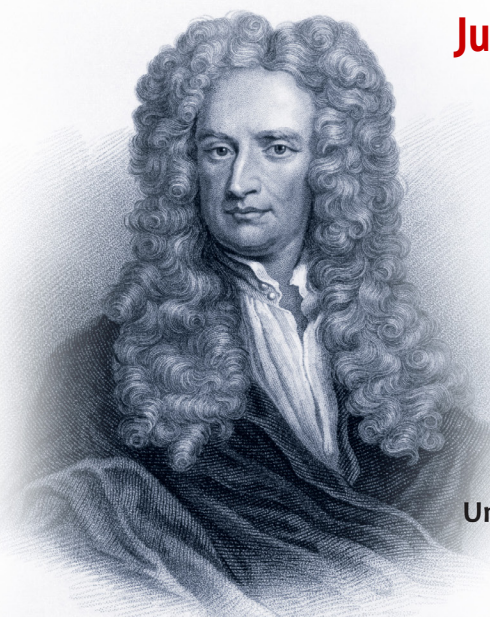




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# PROCESS MANAGEMENT AND SCIENTIFIC DEVELOPMENTS

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## STUDY OF OLDER HOUSEHOLDS WITH THEIR LIVING CONDITIONS

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**Abstract.** The article argues that the growth of the elderly population in the Kyrgyz Republic has exacerbated the housing problem of the older generation. The ongoing improvement of living conditions, including in family households where there is an older generation, is not keeping pace with the growth of their number, therefore, many elderly people are forced to live in cramped conditions, in violation of sanitary standards of living. The work is devoted to the assessment of households with elderly people in the context of an increase in the number of the elderly generation. The method of secondary statistical analysis confirms the aspect that the older generation is one of the main resources of each state. And the higher the quality of this resource, the higher its productivity, efficiency and level of development of society.

**Keywords:** older generation, demography, housing, elderly population, households, housing conditions, housing demography.

### Introduction and relevance

Today's active aging of the population is a global reality, which, in turn, arouses international scientific interest in this phenomenon. The need to ensure a decent quality of life for the elderly population of the country is the main task of a socially oriented state. The relevance of the study of the elderly population, namely its housing well-being, is confirmed by the steady increase in the number of the elderly population and the aging of the population as a whole. Population aging is observed in many countries, including the Kyrgyz Republic, which, in principle, corresponds to the global aging process of the world's population.

**The purpose of the work** was the definition of the dynamics of households with older people and living conditions of the older generation in such households.

In order to achieve the goal of the work, it is necessary to solve the fol-

lowing tasks:

- consider the living conditions of the older generation in these households;
- to study the dynamics of the elderly population in households both in the regional and in the republic as a whole.

### **Foreign research and publications**

It should be noted the works of Mulder C.H., (2006) [1; 2], in which, on the basis of practical research, the relationship between the housing sector and population indicators was proved. And the relationship between housing and public health is reflected in the scientific studies of Braubach, M., Jacobs, D.E., Ormandy, D (2011) [3], Evans GW, Wells NM, Moch A, (2000) [4].

### **Main part**

The share of lonely elderly people in the country is growing and today it is 10% of the total number of elderly people in the country. In addition, at the age of 60, every second woman is a widow and, unlike men in this age group, has a very low chance of remarriage. This is a category of women who in the future may also become clients of social services.

As we all know, the housing problem has been exacerbated by the sharp decline in public housing construction. Despite the significant rise in private construction, it cannot fully satisfy all segments of the population. And it's no secret that their main task is to maximize profits at the expense of the solvent population [5; 6; 7].

Thus, the poor and middle classes, including the elderly, are currently faced with housing and security problems [8].

In general, medium-sized households prevail in the republic, and in the southern regions - larger households due to the high birth rate. The largest households are located in Osh region with an average size of 6.1 inhabitants, followed by Batken region with 5.4 inhabitants. (see Table 1)

**Table 1. Average household size and number of elderly people per household by region (people)**

Region	Average household size	Seniors per household
Batken	5.4	1.6
Jalal-Abad	4.7	1.5
Issyk-Kul	3.6	1.5
Naryn	4.5	1.5
Osh	6.1	1.6
Talas	4.8	1.6

Chuiskaya	3.8	1.5
Bishkek city	2.8	1.3
Osh city	4.1	1.5

Source: compiled by the author based on [9]

To create a clear picture, it is also necessary to consider how many households have 1 to 4 or more elderly people (see Table 2). The table clearly shows that the largest number of households with one elderly person lives in Bishkek and is 67.7%, and the smallest - in Batken region - 43.8%.

**Table 2. The number of older generation in households by region, in%**

	<b>1 senior</b>	<b>2 seniors</b>	<b>3 seniors</b>	<b>4 seniors and more</b>
Batken	43.8	55.1	0.9	0.2
Jalal-Abad	54.3	43.9	1.2	0.6
Issyk-Kul	54.7	43.1	2.2	0
Naryn	52.2	46.4	1.1	0.2
Osh	46.3	51.9	1.8	0
Talas	50.6	48.3	0.7	0.5
Chuiskaya	57.2	40.8	1.8	0.2
Bishkek city	67.7	31.4	0.9	0
Osh city	54.5	43.9	1.6	0

Source: compiled by the author based on [9]

At the same time, the largest number of households with 4 elderly people live in Jalal-Abad region - 0.6% and in Talas region - 0.5%, and in 5 regions there are practically no such households.

