with patients with hemophilia.

There is still a need for timely and modern prevention of major dental diseases in such patients, raising awareness of the need for prevention. This will help to avoid complications, invasive treatment and improve the level of dental care for patients suffering from hemophilia.

When treating such patients, a pediatric dentist must understand and be aware that he is, first and foremost, a doctor, and this concept includes strict adherence to the doctor's oath, moral principles, and guarantees the child's right to maintain dental health.

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# TERATOGENIC EFFECT OF THE PHARMACOLOGICAL PREPARATION OF L-TYPE CALCIUM CHANNEL BLOCKER NIFEDIPINE ON PRENATAL LUNG ORGANOGENESIS

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***Abstract.*** *The influence of hypotensive drug nifedipine – blocker of potential-dependent L-type calcium channels derivative of dihydropyridine on morphological features of prenatal organogenesis of the lungs of Wistar's rat embryos on the 21-st day of prenatal development was studied. Four groups of 25 embryos each,*

*from 13 days to 21 days of prenatal development, were examined. The embryos of the experimental groups received therapeutic, subtoxic and toxic nifedipine doses. Analysis of the data obtained shows the dose-dependent nature of the negative effect of the studied hypotensive drug on lung organogenesis, which is confirmed by the studied indicators. The therapeutic and subtoxic dose of nifedipine has no effect on lung organogenesis. The toxic dose of nifedipine leads to thinning of the bronchus wall due to the absence of smooth muscles and cartilage in medium-sized bronchi, as well as narrowing of the lumen. The diameter of the internal bronchi is 29.27± 0.01% smaller, and their area is 31.11± 0.01% smaller as compared to the lungs of intact rat embryos. It is noted a reduction of the airway and respiratory sections of the lungs, as well as an interstitial tissue predominance. Small hemorrhages are present throughout the interstitial tissue and in the lumens of single bronchi.*

***Keywords:*** *rat embryo, nifedipine, lungs, organogenesis.*

**Introduction**

Only certain hypotensive drugs are allowed for the treatment of hypertensive disease in pregnancy [1]. It should be kept in mind that there are no absolutely safe drugs for treating arterial hypertension in pregnant women [2]. All antihypertensive drugs to some extent pass through the placenta and are potentially capable of having an undesirable effect on the fetus, newborn and/or further development of the child [3]. After the mother has taken nifedipine, it is determined in the fetal blood [4]. According to the FDA (Food and Drug Administration) guidelines which determine the possibility of using pharmacological preparations in pregnancy, the preparations from the group of calcium channels blockers, according to their action on fetus, are classified as category C [5]. Calcium antagonists is a diverse group of drugs with heterogeneous chemical structure and pharmacological properties, whose common characteristic is competitive antagonism in relation to potential-dependent calcium channels. Cardiologists use in their practice calcium antagonists exclusively, which act predominantly on potential-dependent L-type calcium channels. Nifedipine is a blocker of L-type calcium channels (where L means long-lasting, with large channel conductivity) is able to hold down the penetration of calcium ions into smooth muscle blood vessels through these «slow» cell membrane channels. The medication induces arterial vasodilation, reduces the overall peripheral resistance of the vessels, and lowers the arterial pressure [6]. In connection with the above matter, the aim of this study is to investigate morphological features of prenatal organogenesis of rat lungs by the 21-st day of intrauterine development under the influence of L-type blocker of voltage-sensitive calcium channels of dihydropyridine nifedipine derivative.

**Research methods and materials**

We use in the study 100 lungs of embryos of Wistar's female white rats from control group, and from three experimental groups at the age of 13, 15, 17, 19 and 21 days. Three experimental groups were composed of rats receiving therapeutic, subtoxic and toxic nifedipine doses. By daily examination of vaginal smears, a group of animals with dated gestation period was formed [7]. The experiments were carried out in accordance with the principles of humanity laid down in the European Community Directive (86/609/EC) and according to the «Rules for work using experimental animals».

The nifedipine dose calculation (Corinfar, AWD pharma, Germany) was based on recommendations [8].

Formula for calculation: $\frac{\mathbf{r} \cdot \text{dose for human,}}{R}$

where **r** is the species endurance factor for rats = **3.62**,

**R** is the species endurance factor for humans = **0.57.**

The calculation of nifedipine doses was based on therapeutic, subtoxic and toxic doses for humans. The therapeutic dose for human is 20mg/kg, whereas for rat it is 127mg/kg; subtoxic dose for human - 80mg/kg whereas for rat it is 508mg/kg; and toxic dose for human is 120mg/kg but for rat it is 762mg/kg.

The test substance was administered to females from the eighth day of pregnancy by intragastric administration with a probe once per day at the same time. In each group, upon attainment of 13, 15, 17, 19 and 21 days of pregnancy, the females were removed from the experiment by decapitation under ether anesthesia. Taking into consideration the circadian rhythm, sacrifice was performed at the same time. The abdominal cavity and the uterine horns were opened. The embryos were removed, externally examined and quickly fixed with 10% neutral formalin. The material was embedded in paraffin, and then serial cuts of 5-micron thickness were made. Paraffin slices were applied to the glass with adhesive polylysine coating and dried in a thermoregulator for 48-72 hours at a temperature of 42° - 45°C. The resulting preparations were stained with hematoxylin and eosin.

The diameter of internal bronchi and area occupied by bronchi were studied with the help of "ImageJ" per high powered (x400) field of light microscope «Olympus» SCH40 with 50 measurements on a slice. The specific area of the bronchi was calculated as a percentage of the area of lungs in sections. In each organogenesis of lungs period studied, statistical samples of diameter of the bronchial tubes and specific area of the bronchi as related to the control group or to each indicator in the previous period, were carried out using the program MS Office Excel 2007 and STATISTICA 10.0 Enterprise (StatSoft Inc., USA), with the help of Mann-Whitney criterion (U-criterion) with statistical control status of p=0.05.

Statistical methods included normal distribution according to Shapiro-Wilk W test, Mann-Whitney two-taled test, while panel data were described by median, and midhinge (Inter Quartile Range) [9].

**Results**

In all 4 studied groups the organogenesis stage of the lungs was identical up to 19 days of prenatal development. Morphological features of organogenesis were revealed in the canalicular stage of organ development, starting from the 21-st day of gestation.

In the lungs of embryos under nifedipine administration at the age of 21 day, a similar dose-dependent morphological pattern was observed. In this age, nifedipine has a noticeable effect on lung development. When a therapeutic dose is administered, the bronchial tree shows all the control sections available. The wall of the large bronchus has hyaline half-rings, plates and smooth muscles. Fluid is present in the lumen of the bronchus. Alveolar passages and sacculations are formed. However, they are smaller and their clearance is significantly narrower than in the embryos developed under normal conditions. In the presence of subtoxic dose of nifedipine, the bronchial tree is formed, filled with liquid, but the wall of the bronchus is thinner and does not have all the components required. The components of the respiratory lung are separated by very thick layers of embryonic connective tissue. Blood vessels are filled with blood, congested. When nifedipine is administered, the structure and size of the bronchi do not correspond to those under control. Median of bronchus diameter is 29.27± 0.01% less as against the control group (Table 1). Median bronchus area is 31.11± 0.01% less than in control group. Smooth muscles and hyaline

***Table 1.***

*Series of bronchus diameter as against specific area of the bronchi in control group and in that with toxic dose of nifedipine*

| D | Experimental group. Toxic dose of nifedipine midhinge (Inter Quartile Range) | Control group. Midhinge (Inter Quartile Range) | P-value | Studied structures |
|---|---|---|---|---|
| 21 | 430,55 (407,15-433,26)* | 608,73 (561,01-633,05) | <0,01 | Diameter of internal bronchi in μM |
| 21 | 62,05 (53,28-64,01)* | 90,07 (84,21-92,03) | <0,01 | Specific area of bronchi as % |

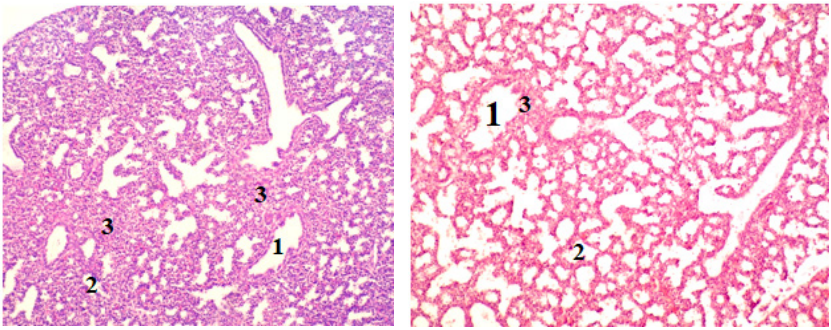
Note: *Statistical significance as against control P= 0,05.

plates are present in the largest internal bronchi only. Branching of bronchi is delayed, respiratory bronchioles develop, but they are small in number and their lumens are significantly narrower as against the control group (Fig.1). There is no evidence of alveoli anlage. Interlayers of the embryonal connective tissue have become thinner, but not enough to match the control ones. The gaps between bronchus remain quite wide. There are isolated hemorrhages in the interstitial tissue and in the clearance of bronchi.

Discussion

Pharmacological and teratogenic effect of calcium channel blocker nifedipine on embryo is not studied enough. Therefore, the doctor prescribing this medicine takes responsibility for the life and health not only of the mother but also of the embryo [10].

According to our studies on lung histopathology in mice without damaging factors, the period of first signs of lung anlage from the 13rd to 18th days is characterized by the process of branching of the right and left epithelial tubes forming the bronchial tree. Fast branching rate occurs simultaneously with intensive growth of bronchi in width. The finite number of bronchi generations appears within 18 days. However, the principle branching in the lungs continues and leads to the appearance of a respiratory section of the lungs. The initial sections of the acini are formed within 19-20 days as a result of the forking of the terminal bronchioles.




*A* *B*

***Figure 1.*** *Lung section of rat embryo at the age of 23 gestational days. Anlages of the lungs with medium (1) and small-caliber (2) bronchi and surrounding embryonic connective tissue (3). Hematoxylin and eosin stain. A - Control group. B - Nifedipine toxic dose. (x150).*

At the end of pregnancy, in 21-day embryos, there is an evident predominance of the respiratory section over the airways. Bronchi are present by 2-3 layers of low columnar epithelium, but then, as a result of proliferation, it acquires a stratified structure. Its differentiation occurs under the influence of mesenchymal cells, which in turn is differentiated into its derivatives by inductive action of the epithelium. Close relationship between epithelium and mesenchyme at both cellular and systemic levels is a necessary condition for lung morphogenesis [11].

However, the therapeutic dose of nifedipine does not yet result in noticeable morphological changes in lung anlages as compared to the control group. The subtoxic dose causes little noticeable changes. Bronchial branches are consistent

with control group, but the diameter of bronchi is somewhat narrowed. When exposed to the toxic dose of nifedipine, there is a decrease in the number of small-caliber bronchi and terminal bronchioles, which is consistent with data from Nawal Ahmed Said et al, 2019 [12]. Bronchi have a smaller diameter than in control group. By the 21st day, the difference with the control group is almost one third - 29.27± 0.01%, and the area occupied by bronchi has been reduced by 31.11± 0.01%. In our study we also reported the occurrence of hematomas in the lungs after subtoxic and toxic nifedipine doses.

**Conclusion**

When introducing calcium L-channel blocker nifedipine, lung development in the rat embryos is dose-dependent. By the 21st day, the diameter of the airways and respiratory section is reduced and single hemorrhages in the lung stroma are noted. The toxic dose of nifedipine leads to thinning of the bronchial wall due to the absence of smooth muscles and cartilage in medium bronchi, as well as to the narrowing of the lumen. The diameter of the internal bronchi is 29.27± 0.01% smaller, and their area is 31.11± 0.01% smaller than that of the lungs of innate embryos of rats. In is noted reduction of airways and respiratory section, as well as the predominance of interstitial tissue. Small hemorrhages are present throughout the interstitial tissue and in the lumens of single bronchi.