In other words, the larger the household, the higher the proportion of older people in it. The size of the household is also influenced by the birth rate and the national mentality - like cohabitation of different generations, this phenomenon is especially pronounced in the southern regions of the republic. Large households are often the most vulnerable socially, as their size is mainly due to the large number of children and the elderly, and, therefore, there is a small share of able-bodied members of the household [10; 11; 12; 13].

However, there is every reason to believe that another equally acute

problem for older people related to housing is the payment or provision of services for a decent living. Meanwhile, the rise in prices for energy carriers in recent years and a decrease in the profitability of housing and communal services enterprises have led to a twofold increase in prices for housing and communal services, electricity, gas and fuel [14; 15; 16]. Despite the fact that a large proportion of older people belong to different categories of beneficiaries, the rise in prices for housing real estate and its maintenance have significantly worsened the already poor living conditions of older people.

The consequence of this situation was a sharp increase in the number of elderly people who switched to full state maintenance. So, according to the National Statistical Committee of the Kyrgyz Republic, at the end of 2019, about 38% of pensioners of women and men pointed to their difficult financial situation, and 13% - to a very difficult one. Of these, 2.5% would like to live in a nursing home [17].

It is clear that the provision of housing is one of the main conditions for the formation of human potential and human development in general. However, without decent living conditions it is impossible to achieve the world goals of human development, such as decent longevity, excellent health, competitive education [18; 19 20]. In this context, Kyrgyzstan has a traditionally high level of housing conditions and housing provision among the older generation. According to a study by the Statistical Committee of the Kyrgyz Republic, 89.9% of households live in their own house or in a privatized apartment.

For a clear advantage, older people live in private houses and this preference can be traced in the north and south of the republic. Nevertheless, in cities, this indicator is almost equal to living in an apartment in an apartment building (see Table 3).

**Table 3. Housing occupied by households by type in%**

	Total	City	Village	North	South
Apartment in an apartment building	18.9	47.8	2.7	20.5	14.7
A private house	79.4	50.0	95.9	77.3	84.9
Part of a private house	1.7	2.2	1.4	2.2	0.4

Source: compiled by the author based on [9]

Only 2.7% of households live in apartments in the countryside, 47.8% in cities. In Bishkek, 57.6% live in apartment buildings, in Osh this figure is slightly lower and reaches 32.7%.

However, across the country, about 10.1% of households live in individual houses and apartments that are not their property.

According to the statistical report of the National Statistical Committee of the Kyrgyz Republic "Elderly People in the Kyrgyz Republic", the highest percentage of rental housing - more than 17% was recorded in Osh and Bishkek, while in other regions it practically does not exceed 7-10% and in the Batken region in total 3% [9].

This situation is quite possibly caused by internal migration, especially urbanization, and it is likely that households may have their own housing in other regions and districts. Here, it is important for us to highlight that 13.2% of single elderly people in cities and 10.8% of single elderly people in villages do not have a home on full private property rights and live in a rented dwelling, which significantly affects the material situation of the elderly. of people. For example, on average, they have to pay 4374 soms for rent per month, but this amount is approximately equal to the average per capita income in the country [21].

As it is quite clear, when analyzing housing provision, it is not enough to take into account quantitative indicators, but it is necessary to take into account the qualitative characteristics of the dwelling and especially its improvement, such as equipping with hot and cold water supply, sewerage, electricity, shower or bath [22; 23; 24; 25].

However, according to statistics, over the past few years, there has been a decrease in the provision of the housing stock with all kinds of amenities. So, relative to 2009. gas supply decreased by 10.1%, amounting to 26.9% in the total area of the housing stock, baths / showers - by 0.6% or 17.5% in the total area.

But at the same time, water supply increased by 13% or 36.6% in the total area, sewerage - by 16.6%, that is, 26.6%, central heating - by 17.3% and, accordingly, 13.3% in the total housing stock area.

It is no secret that the presence of favorable amenities has a positive effect on the health of older people. Meanwhile, the availability of amenities in households is not evenly distributed across the country. It is common knowledge that central communications and amenities are well provided for urban households than rural households (see Table 4).



**Table 4. Availability of amenities in households, in the context of urban/rural, in%**

	kitchen	Ind./ toil.	Out./ toil.	Cold/ water	Hot/ water	Bath- room	Electr.	Nat./ Gas	Cent./ heat.
urban	96.5	55.7	56.4	94.4	58.9	65.3	98.2	58.4	40.9
rural	83	5.4	97.3	66.6	11.1	22.1	98.5	5.3	2.1

Source: compiled by the author based on [9]

However, one should not forget that lonely elderly people, especially in villages, are the most vulnerable category among the elderly population. In such houses, the presence of internal toilets was noted in 5.7%, the presence of a bath was detected in 17.4% of cases, hot water supply - 13.8%, central heating - 5.5%, natural gas - 6.4%. Until now, the most common type of heating, especially in rural areas, is stove. How it affects health is described in the chapter on health and housing.

To truly understand the housing issue among older people, it is necessary to understand how satisfied they are with existing housing conditions [26;27; 28; 29].

According to the results of the assessment of households' satisfaction with living conditions, carried out by the National Statistical Committee of the Kyrgyz Republic, it can be noted that households live in villages in much less favorable conditions than in cities. If the overall level of satisfaction with housing conditions in the surveyed households is 73.6%, in urban areas - 79.6%, then in rural areas - 70.2%.

Thus, residents of Chui and Naryn regions are least satisfied with their living conditions, but in the next 3 years only 3.8% and 5.5% of residents of these regions will move. The largest percentage of those planning to move to Bishkek (13.7%) and Osh (7.8%), of those who live in villages, only 3.3% plan to move. Although living conditions in rural areas are much worse than in cities, the percentage of satisfaction with them is much higher, and the desire to move is much lower [9].

So, the modern generation of the elderly population is adherents of the Soviet era. Decent living conditions for them are some kind of roof over their heads, and even the presence of four walls can create pleasant living conditions for them. The older generation does not need expensive cars and presidential apartments. Coziness and comfort for the elderly are their children and grandchildren, communication with whom gives them energy, strength and health.

This approach to the quality of housing is based on the generally accepted notion that "we live like everyone else" or "no worse than our neigh-

bors", but this limitation is mainly due to the lack of awareness of the population about the higher quality of residential amenities [30; 31; 32].

### Conclusion

Thus, we can state the negative impact of current housing conditions on the health of older people. The overwhelming majority of households in the republic do not have living conditions that meet sanitary and hygienic requirements. Therefore, the modern housing policy of Kyrgyzstan should focus primarily on improving living conditions and providing housing for every family, which will help create a favorable microclimate to maintain not only physical health, but also mental and social well-being of the country's population, especially vulnerable households and single elderly people.

Even with a 90% level of private housing provision, 12% of single elderly people in Kyrgyzstan live in rented housing, which indicates the need to strengthen social housing measures for vulnerable groups of the population. At the same time, the provision of households with elderly people with communal services also wants to be better, namely cold and hot water, as well as gas supply.

In addition, the obtained analysis data will allow adapting national development programs to international conditions, as well as formulating relevant programs that take into account the needs of the elderly population of Kyrgyzstan.

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## ESSENCE OF REGIONAL INNOVATION POLICY

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**Abstract.** The article discusses the issues of regional innovation policy, since the analysis of conceptual views on this issue points to many arguments, which indicates a divergence of theoretical positions. The purpose of the article is to develop parameters on the effective use of investment resources to solve the problems of socio-economic development of the region, improve the quality of life of the population based on the achievements of scientific and technological progress.

**Keywords:** region, regional policy, model, priorities. resources

Currently, the regional factor plays a key role in overall economic development and investment in innovation.

There is an economic need, supported by the ability of the regions:

- to determine the directions of using own economic, innovative and intellectual resources;
- to seek sources of financial support for own programs of socio-economic and industrial-innovative development;
- to create conditions for the effective attraction of investment resources to the region;
- to develop innovative infrastructure.

The combination of the listed actions represents the practical implementation of the regional innovation policy.

Proceeding from this, the essence of regional innovation policy can be defined as purposeful, scientifically based activities of regional authorities and administrations to attract and use efficiently investment resources to solve the problems of socio-economic development of the region, to improve the quality of life of the population based on the achievements of scientific and technological progress.

The process of implementing a regional innovation policy can be represented as a sequence of works performed by regional government bod-

ies[1].

At the first stage, the social, environmental and economic problems of the region are determined, the solution of which requires innovation and investment. When solving the problems of the development of the region, the choice of strategic and tactical goals and priority areas of innovative development and investment is carried out.

At the second stage, the innovative development of the spheres of the region's economy is determined, which will have the greatest impact on solving the social, environmental and economic problems of the region.

At the third stage, the priority directions of innovative development of the regional economy are determined.

At the fourth stage, a regional investment strategy is determined.

At the same time, a number of conditions are determined that must be met by investment projects implemented in the region.

The main ones are:

1) investments should be innovation-oriented, ensuring the modernization of the region's industry, an increase in labor productivity and employment of the population;

2) investments should be regionally oriented and ensure priority observance of the interests of the population of the region when making investment decisions;

3) as one of the main investment criteria, the principle of "non-deterioration" of the living environment of the region's population should be used, which implies taking into account environmental factors when calculating the projected results and consequences of investments. Compliance with this condition can be ensured by the introduction of a mandatory examination of investment projects and proposals.

At the fifth stage, a regional innovation and investment program is being formed.

The strategic goal of the formation and implementation of regional innovation policy - improving the well-being and quality of life of the population of the region - can be attributed to any type of economic policy and territorial entity.