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# MODELLING OF WATER REMOVAL FROM THE GAS GATHERING UNIT OF GAS CONDENSATE FIELDS BY GAS FLOW

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***Abstract.*** *Exploitation of gas fields located in the Far North is complicated by severe climatic conditions. One of the problems is the removal of water accumulations. Optimal from the point of view of energy efficiency is the removal by the gas flow itself. It is shown that in this case the flow velocity should exceed some critical value. A mathematical model of this velocity is obtained, linking the loop diameter, the volume of water accumulation and the properties of liquid and gas phases of the medium moving along the loop.*

***Keywords:*** *gas gathering unit, loop, water accumulation, π-theorem, dimension theory.*

## Introduction

Many large oil and gas condensate fields (OGCFs) in the Russian Federation located in the Far North are now entering the final stage of operation, or the so-called declining production stage. It is characterised by such features as lower reservoir pressure, reduced gas production, watering of gas wells, and accumulation of liquids in low sections of the gas gathering unit (loops).

At the final stage, the number of technological complications, such as water cuttings and failure, is constantly increasing. As a consequence, the probability of ice plugs and hydrates formation increases. Changes in well performance are much more frequent compared to the commercial production stage. Therefore, the data obtained as a result of periodic hydrodynamic studies are clearly insufficient for prompt response to emerging complications.

In addition, downhole equipment (production tubing) and gas gathering unit (GGU) were designed to minimise hydraulic losses at maximum gas flow rates, while ensuring permanent water removal from all sections of the system. For ex-

ample, the Urengoy field facilities were designed to maximise gas production, which peaked 30 years ago. Since then, the volume of gas produced has decreased several times. At present, at the final stage of development, with the reduced gas production volumes in the existing GGU, there are no more conditions for constant water withdrawal (in steady state), so the number of wells and loops operating with liquid accumulation is increasing. The constantly increasing water cut of gas due to the gas-water contact (GWC) pulling up to the bottom of the wells also contributes to this situation. This situation will only worsen over time, so gas producers are considering and testing various technologies and techniques to adapt existing GGUs to accommodate the dramatically reduced gas flow rates.

These problems are the subject of many studies [1, 2], which offer various ways to solve them, both technological and constructive. At the same time, some problems can be solved by changing the concept of construction of the gas field ACS, for example, by wider use of various models, including cognitive models, virtual analysers, introduction of predictive diagnostics elements, continuous monitoring of some parameters, etc.

The cluster arrangement of wells is also an effective measure to reduce field development costs. At the same time, it requires compliance with additional conditions: elimination of mutual squeezing and reverse flows between cluster wells, as well as between clusters connected to a common reservoir [3]. Therefore, in the operation of clusters, it is necessary to prevent water accumulation in loops.

During the falling production phase, wells often self-pressurise or completely shut-in due to pressure build-up at the top of the well. Currently, there are many developed methods and systems for cleaning the loop and pipeline from liquid accumulations, which are discussed in detail in [4]. However, the most commonly used method of maintaining the well stock and gas gathering unit (GGU) in working condition is flare purging. This method has a number of significant disadvantages, such as irretrievable loss of part of recoverable production and environmental pollution, but the main problem of this method is the physical impossibility of constantly blowing out a large number of points in the system.

Consequently, the task of developing a system for removing fluid from a gas well cluster (GWC) loop is relevant and of paramount importance today.

**Statement of the research task**

The review conducted in [4] allows us to conclude that to date there are no approved methods for cleaning loops from liquid accumulations, and the technical solutions described in the literature are either related to main pipelines or do not provide the required quality of cleaning.

The most efficient method of water removal from the loop is the removal of liquid accumulations by means of the energy of the transported gas itself, without releasing the gas into the atmosphere. However, in order to develop a technical

system that realises this principle, it is necessary to obtain a mathematical model describing the dynamics of accumulation removal as the gas moves along the loop.

**Results and their discussion**

In [5] it is shown that when a gas-liquid flow moves along a loop, the key parameters are the pipeline diameter H, since the throughput capacity of the loop depends on it, the angle of inclination of the upstream section $\alpha$, which affects the flow regime, liquid density $\rho_{ж}$ which has a significant influence on the pressure in the loop, and its quantity $V_{ж}$. Other influencing factors include the density of the gas $\rho_г$ and viscosity of the liquid cluster $\mu_{ж}$.

Then the critical velocity of gas-liquid flow $U_{flow}$, which should ensure water removal from the U-shaped elbow can be represented as a function of

$$U_{cr} = F(H, \rho_l, V_l, \mu_l, \sin\alpha, \rho_g, g), \quad (1)$$

where $g$ - free-fall acceleration, m/s$^2$ .

On each particular loop, the parameters of the density of the liquid accumulation $\rho_{ж}$, viscosity of the liquid accumulation $\mu_{ж}$ and the angle of inclination of the pipeline to the horizon $\alpha$ may vary within certain ranges. Possible values of the parameters are summarised in table 1, using the Urengoy OGCF as an example. The pipeline diameter H and acceleration g are constant values. The gas density is also assumed to be constant $\rho_г$.

***Table 1***

*Ranges of density variation, fluid viscosity and loop angle values*

| Parameter | Variation range |
|---|---|
| Density of liquid accumulation $\rho_l$ kg/m$^3$ | 850-1210 |
| Viscosity of liquid accumulation $\mu_l$ cSt | 1-65 |
| Angle of inclination of the ascending section to the horizon $\alpha$, ° | 3-9 |

To obtain a model, we can use the so-called π-theorem, which states: the complete equation of a physical process written in a certain system of units can be represented by a dependence between similarity criteria, i.e. a dependence linking dimensionless quantities obtained in a certain way from the parameters existing in the process [6]. It follows that if some functional dependence exists for the phenomenon under consideration, i.e. the parameters are known, but its mathematical description is unknown, it is possible to obtain similarity criteria. In this case, the number of parameters is reduced by expressing them through the dimensions of the basic quantities (mass, length, time, temperature, current, quantity of matter and light intensity). A similar approach has been used in a number of studies, for example, in [5] to build a model of gas flow in a main gas pipeline.

According to this approach, equation (1) can be written in the following form

$$\Pi = f(\Pi_1, \Pi_2, ...\Pi_{(n-r)}), \quad (2)$$

where $\Pi$, $\Pi_1$ , $\Pi_2$ , ..., $\Pi_{(n-r)}$ are dimensionless complexes; n is the initial number of parameters in the function; r is the number of basic (primary) magnitudes by means of which the dimensionality of the initial parameters can be represented.

Three primary units of measurement are used in hydrodynamics: mass M, time T, length L [7].

The parameters H [m], $\rho_l$ [kg/m$^3$], g [m/s$^2$], for example, can be selected as their corresponding parameters. The selection is made so that all three basic quantities are present in these parameters. The number of similarity criteria is always equal to the difference between the number of parameters involved (n) and the fundamental quantities (r). In this case, r = 3, n = 7, i.e. the number of similarity criteria is 4.

Thus, equation (2) can be rewritten as

$$\Pi = f(\Pi_1, \Pi_2, \Pi_3). \quad (3)$$

Expressions for dimensionless complexes $\Pi_i$ are defined in accordance with the dimensionality theory [8]. Function (1) can be represented through the selected parameters in the form of

$$[U_{cr}] = [g]^{A_1}[H]^{A_2} \cdot [\rho_l]^{A_3}, \quad (4)$$

or through primary units of measurement

$$M^0LT^{-1} = (M^0L^1T^{-2})^{A_1}(M^0L^1T^0)^{A_2} \cdot (M^1L^{-3}T^0)^{A_3}. \quad (5)$$

Equating the exponents of the degrees of the same symbols of the basic units in the left and right parts of equation (5), a system of three linear equations is obtained:

$$\begin{cases} 0 = 0 * A_1 + 0 * A_2 + 0 * A_3 \\ 1 = A_1 + A_2 + (-3) * A_3 \\ -1 = (-2) * A_1 + 0 * A_2 + 0 * A_3 \end{cases}, \quad (6)$$

the solution of which will be the values of the coefficients $A_1$=$A_2$=$\frac{1}{2}$, $A_3 = 0$.

Then equation (4) will take the form

$$[U_{cr}] = [g]^{1/2}[H]^{1/2} = \sqrt{[g][H]}. \quad (7)$$

dimensionless complex $\Pi$ can be written in the form

$$\Pi = \frac{U_{cr}}{\sqrt{gH}}. \quad (8)$$

The dimensionality of liquid and gas densities are the same, so the dimensionless complex $\Pi_1$ can be represented as:

$$\Pi_1 = \frac{\rho_l}{\rho_g}. \quad (9)$$

When finding dimensionless similarity criteria it is necessary to take into account, as far as possible, their similarity with real processes. In this case, it is necessary to take into account that the gas density in the real gas pipeline varies directly proportional to the gas pressure, which means that the dimensionless criteria in the model and in the real gas pipeline will be different. It is logical to assume that, all other things being equal, it is easier to carry the liquid out at higher

gas densities. In this case, the critical velocity calculated by the model will be applicable in the real pipeline only for a smaller angle. Then we can assume that the dimensionless complex has the following form

$$\Pi_1 = \frac{\rho_l * \sin\alpha}{\rho_g}. \quad (10)$$

The expressions $\Pi_2$ and $\Pi_3$ are similarly found:

$$\Pi_2 = \frac{v_l}{\sqrt{gH^s}}, \quad (11)$$

$$\Pi_3 = \frac{V}{H^s}. \quad (12)$$

After defining all dimensionless complexes, equation (3) can be represented as:

$$\frac{U_{cr}}{\sqrt{gH}} = f\left(\frac{\rho_l * \sin\alpha}{\rho_g}, \frac{\mu_l}{\sqrt{gH^s}}, \frac{V}{H^s}\right) \quad (13)$$

or, considering expressions (10) - (12), in the form of the criterion equation

$$U_{cr} = A_0 * \left(\frac{\rho_l * \sin(\alpha)}{\rho_g}\right)^{A_1} * \left(\frac{\mu_l}{\sqrt{gH^s}}\right)^{A_2} * \left(\frac{V}{H^s}\right)^{A_3} * \sqrt{gH}, \quad (14)$$

where $A_0$ - $A_3$ - are constant numerical coefficients.

The COMSOL Multiphysics programme [9] was used to obtain specific values of these coefficients.

The equation obtained in the course of modelling and data processing has the following form

$$U_{cr} = 3{,}56 * \left(\frac{\rho_l * \sin(\alpha)}{\rho_g}\right)^{0{,}197} * \left(\frac{\mu_l}{\sqrt{gH^s}}\right)^{-0{,}027} * \left(\frac{V}{H^s}\right)^{0{,}031} * \sqrt{gH}. \quad (15)$$

To assess the adequacy of the model, the parameter values were used, which were obtained during the well blowout through the gas gathering pipeline at the Urengoy gas treatment unit (GTU), conducted in January 2023. The estimation was performed on the basis of Fisher's F-criterion [10]:

$$F = \frac{S^2_{act.}}{S^2_{res.}}, \quad (16)$$

where $S^2_{act.}$ - actual variance; $S^2_{res.}$ - residual variance.

The variance characterising the experiment error is calculated by the formula:

$$S^2_{act.} = \frac{1}{n-m-1}\sum_{l=1}^{N}(Y_l - \bar{Y}_l)^2, \quad (17)$$

where n is the number of observations; m is the number of varying experimental factors; $Y_l$ - measured value of the critical velocity in the experiment; $l$ - order of the gas flow velocity value; $\bar{Y}_l$ - calculated value of critical velocity by formula (15).