The content of specific tasks facing innovation policy is determined by: regional characteristics:

- implementation of innovative activities;
- natural and climatic conditions of the region;
- specialization of the regional economy;
- level of education;
- the level of development of innovation and investment infrastructure.

Thus, the innovation policy of regional government bodies should, on the one hand, be aimed at overcoming existing problems, and on the other, use regional features [2].

There are three basic directions of investment and innovation policy:

- solving environmental and social problems of the region;
- use of resource features of the region;
- solving the problems of diversification and modernization of the regional economy.

We have identified the directions of the target innovative program for the development of the regional economy:

- 1) development and adoption of regulations aimed at stimulating innovation and investment activities;
- 2) the formation of an innovative and investment image of the region, the most important component of which is the level of development of the innovative and investment infrastructure of the region;
- 3) consulting assistance to subjects of economic activity of the region;
- 4) stimulation of production and completion of scientific research;
- 5) stimulating the innovative activity of the manufacturing sector and the demand for scientific and technical products of regional innovation centers;
- 6) promoting the use of unused production areas.

In real life, the process of economic regionalization in the innovation and investment spheres is complicated and contradictory.

It should be borne in mind that the regional innovation policy is, on the one hand, an element of the general socio-economic policy, on the other hand, one of the tools for implementing the regional development program.

Thus, the presence of a well-grounded regional innovation policy allows the region to build its relationships in a balanced manner with central government bodies, with investors, and with other regions.

At the initial stage, the innovation policy is formed on the basis of: the previously formed innovation infrastructure of the region, the prevailing trends in the practice of allocating capital investments, the general knowledge of the regional management elite.

However, the continuation of the work requires the availability of instruments based on quantitative measurements in the form of criteria and indicators, an integral system of which is currently lacking.

With the advancement of the formation and implementation of innovation policy, there is an objective need for a methodology for the development and implementation of an objectively substantiated and effective regional innovation policy, in its practical implementation in the form of an innovative program for the development of the region [3].



The possibilities and actions of the regions are largely determined by the general conditions in the country and factors of a higher order, in relation to which the actions of the regions are not decisive. Thus, the country's political course through the legislative framework determines the economic course, which sets the macroeconomic indicators.

In addition, it is necessary to take into account the historically formed factors affecting the state of the innovation sphere of the region and the inflow of investments into it.

These include:

- the structure of the region's economy,
- reserves of natural, including energy, resources,
- production and intellectual potential of the region.

The formation of a regional innovation policy plays a decisive role in modern conditions, both for the development of the region's territory and for ensuring social stability in it.

Based on the characteristics of regional innovation policy, two key blocks can be identified.

One block - the criteria and methods for the selection of objects and projects of regional development.

The second block is mechanisms for attracting investment resources.

The main prerequisite for the formation of a regional innovation policy is a general strategy for the socio-economic development of the region. In relation to it, the innovation policy acts as an instrument and should be coordinated in terms of the goals and timing of the implementation of individual projects, taking into account their synergistic influence.

The definition of priorities for innovation policy should be based on the goals of the general strategy of socio-economic development of the region. These goals may be different, depending on the level of development of the region itself and the goals of the regional power elites.

Thus, taking into account the long-term nature of innovation and investment projects and programs, calculated, as a rule, for several years, the inherent internal contradiction between the timing of the implementation of the region's innovation policy and a stably functioning governing body becomes obvious [4].

The model of regional innovation policy should include not only the processes for determining priorities in the formation of an innovation program, but also mechanisms for attracting and forming the resources necessary for its implementation.

Thus, we are talking about a strategy for the formation of investment resources in the region.

The process of forming an innovation strategy is an element not only of the innovation policy of the region, but also of its financial, scientific and technical, educational and organizational and economic policies.

Thus, the model of regional innovation policy at the stage of transition to a new innovative economy has a number of fundamental features that distinguish it from the investment policy models of previous periods. A prerequisite for the formation of a regional innovation policy is a general strategy for the socio-economic development of the region. In relation to it, the investment and innovation policy acts as an instrument and should be coordinated in terms of the goals and timing of the implementation of individual projects, taking into account their synergistic influence.

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## STRATEGIES OF NEW INNOVATIVE COMPANIES

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**Abstract.** In recent decades, small and medium-sized enterprises (SMEs) have become actively introduced into the innovation process. The main trend in the development of small and medium-sized businesses is an increase in the share of small innovative companies involved in research and development and manufacturing of high-tech products. The success of small innovative companies depends on the right strategy which is based on detailed analysis of the market situation, resources available and the specifics of the field of activity, as well as on a quick response to changes in the market.