The variance characterising the experiment error (residual variance) is calculated by the formula:

$$S^2_{act.} = \frac{1}{N(m-1)}\sum_{l=1}^{N}\sum_{t=1}^{m}(Y_{lt} - Y_l)^2, \quad (18)$$

where m is the number of repetitions of experiments; $Y_{lt}$ - measured value of the critical velocity at repeated experiment $t$.

The model is considered adequate if the condition $F \leq F_{tab}$ is fulfilled, and the tabular value of $F_{tab}$ is selected based on the accepted significance level [10]. In this study it is taken as 0.05 or 5 %, i.e. fulfilment of the condition $F \leq F_{tab}$ means that equation (15) adequately describes the process of liquid accumulation removal from the reduced pipeline section in 95 % of cases.

Calculation of the gas flow velocity $U_{cr}$ was performed for three experiments. Initial data for calculation: gas flow density $\rho_г$ =1.2 kg/m$^3$ , free fall acceleration g = 9.81 m/s$^2$ , other data are taken from table 1. The volume of the accumulated liquid V is taken equal to 20 m$^3$ .

The obtained values of variance $S^2_{act} = 0{,}01214$, a $S^2_{res} = 0{,}0094$. The value of Fisher's criterion is F = 1.29. For 5% significance level $F_{tab}$ = 1,4 [10]. The inequality $F \leq F_{tab}$ is fulfilled, therefore, the obtained model is adequate.

**Conclusion**

The problem of water removal from gas gathering unit loops is relevant for almost all gas fields. The problem is particularly acute for northern fields, as the extremely low winter temperatures cause water to instantly turn into ice plugs.

The optimal way of water removal from the point of view of energy consumption is removal by the gas flow itself. This is possible if the flow velocity exceeds a certain critical velocity. At the same time, the parameters influencing the process of removal of liquid accumulation from the low section of the loop are the pipeline diameter, the angle of inclination of the low section of the pipeline, the density of liquid and gas, the viscosity of liquid, the volume of liquid accumulation.

As a result of the conducted research on the basis of the theory of dimensions and π-theorem, the criterion equation for determining the critical gas flow velocity ($U_{cr}$), which is able to ensure water removal from the U-shaped elbow.

The process of liquid accumulation removal by gas flow was modelled in COMSOL Multiphysics software. The adequacy of the model was verified on the experimental data obtained at the Urengoy OGCF. The practical significance of the obtained results lies in the possibility of building an automatic control system for a gas well cluster on the basis of this model.

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# DOMINANT VIOLATIONS OF HYDRAULIC STRUCTURES OF WATER BODIES OF THE STEPPE LANDSCAPE ZONE OF THE SOUTHERN URALS

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***Abstract.*** *The article considers the results of visual inspections of hydraulic structures of water bodies of the steppe landscape zone of the Southern Urals using the example of reservoirs of the Bolshoy Yushatyr River basin. The composition and types of hydraulic structures of hydraulic structures, their technical condition, and dominant violations are identified. It has been established that most of the reservoirs are channel ponds and their dams are earthen embankments. Dominant violations of hydraulic structures and their hydraulic structures: overgrowing with grass, reeds, bushes and trees; partial erosion of the crest and slopes; destruction of parts of spillways from the side of the upper and lower pools.*

***Keywords:*** *water body, reservoir, channel pond, hydraulic structures, slopes, crest, pools, overgrowing, erosion, destruction.*

Currently, the method of neural network modeling is beginning to gain widespread acceptance in processing remote sensing data for identifying water bodies, determining their parameters (surface area) and calculating water management balances of rivers in terms of specifying losses due to additional evaporation from the surface of water bodies.

Considering that modern methods of decoding remote sensing data from space do not allow for sufficiently accurate determination of bathymetric data of water bodies and have fairly high requirements for the spatial resolution of images and water transparency, route surveys are required to determine the volumes of water bodies. Route surveys, along with engineering and hydrological surveys, provide for visual inspections of the state of hydraulic structures and identification of dominant violations in them.

The aim of the work is to establish dominant violations of hydraulic structures of water bodies of the steppe landscape zone of the Southern Urals based on their visual surveys using the example of reservoirs of the Bolshoy Yushatyr River basin. To achieve the set goal, the following tasks were solved:

- identification of natural-climatic and engineering-hydrological conditions of the Bolshoy Yushatyr River basin;
- establishment of a list of water bodies in the Bolshoy Yushatyr River basin for visual inspection;
- analysis of the results of visual inspection of water bodies in the Bolshoy Yushatyr River basin.

The territory of the Bolshoy Yushatyr River catchment basin is located in the steppe zone in the south of the Republic of Bashkortostan and in the north of the Orenburg region, in the northern part of Obshchy Syrt. The relief is undulating, heavily dissected by large ridges and hollows.

The Bolshoy Yushatyr River is a left tributary of the Salmysh River. The mouth of the river is located 55 km along the left bank of the Salmysh River. The length of the river is 92 km. The catchment area is 3.4 thousand $m^2$.

According to the State Water Register of Russia, the river belongs to the Ural Basin District, the water management section of the river is Sakmara from the confluence of the Bolshoy Ik River to the mouth. The river basin of the river is the Ural (Russian part of the basin). The object code in the State Water Register is 12010000712112200006831 [1]. The Bolshoy Yushatyr River has 17 tributaries, of which 8 rivers are 1st order tributaries, 7 rivers are 2nd order tributaries and 2 rivers are 3rd order tributaries. There are 10 left tributaries of the river, 7 right tributaries. The longest tributary is the Kuyanysh River (71 km), the largest catchment area is the M. Kuyurgaza River (360 $km^2$). The lengths of the rivers vary from 10.0 km to 71.0 km, and the catchment areas - from 30 $km^2$ to 666 $km^2$ [2].

A map-scheme of the location of water bodies in the Bolshoy Yushatyr River basin is shown in the figure.

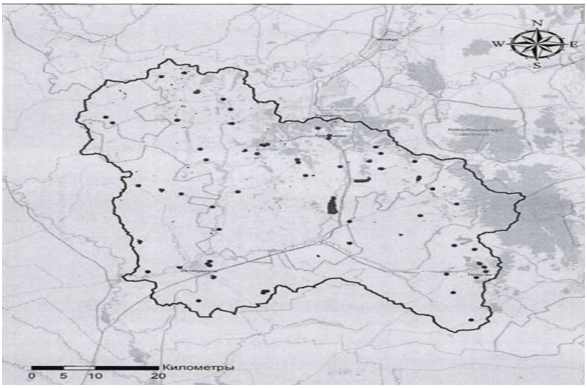


***Figure.*** *Map of the location of reservoirs in the Bolshoy Yushatyr River basin: the locations of reservoirs are indicated by black marks.*

The largest reservoirs in the basin are: Aksarovskoye (Yushatyrskoye) reservoir on the B. Yushatyr River with a water surface area of 8800 thousand m2 and a volume of 49000 thousand m3, Otradnoye reservoir on the Kuyanysh River with a water surface area of 1680 thousand m2 and a volume of 9850 thousand m3.

The reservoirs of the Bolshoy Yushatyr River basin are located in four districts of two subjects of the Russian Federation:

- districts of the Orenburg region: Tyulgansky (20 units), Oktyabrsky (19 units), Sharlyksky (5 units);
- Kuyurgazinsky district of the Republic of Bashkortostan (75 units).

Before the start of field work on visual inspection of hydraulic structures of water bodies, a survey route was drawn up. After arriving at the survey area, the route drawn up in advance had to be adjusted taking into account local features, field and country roads, the presence of bridges and fords, weather conditions, etc. Local specialists familiar with the area were involved in optimizing the visual survey route.

Visual surveys of hydraulic structures included:

- inspection of water bodies and their hydraulic structures with the preparation of inspection reports;
- visual establishment of the hydraulic connection of the reservoir with other water bodies;
- photographing the structural elements of hydraulic structures and the general appearance of the reservoir;
- recording the coordinates of the hydraulic structures of water bodies with a GPS navigator.

The survey of water bodies and their hydraulic structures was carried out visually, recording any deficiencies in the survey report. The survey report lists the types of structural elements of hydraulic structures of water bodies and their technical conditions. Hydraulic connection was established visually, while checking with Yandex maps (type: hybrid). The presence or absence of hydraulic connection was recorded in the survey reports. Permanent hydraulic connection was present in 67%, partial (during spring and summer floods) - in 8% and absent - in 25% of the surveyed water bodies.

The coordinates of the middle points of the dams of the hydraulic structures were recorded by a GPS navigator. In the process of processing the measurement results, the coordinates of the corresponding points were compared by the echo sounder and by the navigator to establish the reliability of the obtained results. The results of the navigator's measurements of the coordinates of the hydraulic structures were recorded in the survey reports of the water bodies.

The survey reports indicated information on the location of the water body in free form, the geographic coordinates of the water body, the dates of the survey, information on hydraulic structures and hydrological connection with other surface water bodies, photography of the water bodies and their structures. 82 survey reports of water bodies were prepared. Based on the results of the survey of water bodies, a comprehensive analysis of the composition of hydraulic structures of the hydroelectric complexes, types of hydraulic structures and their technical conditions was carried out:

- of the surveyed water bodies, 63% are channel ponds, 11% are reservoirs (large ponds), 9% are lakes or filling ponds, 8% are flooded quarries or isolated ponds, 9% are others;

- 84% of hydroelectric complexes have dams, 87% have spillways, 28% have water outlets, 23% have ice protection devices, 7% have emergency channels;

- all dams, except one, are earthen embankments, one is rock and earth.

The main violations of the structural elements of the hydraulic structure (crest, slopes, inlet and outlet heads) were revealed:

- in 24% of cases the dam crest is impassable, in 76% - passable, of which 16% are service roads, and 3% are country roads. Crest material: soil (67%), crushed stone (11%), asphalt, sand and gravel mix, slag (22%). Technical condition: in 14% - good, in 56% - satisfactory and in 30% - poor. The main violations of the crest: overgrowing with grass, bushes and trees in 16%; partial erosion and narrowing of the crest in 16%; formation of a gap in 4% of cases;

- upstream slope stabilization: by sowing grass (77%), rock fill and reinforced concrete slabs (6%), isolated cases - stabilization with tires, concrete blocks, slag backfill; in 10% of cases there was no stabilization. Technical condition: in 7% - good, in 70% - satisfactory, in 23% - poor. The main disturbances of the upstream

slope: overgrowing with reeds, grass, bushes, trees (54%), partial slope erosion (19%), isolated cases - slope disturbance by cattle;

- downstream slope stabilization: by sowing grass (87%), rock fill and crushed stone (6%), in 7% of cases there was no stabilization. Technical condition: in 7% - good, in 77% - satisfactory, in 16% - poor. The main downstream slope violations: overgrowing with reeds, grass, bushes and trees (43%), slope erosion (13%); - 87% of hydraulic structures have spillways: bucket (31%), bucketless (24%), shaft and siphon (7%), in the form of pipes (horizontal, vertical, overflow) (26%), in the form of a socket wall, open chute, stopcock (7%), other (5%). The energy dissipation of the flow in the lower pool is organized in the form of a pipe (77%), a stilling wall, a well, a tray with a spillway and a console (23%). Technical condition: in 6% - good, in 75% - satisfactory and in 19% - poor. The main violations of the spillway: overgrowing with grass, bushes and trees (28%), destruction of a part of the spillway in the lower pool (washout funnel, destroyed discharge channel, destroyed outlet head, severe erosion near the pipe, etc.) (32%), destruction of a part of the spillway from the upper pool side (the gate does not work, there is a blockage of trees and debris at the inlet, the stopcocks do not work, the bucket perimeter is overgrown with bushes, etc.) (17%); - in 72% of hydraulic structures, water outlets are missing or visually invisible, in the rest there are tubular ones. They are mainly used to discharge water and for technical needs. Technical condition: 15% - good, 70% - satisfactory and 15% - poor. The main violations are isolated (pipe washouts from the downstream side, overgrowing with trees and bushes, difficult access, out of order); - 77% of hydraulic structures do not have ice protection devices, while the rest have them mainly in the form of piles (reinforced concrete, metal) and metal pipes with fences. Technical condition: 7% - good, 71% - satisfactory and 2% - poor. The main violations are: violations of the protective fence (21%), partial destruction of scaffolding (7%). Thus, it was established that the majority of the surveyed reservoirs are channel ponds and their dams are earthen fill dams. The dominant violations of the hydraulic structures and their hydraulic structures are as follows: overgrowing with grass, reeds, bushes and trees; partial erosion of the crest and slopes; destruction of parts of spillways from the upper and lower pools.

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# ANALYSIS OF STRENGTH CHARACTERISTICS AND HYDRODYNAMIC MODELING IN A TURBULENT MIXER

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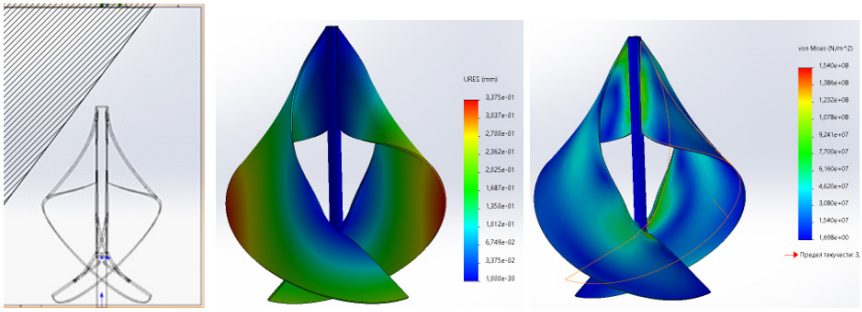
***Abstract.*** *The article discusses the main characteristics of solutions, the description of the new working body is given. Strength calculations of the elements of the turbulent mixer have been carried out (working body, inclined partition), as well as hydrodynamic modeling, as a result of which the following are obtained: maximum Mises displacements and stresses; trajectories of particle motion with phase portraits of changes in flow velocities at various design and technological parameters.*

***Keywords:*** *turbulent mixer, solution, hydrodynamic modeling, phase portrait, technological and design parameters, strength calculations.*

Masonry mortar is a building material used in the construction of houses, finishing of buildings, facilities, filling seams, etc. Over the past 3 years, the consumption of masonry mortars has increased by 25 %: from 16 thousand tons to 20 thousand tons.

The composition of this material includes the following components: sand, cement, water. Their ratio is adjusted depending on the characteristics, required for a particular task, as well as the necessary properties of the final product. The quality of masonry mortars depends on the following characteristics: plasticity, water retention capacity, etc. [1]. Due to these properties, it does not delaminate during transportation, does not lose mobility when laid on a porous base and it does not crack during the hardening process. Therefore, turbulent mixers are used to ensure the above-described properties, allowing to organize circulation and vortex flows of material above the loading level.

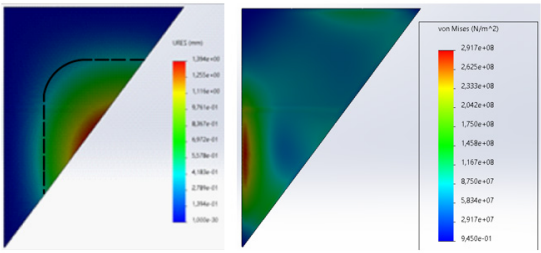
For this purpose, a new vertical screw working body has been developed (Fig. 1, a) [2], ensuring the creation of circulating and vortex flows of material. It is made by twisting two arc-shaped surfaces at an angle $\alpha = 270^0$ around its own axis, forming blades. An inclined partition was additionally used to create vortex flows and chaotic movement of the mixture (Fig. 1, a), located in the upper part of the mixer body. With the help of the SolidWorks Simulation software product, the strength calculation of the working body of the mixer and the partition was carried out. The calculation showed, that the maximum displacement of the blades was 0,375 mm in the wide part outside (Fig. 1, b), and the maximum voltage according to Mises is $1{,}1 \cdot 10^{-8}$ N/m$^2$ (Fig. 1, c) in the widest parts of the screw blades inside and in the upper area of the blade attachment to the shaft. The values of maximum displacements and stresses do not exceed the strength conditions of the material, what makes it possible to use it in these conditions.



a) b) c)

***Figure 1.*** *Digital model of a turbulent mixer with a new screw vertical working body and an inclined partition (a); changing the maximum displacements of the blade elements (b); Mises stress distribution in the screw working body (c)*

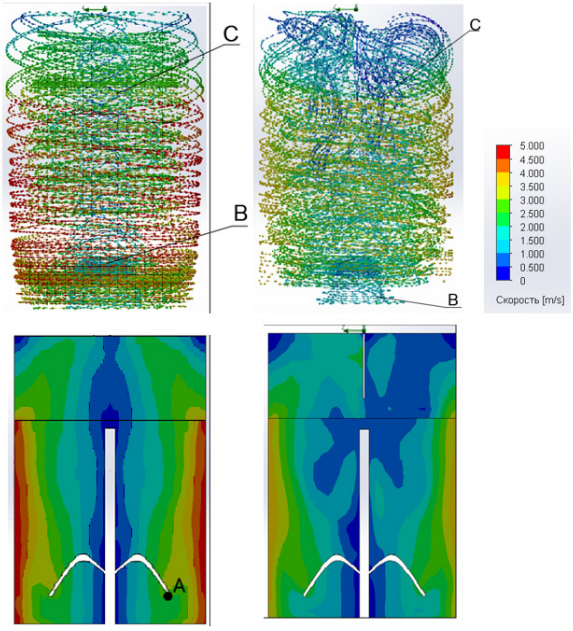
In the inclined partition (Fig. 2), the maximum displacement was 1,34 mm and the maximum Mises voltage $2{,}9 \cdot 10^{-8}$ N/m$^2$ mm in the central part. Because during long-term operation, the main wear falls on the most loaded part, that, from the point of view of constructive execution. We can assume, that it is advisable to use a partition Г- shaped shapes with a rounded inner corner. At the same time, the maximum stresses are concentrated in the places where the partition is attached to the walls of the mixing chamber, which sets more stringent requirements for the mounting method [3].




a) b)

***Figure 2.*** *Changing the maximum movements (a) and the Mises stress distribution (b) in the inclined partition*

As a result of hydrodynamic modeling, the trajectories of particle motion are obtained and phase portraits at a load factor $K_z$=0,7 and the rotation frequency of the working body $n$=500 min$^{-1}$ in models of a turbulent mixer without a partition (Fig. 3, a) and with an inclined partition (Fig. 3, b).




a) b)

***Figure 3.*** *Particle trajectories and phase portraits of velocity changes in a model with a new screw working body (a) and with an inclined partition (b) at short circuit $K_z$ = 0,7 and n=500 min$^{-1}$*

Analysis of trajectories and phase portraits of changes in the velocities of the mixture showed that:

1. At $K_z$ = 0,7 and $n$=500 min$^{-1}$ in a mixer with a new screw working body at the point *A*, in the area where the arc-shaped surfaces of the blades intersect (Fig. 3, a) There is a decrease in the flow rate at the bottom, where the particle velocity varies in the range υ=1,5-2 m/s ($\upsilon_{sr}$=1,75 m/s), after that, most of the particles are accelerated to 4-5 m/s ($\upsilon_{sr}$=1,75 m/s), climbing along a tight spiral path along the walls to the top of the chamber.
2. When accelerating along a circular trajectory of the particle, going up, they lose speed above the loading level in the area *C* to υ=2-3 m/s ($\upsilon_{sr}$=2,5 m/s), and at the surface of the mixing chamber, it decreases to υ=1,5-2 m/s ($\upsilon_{sr}$=1,75 m/s). Hitting the top of the camera, the particles descend along a helical trajectory down along the shaft of the working body, moreover, the maximum diameter of the trajectory is less than the maximum transverse size of the working body. Here there is a transition of a part of the particles from the wall zone to the shaft, they lose speed and move down along the shaft along the helical trajectory, at the same time, large particles fall out.
3. As a result of the installation of an inclined partition, the nature of the movement of the mixture changes, that is, above the loading level, there is a chaotic movement of particles. When they are moved down along the working body, the helical trajectory is destroyed, which contributes to a more intensive mixing of the components of the mixture, and when it is lifted up, the circular trajectory along the chamber wall is stabilized, what has a positive effect on the plasticity of the mixture. At the bottom, in the mounting area of the working body, there is a decrease in the speed of movement of particles.
4. In a chamber with an inclined partition, the velocities of particle movement at $n$=500 min$^{-1}$ decrease: in the zone *B* the travel speeds are equal υ=1-1,5 m/s ($\upsilon_{sr}$=1,25 m/s). As the distance from the shaft increases, the particles accelerate towards the walls of the chamber when rising upwards, mainly to a speed of υ=2-3,5 m/s ($\upsilon_{sr}$=2,75 m/s). Thus, the formation of a screw flow increases the plasticity of the mixture and does not contribute to its stratification [4, 5].

Thus, the use of an inclined partition is advisable when obtaining solutions, because the mixing of the components of the mixture takes place along chaotic trajectories in the upper part of the chamber above the loading level and the helical trajectory is destroyed when the mixture is moved down along the shaft, which reduces the loss of large particles, and also the rise of particles along ordered trajectories stabilizes the mixture, this reduces the stratification of the solution and increases its plasticity.

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# THE INFLUENCE OF DESIGN AND TECHNOLOGICAL PARAMETERS ON THE UNIFORMITY OF THE MIXTURE IN A STATIC MIXER

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***Abstract.*** *The issues of increasing the homogeneity of the mixture in static mixers used in construction and other industries for mixing slips, suspensions, etc. are considered. It is established that the coefficient of uniformity of the mixture depends on the diameter of the chamber, the shape and diameter of the holes, the distance between the mixing elements, their number, pressure and viscosity of liquids. It was revealed that when using an insert in a static mixer in the form of a Maltese cross in an amount of 5-9 pieces, a maximum uniformity coefficient of 100% is achieved.*

***Keywords:*** *static mixer, mixing, uniformity coefficient, mathematical modeling, energy efficiency.*

In various industries, it is necessary to obtain a homogeneous mixture and maintain its stability throughout all subsequent stages of the technological process. For example, in the construction materials industry, various types of mixers are used in production, which are used at the beginning or in the middle of the production line. As a result, there is a problem of leveling the composition of the mixture at the subsequent and output stages of production. To solve this problem, averagers are used in ceramic production [1]. These are devices in which the ceramic mass in the form of a slip, suspension, etc., accumulating for several hours, shifts, days, depending on the technological process, is mixed, while the composition and quality of the mixture is stabilized before being fed to molding. Averagers have significant disadvantages: they are bulky, as a result, energy-intensive and, as a rule, occupy large areas in production.

Therefore, there is a need to search for mixing structures that allow for the uniformity of the mixture at low energy consumption, as well as having small di-

mensions and the ability to easily integrate into the production line. Such devices include static mixers [2,3], which have the following advantages: simplicity of design, due to the absence of moving parts; low energy consumption; small dimensions and relatively low metal consumption; used as an insert in other equipment. For example, at the outlet of the pipeline during transportation to the place of use. The uniformity coefficient of the mixture coming out of the static mixer directly depends on the geometry of the mixing chamber, the type, size of the mixing insert and/or inserts and their design features.

To obtain a mixture with the maximum possible uniformity coefficient (Kmax=1), it is proposed to conduct an experimental study using mathematical modeling and a prototype of a static mixer to identify the necessary design and technological parameters of the device [4, 5].