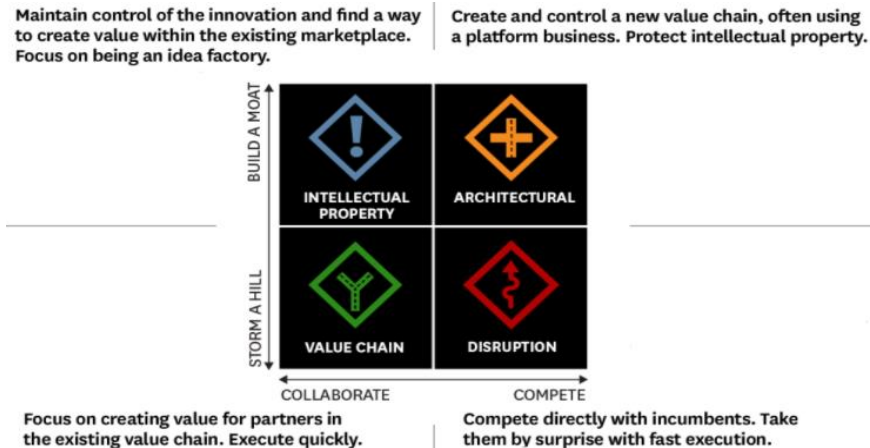
The article considers the main strategies of innovative companies at various stages of the innovation cycle: from idea generation to commercialization and scaling of the finished product.

**Keywords:** SMEs, startup, innovations, strategies, competitiveness, intellectual property, market conquest.

Nowadays, the role of innovation has increased significantly. It is almost impossible to create new competitive products without innovations. These days, competition between companies differentiates a lot compared to many years before. Some of the main market trends are disintermediation (disappearance of channel intermediaries, such as brokers, travel agents, growth in telephone or online purchasing), dematerialization (increasing value of a product in service rather than the physical object, the emergence of e-money), micro-segmentation (designer labels, proliferation of product ranges). All of these accelerates the pace of our lives and makes competition between companies fiercer. Firms are trying to achieve competitive advantage in order to obtain a better and a stable position

in the marketplace. Therefore, they need to respond immediately to any changes on the market. There are some ways for companies to develop their strategies.

Harvard Business School has created a model that classifies startup business strategies based on enterprise decisions about customers, technology, identity, and competitive space (Fig. 1).



**Figure 1 – Business strategy compass**

Source: Joshua Gans, Erin L. Scott, and Scott Stern, Strategy for Start-ups, Harvard Business School, Magazine, May-June 2018, Available on-line: <https://hbr.org/2018/05/strategy-for-start-ups> (date of the application 12.06.2021)

To select a potential strategy, each new startup has to consider two specific competitive trade-offs:

1. *Collaborate or compete?* Working with established players provides access to resources and supply chains that can enable startups to quickly enter a larger and more established market. On the other hand, an enterprise may face significant delays due to the bureaucratic nature of large organizations, and may also capture a smaller portion of a potentially large benefit (the incumbent is likely to have more bargaining power in the relationship, especially if it can appropriate key elements of the startup idea). There are pros and cons to the alternative too. Competition with established players in the industry means that a startup has more freedom to innovate, to work with customers, to build a value chain, with a chance to supplant existing successful products. However, this means fighting with

competitors that have large financial resources and developed business infrastructure.

2. *Build a moat (protect intellectual property) or storm a hill (get to market quickly)?* Some companies believe they can get more out of maintaining tight control over a product or technology, and that copying by others will make them vulnerable. Thus, they invest in intellectual property protection. Formal protection of intellectual property, while costly, could allow a tech startup to exclude others from direct competition or have significant bargaining power with a supply chain partner. But prioritizing control increases the time, transaction costs, and challenges associated with bringing innovation to market and working with customers and partners.

Conversely, a focus on fast-to-market speeds up commercialization and development, which usually happens in close collaboration with partners and customers. Innovative companies that choose this path prioritize the opportunity to experiment and replicate their ideas directly in the marketplace. Go-to-market startups anticipate competition and use their agility to respond to competitive threats.

An example among French startups is CARMAT, the creator of the world's most advanced complete artificial heart. The sensors built into the heart detect blood pressure and monitor blood flow in real time. It works like a human heart: if the patient walks, blood flow increases, and if the patient is at rest, blood flow remains stable and low.

CARMAT received an award from the French National Institute of Industrial Property (Institut national de la propriété industrielle – INPI)<sup>1</sup> in 2014 in the Patent category. the competition jury considered CARMAT to stand out for its innovative strategy and its ability to assemble a team of engineers, biologists and doctors with complementary areas of expertise. This interdisciplinary approach allowed the first self-regulating bioprosthetic heart to be brought into clinical trials. This French innovation is already protected by 155 already issued national patents and 51 patents pending in Europe and 25 countries [4].

Despite this fact, the company CARMAT, founded in 2008, remains unprofitable - the company's gross loss is USD 24.4 million [7]. Why is the unprofitable CARMAT actively developing, and why do investors continue to regularly invest in it?

Investors continue to invest their money in companies that they see as promising and that can change our lives. CARMAT was the first company

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<sup>1</sup>INPI is a fully self-funded government agency under the authority of the Ministry of Economy, Industry and Digital Technologies. It grants patents, trademarks and industrial design rights, and provides access to all information related to industrial property and businesses.

to create a fully autonomous human heart that can completely revolutionize the entire healthcare industry and improve the lives of millions of people.