It is known [6] that the coefficient of uniformity of the mixture in a static mixer with an insert with elements in the form of a Maltese cross (Fig. 1) is associated with a number of design and technological parameters and is described by the formula:

$$K = f(d, d_{отв}, l, n, P, \upsilon, F), \quad (1)$$

where $K$ – is the coefficient of uniformity of the mixture;

$d$ – is the diameter of the mixing chamber, m;

$d_{отв}$ – the diameters of the holes of the mixing elements, m;

$l$ – is the distance between the mixing elements, m;

$n$ – is the number of mixing elements, pcs;

$P$ – is the liquid supply pressure, Pa;

$\upsilon$ – is the viscosity of the mixed liquids, Pa·s;

$F$ – is the shape of the hole of the mixing element, $m^2$.

***Table 1***

*The levels of variation of the main factors*

| The main factors | | The distance between the mixing elements | Number of mixing elements |
|---|---|---|---|
| Designation | | $x_1$ ($l$, мм) | $x_2$ ($n$, шт) |
| Levels of variation | The main level (0) | 20 | 7 |
| | Upper level (+1) | 23 | 8 |
| | Lower level (-1) | 17 | 6 |
| | Star points:<br>upper (+1,68)<br>lower (-1,68) | <br>25<br>15 | <br>9<br>5 |

***Figure 1.*** *Mixing insert with elements in the form of a Maltese cross, which are deployed on an axis relative to each other at an angle of 45 degrees assembled*

After analyzing the function (1) and based on the evaluation tests, the main factors and levels of their variation affecting the uniformity coefficient of the mixture were selected: the distances between the mixing elements *l* and their number *n*:

$$x_1 = \frac{l-20}{3};\ x_2 = \frac{n-7}{1}. \quad (2)$$

Using regression analysis in the form of rotatable second-order planning of a two-factor experiment, a mathematical model was obtained. The levels of variation of the factors are shown in Table 1, and the results of the experiments (Fig. 2 a and b). To calculate the uniformity coefficient, a regression model was used, presented in equation (3), where the variables *x1* and *x2* describe the distance between the elements and the number of mixing inserts, respectively.

The equation is encoded:

$$y_2 = 19{,}8 - 1{,}6x_1 - 1{,}9x_2 - 0{,}4x_1x_2 + 9{,}2x_1^2 + 18{,}2x_2^2. \quad (3)$$

The decoded equation is used for engineering calculations:

$$K_2 = 1326 - 40l - 254n - 0{,}13ln + 1{,}02l^2 + 18{,}2n^2 \quad (4)$$

Based on equation (4), the percentage ratio of the significance of factors *l* and *n* in relation to the coefficient of uniformity K is determined (Fig. 3), which shows that the number of mixing elements *n* has a 12% greater effect on the coefficient of uniformity of the mixture than the distance *l* between them.

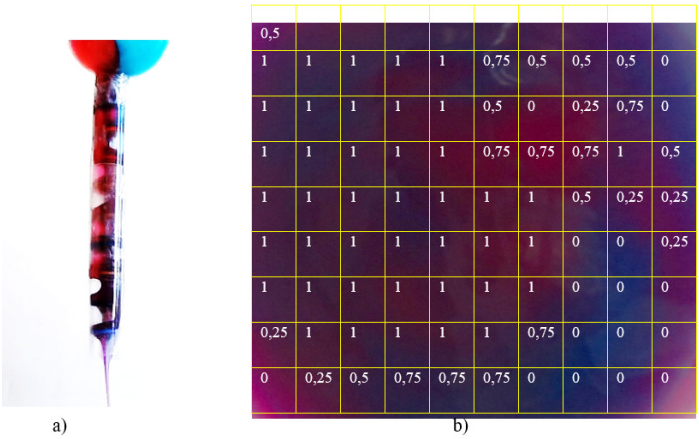


***Figure 2.*** *Experiment of the mixing process with mixing elements located at a distance of 20 mm in an amount of 9 pieces:*
*a – process; b - calculations of the results of the uniformity coefficient*

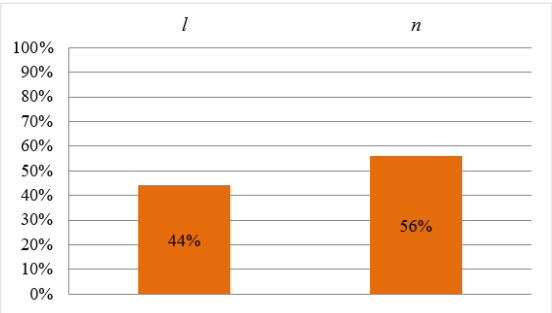


***Figure 3.*** *The significance of the factors:*
*n - the number of elements; l - the distance between the elements*

Based on experimental data using the Maple software product, the following results were obtained:

- a three-dimensional surface visualizing the influence of the main factors on the response function (Fig. 4, a), which is parabolic in nature, has a minimum: $K$= 25% at $l$=20 mm and $n$=7 elements;
- projections of a three-dimensional surface on the $l$ and $n$ axes (Fig. 4, b, c);
- a nomogram (Fig. 4, e), which shows lines showing a change in the coefficient of uniformity in % of the main parameters, for example, all points lying on

the green and black lines show at what ratio of the main parameters the coefficient of uniformity will be equal to 90 and 100%, respectively, as well as any point lying between the specified lines, makes it possible to determine at which values of l and n we will get the necessary result.

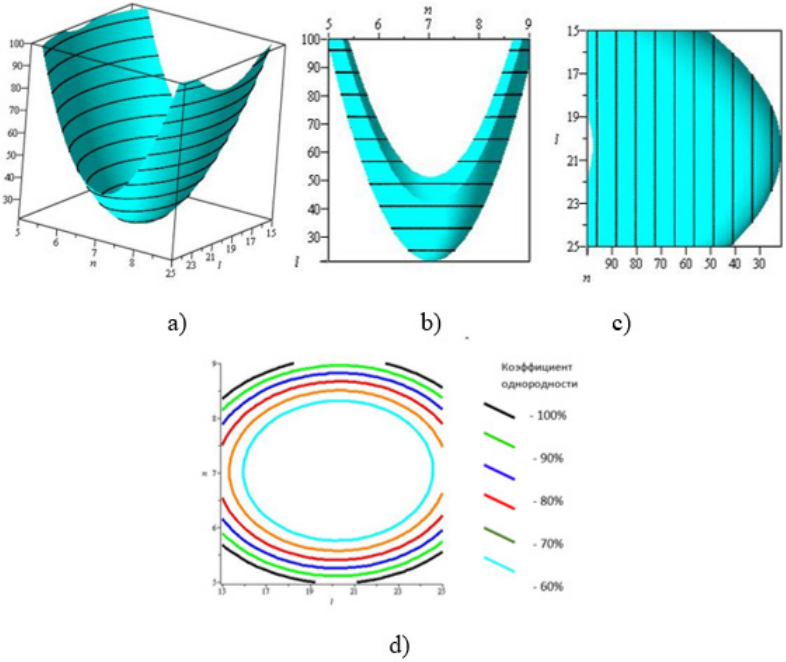


***Figure 4.*** *Surfaces of the response of the coefficient of uniformity K to changes in the main factors: the number of elements n and the distance between them d (a)*

It should be noted that the maximum uniformity coefficient of the mixture equal to 100% can be achieved with certain combinations of parameters l and n. For example (Fig. 4, d, the black line at the break points):

- with the number of elements equal to 5 and with a distance between them of 19 and 21 mm;
- the number of elements equal to 9 and the distance between them in the range of 17.5 and 23 mm, the uniformity coefficient of the mixture can reach 100%;
- other whole numbers of elements (from 5 to 9 pieces), and the distance between them can be set by moving them along the hairpin on which they are located in one way or another.

**Conclusions.**

1. Static mixers are widely used in construction and other industries to mix the mass in the form of a slurry, slurry, etc., as well as to stabilize the mixture.

2. Analysis of the basic and technological parameters of the insert in a static mixer in the form of a Maltese cross, which are deployed on an axis relative to each other at an angle of 45 degrees, showed that the uniformity coefficient of the mixture in it is related to: the diameters of the mixing chamber, the holes of the mixing elements; the distance between the mixing elements; the number of mixing elements; the pressure of liquid supply; the viscosity of the liquids to be mixed; the shape of the holes of the mixing elements..

3. Using rotatable second-order planning of a two-factor experiment, a regression equation for the change in the homogeneity coefficient of the mixture from the main factors: the number of elements *n* and the distance between them *l* was obtained.

4. The importance of the main factors for the coefficient of uniformity K has been established, which shows that the number of mixing elements *n* by 12% has a greater effect on the coefficient of uniformity of the mixture than the distance *l* between them, i.e. *n*= 44%, *l*= 56%.

5. The maximum coefficient of uniformity of the mixture equal to 100% can be provided for certain combinations of parameters: integer values of the number of mixing elements *n* = 5-9 pcs., and the distance between them *l* can be set by moving them along the stud on which they are located in one way or another, which can be determined using a nomogram (Fig. 4, d) obtained from the regression equation.

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# APPLICATION OF VISION ZERO IN RUSSIA. NEW TRAINING PROGRAM: PERSONAL OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT SYSTEM DEVELOPED FOR EMPLOYEES PROTECTION AT WORKPLACE

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***Abstract.*** *Any technology or system in the modern world cannot operate without human participation. This is especially true for human actions in extreme and emergency situations. The authors are talking about an inevitable part of human life – mistakes. When an individual's personal qualities influence the process of any of his activities due to inattention and personal experience, we mean the Human Factor (HF).*

*The HF is a driving force of any work process. In order to control this driving force, it is necessary to establish in this force some elements that can be controlled and measured. The authors have chosen the following human abilities as such elements: Intellectual, Sensory, Protective and Physical. All abilities are measurable and manageable.*

*In their work, the authors rely on the following definition of the human factor: The human factor is a difference between the actual and required abilities of an employee. Thus, HF can be positive, neutral or negative.*

*From this model of the HF it follows that the management of human factor is regulation of the personal occupational health and safety management system ( POHSMS) of the employee, which is a part of the human self-management system*

*and it's manifested through his behavior: safe (HF>0), satisfactory (HF≈0) and dangerous (HF <0). The authors emphasize that each person has his own "Personal Occupational Health and Safety Management System" which he uses throughout his life.*

*The paper presents the POHSMS training scheme. The ultimate goal of this training is safe behavior of the employee in any emergency situation.*

*Currently, one of the most effective ways to implement the POHSMS training scheme is training using virtual reality technologies ( VR technologies).*

*For example, a methodology of preliminary POHSMS training of auxiliary mine rescue crews (AMS) using VR technologies. The methodology contains three blocks. Block 1 presents the formation of primary knowledge that occurs with the help of educational video films demonstrating the correct actions in various emergency situations. Block 2 was developed for consolidation and testing obtained knowledge. For that purpose the software "Electronic Courses" are used, which allows combining training and monitoring of knowledge in the field of occupational health and safety of AMS members. Block 3 contains a practical application of acquired knowledge using VR technologies. This block includes two stages of training: one is the individual OSH practice and second is - practice of group interaction during the elimination of various occupational accidents using a virtual reality.*

*This methodology is used in various versions by some large mining companies in the process of AMS members training and gives them the knowledge of decisive and safe behavior in arising emergency situations.*

*This report contains the findings obtained during the researches accomplished in the frame of Global Programme "Application of Vision Zero in Russia".*

***Keywords:*** *occupational safety, human factor, personal OSH management system, training scheme, VR technologies, virtual reality.*

Any technology or system in the modern world cannot operate without human participation. A person, possessing reason and consciousness, is capable of involuntarily taking a system beyond acceptable boundaries, which can lead to unintended results, including disastrous consequences. We are talking about an inevitable part of human life – mistakes. When an individual's personal qualities influence the process of any of his activities due to inattention and personal experience, we speak of the human factor.