The market capitalization of the company today is 393.7 million euros [7]. The share price tended to grow strongly in 2020, then declined slightly in the first four months of 2021, then the growth began to recover. Five-year beta, reflecting the risks of volatility, is less than one ( $\beta = 0.87$ ), which indicates low volatility of CARMAT shares relative to the market. CARMAT share price is 25.7 euros (Fig. 2).

CARMAT is a leader recognized at the European level: with the support of the European Commission, CARMAT received the largest subsidy ever provided by Bpifrance to small and medium-sized businesses, totaling 33 million euros [4].



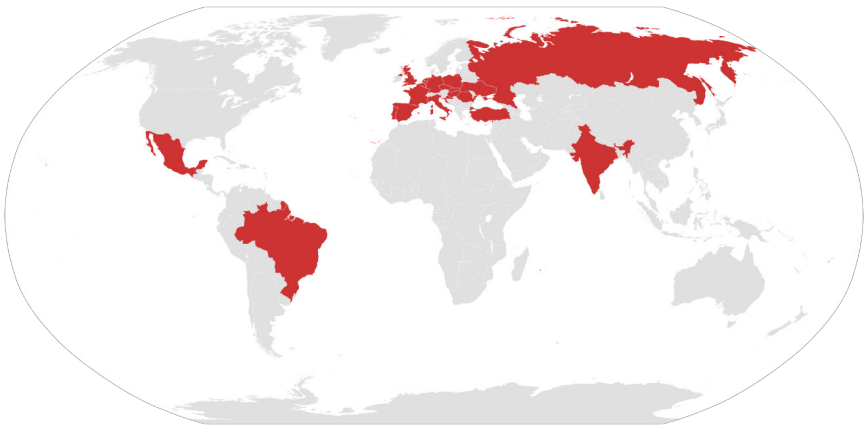
**Figure 2 – CARMAT share price, 2016-2021, euro**

Source: built by the author based on data Finance Yahoo, Carmat SA (ALCAR.PA), Available online: <https://finance.yahoo.com/quote/ALCAR.PA/financials?p=ALCAR.PA> (date of the application 12.06.2021).

**The Disruption Strategy.** This strategy is the complete opposite of the IP strategy. It involves a decision to compete directly with incumbent players with an emphasis on the commercialization of the idea and the rapid growth of market share, rather than control over the development of the idea. The startup seeks to rapidly build capabilities, resources and customer loyalty so the imitators cannot catch up. For this reason, the initial customer choice is usually a niche segment that is poorly served

by incumbent operators and is out of their sight. This allows the startup to build trust and explore new technologies that may have initial flaws but have significant potential for significant improvement.

An example of a company that has chosen this strategy is BlaBlaCar, the world's leading online travel companion service. Basically, the service works for intercity trips, and travel costs are divided proportionally among all participants in the trip. Three years ago, BlaBlaLines was launched to organize short-distance ridesharing and daily city or suburban routes. BlaBlaCar raised a total of \$ 563.5 million in 7 rounds. The last funding was received on April 20, 2021 as part of the round of convertible bonds [5]. The company was founded in 2006, entered the international market in 2009, offering its services in Spain. The company's big breakthrough came in 2007 when the French rail network was closed due to a strike and passengers were looking for alternative means of travel. Today BlaBlaCar is represented in 22 countries (Fig. 3), and has 90 million users [3].



**Figure 3 – Geographic representation of BlaBlaCar, 2021 r**

Source: BlaBlaCar, Available online: <https://blog.blablacar.com/about-us> (date of the application 10.06.2021).

As the company has grown, competitors have emerged. The American transit company Via, established in 2012, and the American company Lyft, established in 2021, is engaged in transportation, connecting passengers with drivers. BlaBlaCar chose this business development strategy, introducing a completely new service for the first time and embarking on a

rapid development and international expansion, allowing competitors to try to copy its success. In the innovation market, it is critical to be the first. The BlaBlaCar's idea has something in common with such well-known companies as Airbnb, eBay, Uber. By minimizing transaction costs, these platforms bring together two types of groups, usually «buyers» and «sellers»: Airbnb connects people with vacant rooms and travelers in need of accommodation, Uber connects drivers and passengers, eBay connects buyers and sellers, BlaBlaCar connects drivers with empty seats in their car with passengers traveling to the same destination.

BlaBlaCar announced that its revenue grew 71% in 2019 compared to 2018 [2]. The startup has built a global transportation network that has allowed the firm to become a unicorn company [1] with a market value of US \$ 1.6 billion [8].

**The Value Chain Strategy.** Undoubtedly, competition is exciting. By comparison, the value chain strategy seems a bit simple. However, the identity of such companies stems from competence rather than aggressive competition, in this case, companies focus on developing scarce talent, unique abilities, unique products and services to become preferred partners. The startup invests in commercialization and day-to-day competitiveness rather than control over a new product and creating barriers to entry, but its focus is on fitting into the existing value chain, not reversing it.

Finexkap is a prime example of a French startup that has chosen this strategy. This innovative FinTech company has transformed the way French SMEs do business by providing an online platform through which they can access the required working capital. In France it has been estimated that 25% of corporate bankruptcy happened due to lack of short-term financing [9]. And in the United States, half of SMEs admit that this is a constant obstacle to their operation. More often than not, cash flow depletion is the result of unpaid bills. Traditionally, companies have had to go to the bank to access the funding they need to fill the gaps. Unlike traditional banks in France, which usually do not offer spot financing, Finexkap has developed a flexible way of financing working capital for SMEs, allowing them to choose the invoices they want to issue without having to analyze the underlying assets. With an astronomical 3500% revenue growth in its first year, Finexkap easily outpaced its competitors in the race to become France's fastest growing startup in 2016 [10].

Moreover, Finexkap fulfills a real social function, allowing small businesses to thrive when companies would otherwise face difficult financial choices or inevitable failure.

**The Architectural Strategy.** This strategy allows startups to both com-



pete and gain control, but it is beyond the reach of many companies and highly risky. A fast-growing company that is also investing heavily in protecting its intellectual property is French startup ContentSquare, which has developed a digital experience analytics platform that allows businesses to track customer behavior online and use that information to better interact.

The company has created unique technologies that track trillions of digital interactions and turn these behaviors into smart recommendations that various companies and their marketing departments, e-commerce departments, digital design, merchandising and many others can use to improve the digital experience, increase revenue and stimulate innovation. These technologies can, for example, create an entire map of how visitors navigate a customer's site from entry to exit, visualize how users interact with each page and how this affects their behavior, reconstruct individual visitor sessions on their website, and much more. In the eight years since its inception, the company has grown enormously, invested multi-million-dollar amount of money in innovation that needed to be protected by patents. In the software start-up market, patent litigation is not always on the agenda, as is the case for, for example, fashion companies. However, in ContentSquare's strategy, protecting its intellectual property is one of the most important points. After developing a patent strategy, the company doubled its investment in research and development [6].

We can conclude that to be innovative means to be different from everyone else. Innovation leaders achieve extraordinary success, revolutionize the market, create new niches in it, and lead everyone else. It is extremely important to choose the right strategy by analyzing the current market conditions, the specifics of the chosen area and the company's capabilities. The key performance indicators of innovative companies are not just the lines of the profit and loss statement, but also the geographical distribution, the number of regular customers, the amount of gross investment made by external investors and the uniqueness that can be provided by patent protection of property rights. All this is included in the strategies of the most successful innovative companies and determines the market capitalization or, in other words, the market value of the company.

In the new economy, when the situation is changing at a very fast pace, there are only two types of firms: fast and dying. Today, «it is not the big one who eats the small, but the fast one eats the slow», so flexible and fast firms, regardless of their size, have a much better chance of survival and success, be in the driver's seat and become a truly market leaders through innovation.

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## DEVELOPMENT OF STUDENTS' THINKING IN THE PROCESS OF TEACHING MATHEMATICS BY MEANS OF EXAMPLES AND COUNTEREXAMPLES

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**Abstract.** The article examines the essence of the concepts "example", "counterexample", provides all kinds of examples and counterexamples that take place in mathematics, and argues how they can help develop the thinking of students.

**Keywords:** development of students' thinking, examples in mathematics, counterexamples in mathematics, teaching mathematics.

In modern conditions in education, priority is given to the developmental function, which requires the teacher to search for and use active teaching methods. Such an active method in teaching mathematics is the organization of educational and research activities of students. This activity can be organized in the course of solving special search and research problems.

The reader can learn more about the essence of search and research tasks, their classification and didactic functions in the learning process in our work [2].

In the process of working on a search and research task, the student considers various solutions, thereby demonstrating the work of convergent, divergent and critical thinking.

Studies [7, 8] highlight the following qualities of critical thinking: clarity, transparency, accuracy, correctness; relevance, involvement in the case; consistency, consistency, consistency; depth, completeness and originality; beauty and perfection; evidence, argumentation.

In mathematics, the following four logical formulas are most commonly used:

1.  $\forall x(A(x) \Rightarrow B(x))$ ; 3.  $\exists x(A(x) \wedge B(x))$ ;
2.  $\forall x(A(x) \Rightarrow \overline{B(x)})$ ; 4.  $\exists x(A(x) \wedge \overline{B(x)})$ .

Judgments 1) and 2) are refuted by counterexamples, and judgments 3) and 4) are proved by examples.

Examples and counterexamples are objects of the same nature and the strategy for their search does not depend on the content of the judgment, but is dictated by its structure.

N.A. Kurdyumova [3] studied the impact of examples and counterexamples on the achievement of the developmental goals of teaching mathematics and concluded that these didactic tools enhance the developmental function of the learning process in mathematics, as they allow the development of logical and critical thinking.

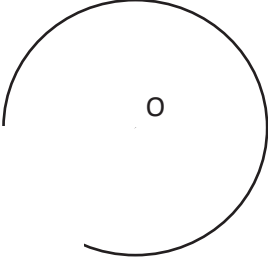
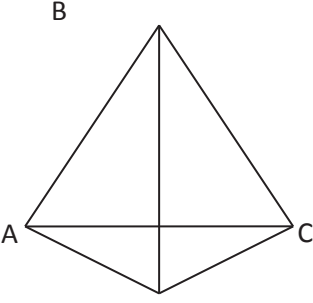
Student constructing counterexamples can be seen as a heuristic activity that goes through five phases of creative decision.