The human factor is a driving force of any work process. In order to control this driving force, it is necessary to establish in this force some of its elements that can be controlled. We have chosen the following human abilities as such elements:

− Intellectual abilities are the ability to use knowledge, skills and experience to perform work.

− Sensory abilities are abilities (vision, hearing, smell, touch, feeling pain) that allow one to control working conditions using senses.

− Protective abilities are abilities that allow one to withstand certain loads of dangerous and harmful factors of the environment and work process. − Physical abilities are the abilities that enable one to perform the necessary physical actions when performing work.

All abilities are measurable and manageable.

In this paper we will rely on the following definition of the human factor: human factor (hereinafter referred to as the "HF") is a difference between the actual and required abilities of an employee:

$$HF = AA - RA,$$

where actual abilities ("AA") are the employee's abilities to perform work safely,

based on the following main components: intellectual, sensory, protective and physical; required abilities ("RA") are the set of requirements for the person's intellectual, sensory, protective and physical abilities that are required to perform a work. The employee's behavior is formed depending on the level of actual abilities. By behavior in the process of work activity we mean the employee's implementation of necessary labor safety measures aimed at preserving his life and health. If RA < AA, then HF is a positive value. The number of errors and probability of accidents are below the required level.

The employee's behavior is assessed as safe. If RA ≈ AA, then HF is a neutral value. The number of errors and probability of accidents meet the required level. The employee's behavior can be characterized as satisfactory.

If RA > AA, then HF is a negative value. The number of errors and probability of an accident exceeds the required level. The employee exhibits dangerous behavior. Thus, human factor management is management of the personal occupational health and safety management system (hereinafter referred to as the "POHSMS") of an employee, since the POHSMS is part of the human self-government system and is manifested through his behavior: safe (HF**AA**0), satisfactory (HF≈0) and dangerous (HF<0). Each person has his own "Personal Occupational Health and Safety Management System", which he uses being guided by his own experience throughout his life.

Behavior adapts to the conditions of human life and manifests itself as significant actions, the source of which is the person himself. That is, a person can be characterized as a self-governing subject who has his own "personal occupational health and safety management system" that regulates his behavior.

The POHSMS is aimed at achieving high-quality safe work, thanks to the use of a special form of presentation of educational material with the help of a sample of target audience, to study the ways in which the employee can receive information from the outer world (hearing, sight, smell, touch, bodily sensations, feeling pain), and also using the individual abilities of the employee:

− Intellectual – knowledge, skills, experience, thinking.

− Sensory – correct response to visual and light danger signals (sent to the sense organs), ability to use hazard control devices.

Protective – knowledge and understanding of dangers associated with the use of protective equipment, as well as taking into account employee's fatigue and the body's protective response.

− Physical abilities – ability to use safe methods and techniques to perform work.

Figure 1 shows the POHSMS model, which consists of four blocks:

− Management

− control of working environment

− protection

− performance

Control and communications block relies on Intellectual abilities (knowledge, skills, experience and mental abilities) and carries out overall management of the system.

The work environment control block relies on Sensory abilities (vision, hearing, smell, touch, feeling pain) and controls the surrounding work environment. Protection block is based on Protective abilities (endurance in relation to environmental factors and the work process) and ensures the system stability in the work environment.

Performance block is based on physical abilities (speed, strength, agility, flexibility) and ensures performing by the employee of the necessary work operations.

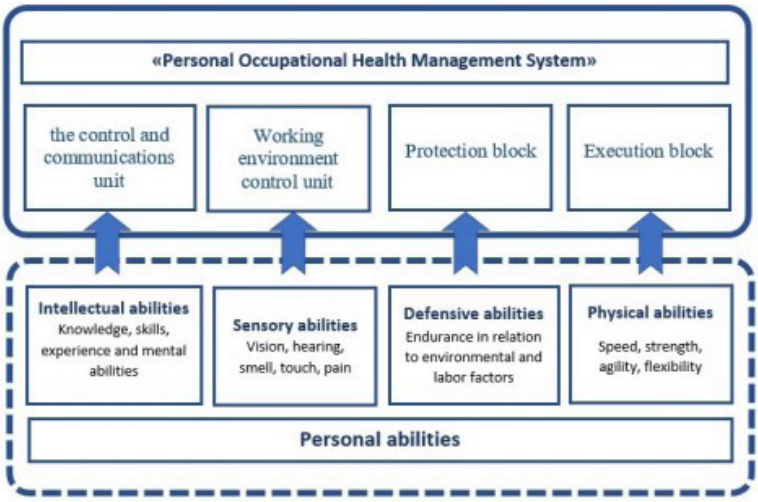


***Figure 1.*** *Model of "Personal Occupational Health Management System"*

Figure 2 shows a diagram of the employee's POHSMS training, which involves all four types of employee abilities (intellectual, sensory, protective and physical). All human abilities are interconnected and are formed throughout the life depending on experience and education.

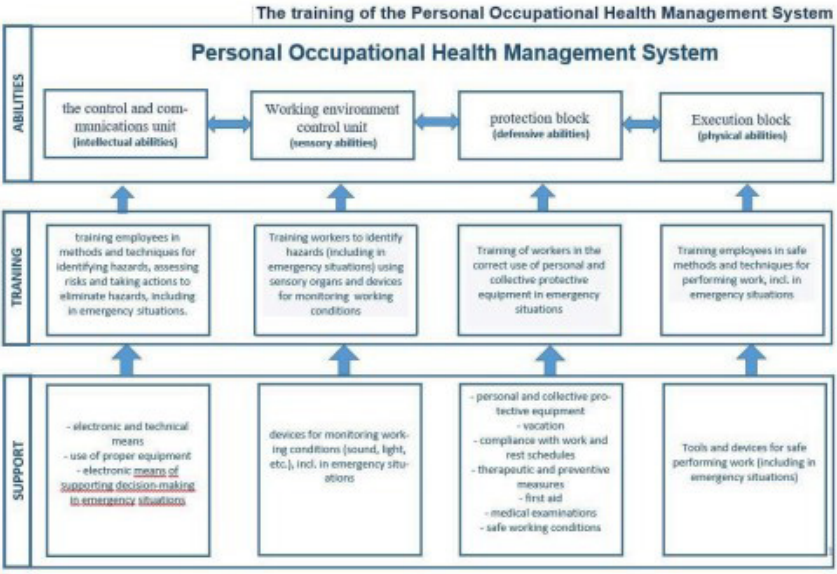


***Figure 2.*** *Diagram of the employee's POHSMS training*

To develop abilities beyond the human level, each ability of the employee can be improved through the targeted type of training.

For example, to develop intellectual abilities, training is used that is aimed at understanding what is happening, as well as teaching methods and techniques for identifying dangers. The employee is trained, the employer provides the development of his training abilities with electronic and technical training tools, and uses serviceable equipment.

Training is also used to develop the employee's sensory abilities, but it is aimed at identifying hazards using the senses (vision, hearing, etc.). In turn, the employer ensures the development of the employee's abilities by providing working conditions with control devices.

The development or improvement of protective abilities is achieved by training the employee in the correct use of protective equipment, as well as compliance with work and rest regimes, the ability to provide first aid, undergo medical examinations, etc., which is ensured by the employer.

To develop physical abilities, the employee is trained in safe methods and techniques for performing work, using special tools and devices provided by the employer.

Currently, one of the most effective ways to combine the "training" block with the "provision" block of the POHSMS training scheme is training using VR technologies.

At industrial enterprises whose production activities are associated with the risk of accidents, various approaches and tools are used for emergency response, organizing the rescue of people, eliminating accidents and their consequences. One such approach is the use of auxiliary mine rescue teams (hereinafter referred to as the "AMT"). The mandatory presence of such teams at mining enterprises is enshrined in law by Order No. 765 of the Ministry of the Russian Federation for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters (EMERCOM of Russia). At the same time, the level of required abilities (RA) of AMT members must significantly exceed the RA of the employees.

The Kuzbass-TsOT company has formulated a methodology for training members of AMTs (see Fig. 3) based on the POHSMS. This method is universal and is used to form a personal occupational health and safety management system for ordinary employees.

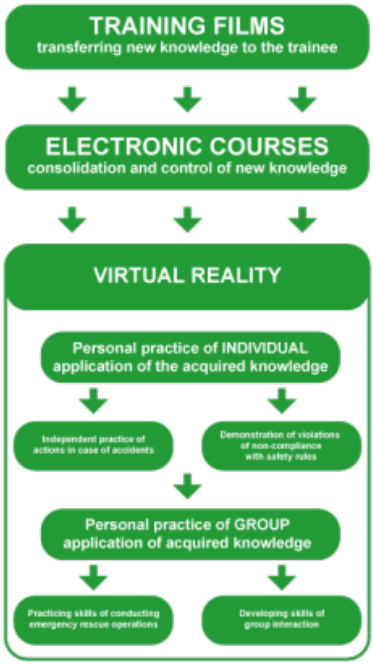


***Figure 3.*** *Methodology of Kuzbass-TsOT for training AMT members*

As can be seen from Fig. 3, the essence of methodology lies in the application of POHSMS within the framework of specially developed educational, methodological and software complexes that allow training AMT members using visualized theoretical material, personal and group practice.

Formation of primary knowledge occurs with the help of educational films on occupational health and safety in the required areas: first aid, actions in emergency situations, use of personal protective equipment, etc. According to the developed methodology, educational films on occupational health and safety must include:

− approaches concerning the laws of memory and perception, Ukhtomsky's dominants, etc.;

− requirements according to regulatory and legal documentation, charters, safety regulations, manuals and technological documentation. At the same time, the amount of "unnecessary or formal" information is minimized;

− video and photographic footage from operating enterprises filmed on the basis of current occupational health and safety regulations;

− recreated 3D models of accidents and emergency situations to demonstrate negative consequences and correct actions;

− emphasis, repetitions for the purpose of consolidation, analysis of correct safe actions, etc.

Having studied the necessary educational films on occupational health and safety, the student receives primary knowledge for further consolidation and verification using the "Electronic Courses" software. Formation of the Personal Occupational Health and Safety System by the Electronic Course occurs due to:

− effective organization of training and control of knowledge on occupational health and safety;

− use of interactive means of teaching safe methods and techniques for performing work with the extensive use of photo and video materials;

− 3D computer animated microfilms for analyzing the causes of real accidents and practicing correct actions to prevent injuries.

At the end of each section, the student must pass a test in which an incorrect answer leads to a demonstration of negative consequences of the wrong choice. A correct answer results in a demonstration of possible injuries that the student has managed to avoid by performing the actions correctly.

Thanks to this approach, the Electronic Courses are massively introducing into the consciousness of AMT members the principles of correct actions in emergency situations, when providing first aid and using personal and group protective equipment.

The next stage of methodology implementation is application of the acquired knowledge in practice, through virtual reality. This stage is divided into 2: personal practice of individual and group application of acquired knowledge.

Personal practice of individual application of acquired knowledge consists of sequentially completing individual scenarios for training in safe actions in emergency situations. Examples of such scenarios include actions in the event of a fire, collapse, gas contamination, disruption or cessation of ventilation of mine workings, sudden release of coal and gas, rock burst, etc.

Personal practice of group application of acquired knowledge consists of going through group scenarios, such as evacuation from a mine, liquidation of accidents, etc. During the training, AMT members learn to act together, in accordance with the command hierarchy and the current operational situation. At the same time, they gain unique experience and consolidate previously acquired knowledge on actions in emergency situations.

The presented methodology in different variations is used in large industrial companies to prepare AMT members.

At the XI International Mines Rescue Competition IMRC 2018, the presented methodology was partially demonstrated by using a virtual reality simulator for group training as a separate stage. The competition was attended by 25 teams from 11 countries, including 2 teams from India.

The teams were tasked with extinguishing a fire on a conveyor belt in a dead-end working. The sequence of actions was as close to reality as possible. The simulator included voice communication between team members, the use of respirators, gas measurements, air flow movement from the ignition point, etc.

The event organizers noted the high level of preparation of the simulator, and the results of virtual reality stage reflected the current level of the teams' ability to act in emergency situations.

Thus, the Kuzbass-TsOT methodology based on the POHSMS clearly allows not only to form and consolidate new knowledge, but also to form the ability of AMT members to analyze the available information, apply it in various conditions, identify cause-and-effect relationships of certain events, predict the possible consequences of their actions and choose the correct and safe option from the available ones. Group training in stressful situations allows the employee to adapt to the perception of a non-standard situation, reduce the panic factor, initiate the reproduction of the necessary actions on a subconscious, emotional level, and act in a group with maximum efficiency.

This report contains the findings obtained during the research accomplished in the frame of Global Programme"Application of Vision Zero in Russia".

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# APPROACH TO STABILIZING A WIDE RANGE OF DISTURBANCES IN MULTI-DIMENSIONAL NONLINEAR CONTROL PROBLEM

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***Abstract.*** *This paper presents an approach to stabilizing a multidimensional nonlinear control system that is subject to a wide range of disturbances. The system is stabilized within an area with highly nonlinear effects, where control based on a linearized approximation of the system cannot provide the required level of stability. The presented approach allows for the estimation and optimization of the quality of stabilization of a nonlinear control object perturbed by a set of initial and external disturbances.*

***Keywords:*** *nonlinear control system, stabilization, trajectories ensemble optimization, feedback control, magnetic levitation, real-time feedback.*

The approach is applied to the design and optimization of a nonlinear real-time feedback optimized control system for specific applications. Many unstable and highly dynamic control objects require the design of such systems. These include examples of nonlinear classes of controlled objects.

As an example, the stabilization of the MagLev levitation platform [2-5] and the search for tokamak plasma control [8] can be considered. Other examples include [9]. These systems are multidimensional, highly dynamic, and unstable, with highly nonlinear dynamics.

Magnetic levitation, or Maglev, is a modern technology that utilizes directed upward magnetic forces to counteract the dominant downward gravitational force. This technology has been applied to a variety of fields, ranging from small-scale laboratory experiments to large-scale transportation systems such as Maglev trains, which are capable of carrying heavy loads at speeds up to hundreds of kilometers per hour.

There are two main types of suspension systems used in Maglev vehicles: the electrodynamic suspension (EDS), which utilizes the repulsive force generated by magnets moving relative to electrical conductors, and the superconducting mag-

netic suspension (SFS), which relies on superconductors to create a strong magnetic field that counteracts gravity.

Both systems have their advantages and disadvantages, and ongoing research and development are aimed at improving their efficiency and reliability for future applications.

One type of system is called an electromagnetic suspension (EMS) and uses the force of attraction between magnets and ferromagnetic materials. In these cases, gravity is balanced differently due to the different nature of magnetic forces. The EMS force depends on the air gap, the speed of the vehicle, the electrical conductivity of the track material, and the source of the magnetic field. As a result, levitation occurs as long as the vehicle is moving at significant speed.

The hanging frame of the rolling stock above the track with EMS design faces inherent instability. It takes exact balance between magnetic attraction forces and gravity for an air gap to exist between the track structure and the magnet. However, if the air gap size deviates slightly, the attractive force between the short-circuited track coil and onboard magnetic system increases or decreases accordingly.

The mentioned features make providing stability for a Maglev system a difficult nonlinear control task. Various methods have been proposed to control magnetic levitation, with the primary one being a linearized model around a nominal operating point. This is a common technique. Therefore, it can be said that the development of a nonlinear controller for nonlinear systems is an important problem for both theoretical and practical research.

Various linearization techniques are based on solving matrix linear Ricatti equations [12] and optimization approaches with metrics in spectral spaces [12-16]. These techniques are quite common, but for the objects presented above, the area of the state space in which these objects can be stabilized using linear methods is quite small. In such cases, the simulated responses do not cover the required range of disturbances and nonlinear approaches may be more appropriate [13-19].

Proposed approach based on parametric optimization can significantly extend the capabilities of existing tools and methods for regulator design.

To address and handle a wide range of disturbances, the control system uses a polynomial form of the control law. This framework also applies the analysis of the dynamics of a nonlinear ensemble of trajectories that are perturbed within the system. The considered ensemble of trajectories encompasses the entire area of engineering requirements in this problem.

Analytical expressions have been found for the variation of the functional criterion with respect to parameters. These expressions allow the implementation of various optimization methods, such as gradient, random, and machine learning. As a result, computational optimization operates on all trajectories from the ensemble.

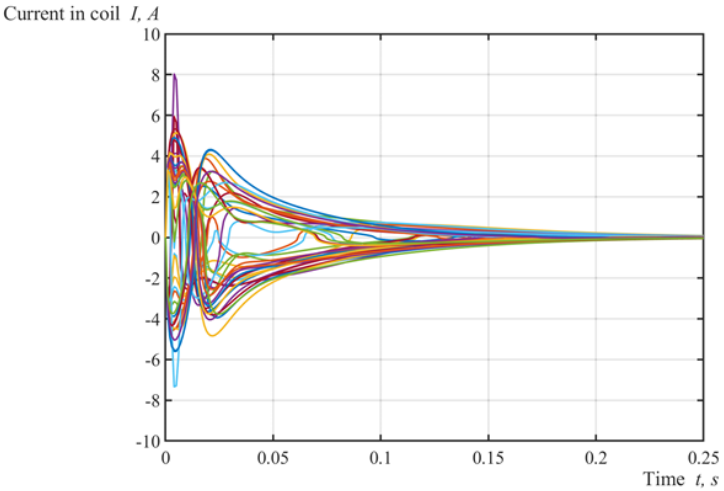


***Figure 1.*** *Controlled trajectories ensemble currents in coils (A)*

Figure 1 shows some examples of controlled trajectories ensemble of electric currents in the coils at different times (sec.)

In this case, we consider not one trajectory but an entire ensemble of dynamic movements that are perturbed by a set of initial and external disturbances. This allows us to more accurately estimate the quality of stabilization [18].

In the examples presented, the control system that solves the initial nonlinear equations of the controlled objects is considered as a set of parameters that need to be found. A representation of the first variation of an integral quality criterion that is defined on an ensemble of nonlinear trajectories was obtained, and an optimization approach based on this representation was programmed [18]. Using this approach, we evaluate the quality of nonlinear stabilization while working with a given set of initial and external perturbations, and we optimize the dynamics of the entire ensemble of nonlinear movements.

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# ANALYSIS OF THE STATE OF REGULATORY DOCUMENTATION ON OBTAINING GEOSPATIAL DATA USING UNMANNED TECHNOLOGIES

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***Abstract.*** *The article discusses the documents regulating the conduct of complex cadastral works. An analysis of the standardization of cadastral activities has been performed, which showed that the issues of algorithmization and standardization of the use of unmanned technologies for performing complex cadastral works have not been settled today. There is no systematic analysis in the study and formalization of problems related to the use of unmanned technologies to obtain geoinformation data of the necessary accuracy in the form of coordinates of real estate objects, including, despite the fact that recently preference has been given to the use of the photogrammetric method. At the same time, there are problems of coordinating the use of airspace, regulating the types of work that needs to be solved at the legislative level, the use of unmanned technologies in cadastral works.*

***Keywords:*** *complex cadastral works; unmanned technologies; geoinformation data, photogrammetric method.*

Complex cadastral works (KKR) have been carried out in the Russian Federation since 2015 [1], this type of work has become more relevant during the period from 2014 to 2020 under the Federal Target Program [2]. The main application objective of the Program was to combine the unified state register of rights to real

estate and transactions with it and the state cadastre of real estate into a single state information resource and create a Federal state information System for maintaining the Unified State Register of Real Estate.

New opportunities for improving the methodology of complex cadastral works have appeared in connection with the development of spatial data infrastructure in the Russian Federation, as well as new digital technologies that ensure the creation and operation of databases of up-to-date data on real estate objects. The accuracy and methods of determining the coordinates of the boundaries of land plots, buildings and structures were [2, 3] indicated, methods for finding the coordinates of real estate objects were named: geodetic method; method of satellite geodetic measurements (definitions); combined method; photogrammetric method; cartometric method; analytical method. Of these, photogrammetric is preferable for cadastral registration in the KKR, which has recently been increasingly used by unmanned aerial vehicles (UAVs). It was established [4, 5] that the accuracy of the survey results performed by both photogrammetric and geodetic methods meet the requirements [2].

The advantage of the photogrammetric method in the cadastre [5] is the ability to perform a more in-depth analysis of the objects and terrain under consideration, creating an orthophotoplan and a 3D model based on the survey data obtained. It is more accurate, convenient, and when used, the costs of difficult field work on large areas are much lower, as well as when direct access to the necessary facilities is impossible. The main advantages of using UAVs in KKR:

- the efficiency of obtaining survey results, which is very important when working with large areas;
- the necessary accuracy (GPS receiver on board and control identification marks allow you to accurately determine the coordinates of the center of the image (terrain points) and the real area of the property) and, if possible, use the right amount of special attachments;
- carrying out work at any time of the year under acceptable weather conditions;
- carrying out work in hard-to-reach places;
- carrying out work in hard-to-reach places;
- the cost-effectiveness of the method compared to other methods of obtaining photogrammetric material, including the cost-effectiveness of performing work on large territories compared to traditional geodetic methods, which is typical for complex cadastral works (Table 1), etc.

When conducting the KKR (Tabl. 1) in the Belgorod region according to cadastral quarter No. 31:09:0803020 p. Bekhteevka, Bekhteevsky rural settlement of Korochansky district, high-resolution images were obtained (field studies were performed using Geoscan Gemini UAV with Agisoft Metashape Professional software). Economic calculations were carried out, which considered the condi-

tions for carrying out complex cadastral works, when free access to all real estate objects was provided by traditional methods and "real" conditions, when it was virtually impossible to provide "ideal" conditions, and also analyzed the performance indicators of the KKR by the photogrammetric method using UAVs. At the same time, a high-precision terrain map corresponding to the orthophotoplane was obtained and field work costs were reduced by almost 50%.

***Table 1***

*The time spent on obtaining the coordinates of real estate objects using traditional methods and photogrammetric using UAVs*

| **Types of work** | **Traditional methods (geodetic, satellite definitions, combined) option** | | **Traditional methods (geodetic, satellite definitions, combined) option 1 (ideal conditions) option 2 (reality)** |
|---|---|---|---|
| | **option 1 (ideal conditions)** | **option 2 (reality)** | |
| Field work | 8 ч | 40 ч | 1 ч |
| Desk work | 4-8 ч | | 4-8 ч |

Thus, photogrammetric technologies are developing quite rapidly, but the regulatory framework that should regulate this activity is lagging behind, i.e. there is no approved methodology or regulation for the use of unmanned technologies for KKR, and therefore there are no requirements for the accuracy of creating maps and plans for various purposes of the cadastre. Also, the problem for the use of unmanned technologies in cadastral works is the coordination of the use of airspace.

The analysis of the standardization of cadastral activities (Fig. 1) showed that the standard standards and rules for the implementation of cadastral activities using UAVs were developed by the National Chamber of Cadastral Engineers in accordance with the requirements [1, 6] relate mainly to issues of terminology and documentation requirements necessary for cadastral registration of real estate. Therefore, the issues of algorithmization and standardization of the use of unmanned technologies for performing complex cadastral works have not been settled today, including due to the lack of a systematic analysis in the study and formalization of problems with the use of UAVs for KKR. The main task in conducting cadastral work is to determine the coordinates of the boundaries of the studied objects with the necessary accuracy [4, 7], on the basis of which cadastral registration or other real estate work is carried out.

Stages of the complex of works for the KKR using UAVs:

– preparatory (preliminary calculation of the necessary parameters for the organization of the flight task);

– creation of a shooting justification (creation and determination of the coordinates of identification marks);

– performance of aerial photography (flight filming);

| Standards of cadastral activity Methodological documentation | Standards of cadastral activity Methodological documentation |
|---|---|
| - STO 11468812.009 - 2023 Characteristics of linear objects | Methodological recommendations: “Assessment of the accuracy of determining the area of buildings» |
| - STO 11468812.008 - 2023 Characteristics of land plots | Methodological recommendations: “Assessment of the accuracy of determining the area of buildings» |
| - STO 11468812.007- 2023 Characteristics of the premises | Methodological documentation: «120-fz: new rules in the field of cadastral registration, registration of rights and cadastral activities» |
| - STO 11468812.006 - 2023 Description of the characteristics of real estate objects. Characteristics of the premises. | Methodological documentation on legislation 2022 |
| - STO 11468812.005 - 2023 Description of the characteristics of real estate objects. Characteristics of the premises. | Methodological recommendations: “Preparation of documents in relation to houses of blocked buildings and land plots under them», 2023 |
| - STO 11468812.004 - 2023 Geodetic support of cadastral activities. Methods and technologies of satellite geodetic measurements (definitions) | Methodological recommendations for carrying out complex cadastral works, 2021 |
| - STO 11468812.003 - 2023 The procedure and terms of storage of acts of approval of the location of the boundaries of land plots prepared during the execution of cadastral works. | Methodological recommendations: «Documentation support of cadastral works in relation to OKS» |
| - STO 11468812.002 - 2023 Forms of organization of cadastral activity. | |
| - STO 11468812.001 - 2023 Forms of organization of cadastral activity.– создание съемочного обоснования | |
| Photogrammetry. | |
| GOST R 57258-2016 Systems of unmanned aircraft systems. Terms and definitions | GOST R 59562-2021 Aerial photography. Technical requirements. |
| GOST R 58854-2020 Photogrammetry. Requirements for the creation of oriented aerial photographs for the construction of stereo models of built-up territories | GOST R 70078-2022 is a software and hardware complex for aerial photography using an unmanned aircraft. Technical requirements. |
| GOST R 59328-2021 Topographic aerial photography. Technical specifications. | |

***Figure 1.*** *Standardization and methodological documentation in the field of research*

– processing of the received materials;

– registration of documents based on the results of aerial photography in accordance with the requirements.

Stages of the complex of works for the KKR using UAVs:

– preparatory (preliminary calculation of the necessary parameters for the organization of the flight task);

– creation of a shooting justification (creation and determination of the coordinates of identification marks);

– performance of aerial photography (flight filming);

– processing of the received materials;

– registration of documents based on the results of aerial photography in accordance with the requirements.

Thus, according to [2], the required pixel projection size on the ground for aerial photographs for land plots classified as lands of settlements should be no more than 5 cm. To ensure the receipt of aerial photographs with the required spatial resolution, the height of photographing (flight), the transverse basis and the interval of photographing should be designed, the route of overflying the territory is designed taking into account the technical characteristics of the UAV, while also taking into account the characteristics of the camera used, the overlap of aerial photographs in the route and between routes should be at least 60%.

Next, the flight route (flight task) is compiled, in which the following are specified and taken into account:

-technical features of the UAV used;

-coverage of the area to be filmed should be with a small margin of territory beyond the shooting border;

-wind direction and strength;

-possible flight time of the UAV;

- shooting on the developed route should partially cover the area of the adjacent section of the flight route scheme.

To ensure greater accuracy, it is necessary to create additional shooting equipment in the form of identification marks [8, 9] using geodetic methods. Identification marks are marked before aerial photography, their size and shape are chosen taking into account the altitude and scale of the survey, and they must also be clearly distinguishable on the ground. Identification marks are installed in such a way that at least 3 signs are present at each survey site, and in general, a closed geodetic network is formed along all routes. Aerial photography should not be performed under adverse conditions, such as strong wind gusts of more than 10 m/s, snow, rain and fog. It is also mandatory to comply with local regulatory requirements of the airspace regulatory authorities, which includes compliance with no-fly zones, altitude and distance restrictions.

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# FEATURES OF DETERMINING THE DEGREE OF CRYSTALLINITY OF SILICIOUS ROCKS BY FTIR

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***Abstract.*** *The degree of crystallinity of siliceous rocks from gas fields in Western Siberia (Russia) was estimated using infrared spectroscopy methods. The calculated silica crystallinity indices were used to demonstrate the possibility of identifying rocks with increased porosity (and gas saturation). The appearance of crystallinity at the early stages of siliceous rock crystallization is indicated by infrared absorption peaks at 778 cm-1 and 695 cm-1, but spectrum decomposition is necessary to calculate the crystallinity index.*

***Keywords:*** *crystallinity, quartz, silica, infrared spectroscopy (FTIR).*

In recent years, increased attention has been paid in scientific literature to phase modifications of silica, amorphous and crystalline [1, 2], including in connection with the peculiarities of their formation and influence on the structure of the pore space of oil and gas reservoir rocks [3, 4]. Interest in the study of unconventional reservoirs is due to modern challenges of the oil and gas industry complex associated with increasing production efficiency and searching for new sources of hydrocarbon raw materials.

In the work [5] it is shown that there is a close connection between the proportion of quartz content in the rock and the total proportion of capillaries and macropores in the void space. With an increase in the proportion of quartz content in the rock, the proportion of the largest pores in the void space naturally increases, which explains the probable mechanism of the appearance of these pores. During the crystallization of the original spongy siliceous sediment (silicic acid gel) into quartz, a redistribution of silica molecules to the crystallization centers occurs. In this case, voids of larger sizes than in the original siliceous sediment are formed along the periphery of the crystallization zones. Thus, the more newly formed quartz crystals in the rock, the larger the size of the voids, the greater the gas saturation, and possibly the gas permeability. It has also been determined that in the process of lithification of silicon biogenic material, the transformation of its structure is accompanied by a change in the material composition due to successive reactions of dissolution-precipitation-recrystallization and polymorphic transitions of silica - opal-A (amorphous silica) to opal-C (low-temperature crystalline cristobalite), and to opal-CT (opal-cristobalite-tridymite, the so-called OCT phase - a metastable form of silica), and as deeper transformations occur - to cristobalite, tridymite, quartz [6]. The appearance of such phases indicates the "silicification" of rocks and an increase in their mechanical properties.

To assess the degree of transformation and crystalline perfection of quartz, the work [7] proposed to use the X-ray diffraction method, and to calculate the "crystallinity index" Kci (or QCI) based on the parameters of the multiplet peak in the region of 67…69° on the X-ray diffraction pattern. This method of Murata and Norman is widely used in world practice,

In [8], it was proposed to use the infrared spectroscopy method to determine the crystalline phase of α-quartz by the presence of a double infrared absorption peak of 800...778 cm-1. In [9-11], it was proposed to calculate the crystallinity index by the ratio of the peak value at 778 cm-1 to the peak at 695 cm-1.

To assess the degree of crystallinity of siliceous rocks from gas fields in Western Siberia (Russia) and to identify potential promising gas-bearing reservoirs, we used the method of X-ray diffraction (XRD) and infrared spectroscopy (FTIR) [3, 4].

Calculation of the crystallinity index Kci according to the Murat and Norman method was carried out using experimental values of the peak (212) corresponding to 2θ = 67.74°multiplet (quintuplet) peak in the region of 67…69°on the X-ray diffraction pattern. The samples were analyzed on an X'Pert PRO diffractometer.

IR absorption spectra were recorded on a Shimadzu IR Prestige-21 spectrophotometer with Fourier transform (FTIR-8400S) in the range of 400...4000 cm-1 with a resolution of 0.01 cm-1 (FT-IR), using IR solution software.

The position of the double peak at 778 and 797 cm-1 in the spectrum, the average intensity, the absence of superposition of other bands and the high sensitivity

to structural changes were the reasons for its use in [6] to calculate the crystallinity index according to the formula

$$Kci = 10\ fa/b,$$

where a / b is the ratio of the magnitude of the weak peak at 778 cm-1 to its short-wave shoulder; f is the proportionality coefficient for the reference quartz, taken in [6] to be equal to 2.8; in this work, the equalizing proportionality coefficient f = 6 was used (Fig. 1).

The crystallinity index was also calculated using the method [10, 11] using the formula: Kci = b/c,where b/c is the ratio of the peak value at 778 cm-1 to the peak at 695 cm-1 (Fig. 1).

In the infrared spectra of silica, the central place is occupied by a medium-intensity double peak (doublet) at 798 and 778 cm-1 (vibrations of bound SiO4 tetrahedra), which clearly characterizes the presence of a crystalline phaseα-quartz (Fig. 2). In the spectra of disordered (amorphous and partially disordered) materials made of silicon dioxide there are no IR absorption peaks at778 and 695 cm-1, which indicates the absence of a crystalline phase in them [12].

In works [10, 11] a method for calculating the crystallinity index of quartz was applied, using the ratio of the magnitude of the infrared absorption peaks at 778 and 695 cm-1; since it is the symmetric bending vibrations at 695 cm-1 that characterize the presence crystalline phase [12].

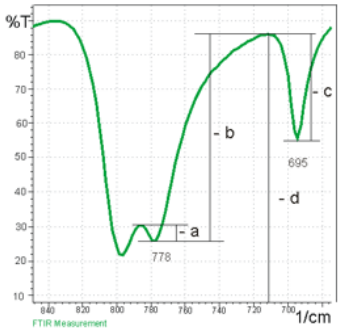


***Figure 1.*** *Explanation of the calculation of the crystallinity index of silica using the FTIR method*

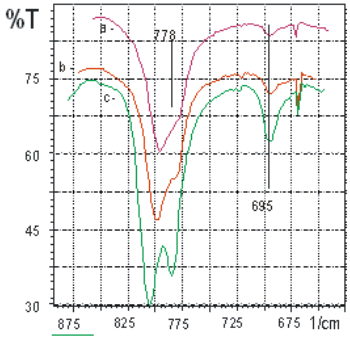


***Figure 2.*** *Infrared spectra of silica*

Infrared spectra of siliceous reservoir rocks differ in intensity of characteristic peaks used to assess crystallinity. As a rule, in the presence of a clearly expressed peak at 778 cm-1, the crystallinity index calculated by the method of I.I. Plyusnina [8] is quite high (Fig. 2, c). These rocks are also characterized by measurable permeability values at the level of mD units. Weakly crystallized rocks are char-

acterized by a low intensity of the peak at 778 cm-1 (Fig. 2, a, b), and, as a consequence, low values of the crystallinity index. Determining permeability becomes extremely difficult due to the low sensitivity of the devices used.

During the degradation of quartz, quartzite, and crystalline materials made from quartz, their degree of crystallinity changes (decreases), which is well confirmed by calculations of the crystallinity index using all the FTIR and XRD methods used [12]. However, it should be noted that the application of the considered IR spectroscopy methods for identifying the initial stages of crystallization is limited. Since the methods propose using the ratio of peak intensities778 cm-1and 695cm-1, then there is a need to isolate the peak778 cm-1by decomposing the complex doublet into Gaussian curves. Using the baseline method for processing infrared absorption spectra, it is also possible to isolate the peak695 cm-1 in the ratio of c/d values (Fig. 1), the appearance of which already indicates the appearance of a crystalline phaseα-quartz. Deconvolution of spectra to isolate weak peak intensities778 cm-1caused by the need to evaluate weakly crystallized reservoir rocks containing silica and to identify promising areas with increased porosity (and permeability) that can be recommended for further involvement in development tdeposits.

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