Students' activities to construct examples and counterexamples should be organized on various problems, including math. At first, it is advisable to invite students to build examples and counterexamples proving the falsity of statements for which the true meaning has already been indicated, and only then propose the construction of examples and counterexamples proving or refuting the truth or falsity of these statements or statements regarding which their true meanings are not indicated. Here are some examples.

I. The first series of examples is aimed at working with definitions of concepts, at bringing objects under the scope of concepts.

Give counterexamples proving the fallacy of the following definitions of concepts (table 1).

**Table 1**

№	Definitions	Counterexamples
1	2	3
1	<p>A circle is a plane curve, the points of which are equally distant from one point lying in this plane, called the center of the circle.</p>	 <p>All points of the specified flat line are removed from point O by the same distance, but the line is not a circle. The definition does not specify the essential feature "all".</p>
2	<p>A rectangle is a rectangle whose diagonals are equal.</p>	 <p>Quadrilateral ABCD has equal diagonals AC and BD, but it is not a rectangle.</p>

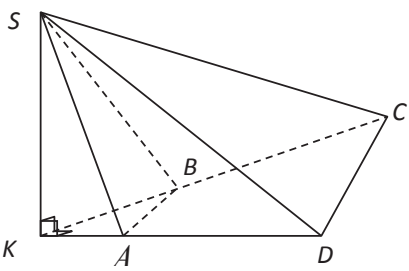
II. Give counterexamples proving the falsehood of the following statements (table 2). The table in the third column provides counterexamples.

Table 2

№	Statements	Counterexamples
1	2	3
1	Any number ending in one is divisible by 3.	41, the number ends in one, but it is not divisible by 3.

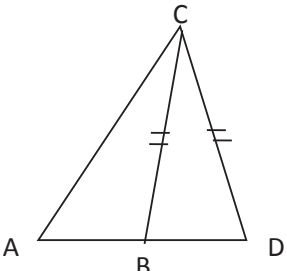
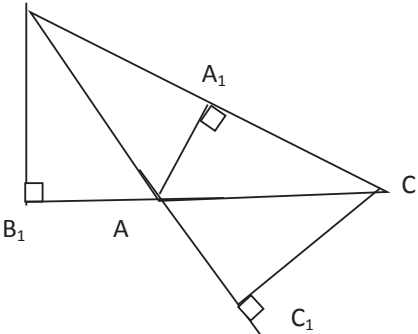
III. Give examples proving or refuting the following judgments (table 3). In the third column of the table, examples are given.

Table 3

№	Judgments	Examples
1	2	3
1	For any value of the variable $x$ , the expression $\sqrt{\frac{-(x-1)^2}{x^2+1}}$ is meaningless.	An example refuting the judgment: for $x=1$ , the expression makes sense and its value is zero.
6	There is no quadrangular pyramid with two opposite faces perpendicular to the base.	 <p>A counterexample refuting the statement.</p> <p>In the pyramid (see fig.) SABCD faces SBC and SAD are perpendicular to the base ABCD (The desired pyramid is obtained from the triangular pyramid SKCD in which the faces SCK and SDK are perpendicular to the base of KCD).</p>

IV. Give counterexamples proving the falseness of these inferences (table 4).

Table 4

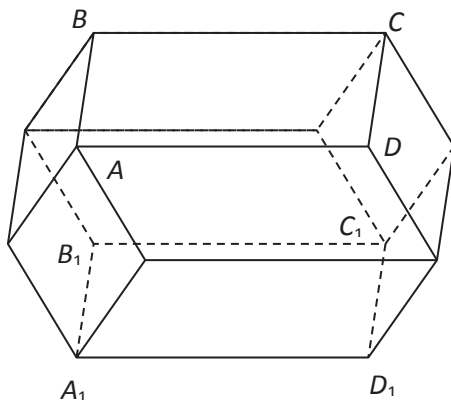
№	Inferences	Counterexamples
1	2	3
1	If two sides and an angle opposite one of them, of one triangle are respectively equal to two sides and an angle opposite one of them, of the other triangle, then such triangles are equal	<p>Counterexample confirming the falseness of the inference</p>  <p>In triangles ABC and ADC, side AC is common, sides CB and BD are equal, angle A is common, but triangles are not equal.</p>
2	The heights of the triangle intersect at one point	<p>Counterexample to refute the inference</p>  <p>In obtuse triangle ABC, the heights BB<sub>1</sub>, AA<sub>1</sub>, CC<sub>1</sub> are drawn, do not intersect at all. If straight lines are drawn through the heights, then the latter will intersect at one point. The theorem should be formulated as follows: "Lines containing the heights of a triangle intersect at one point."</p>

The tasks described in tables 1,2,3,4 are widely presented in our work [1] and in works [5, 6].

The next important stage in teaching students to work with examples and counterexamples should be the stage at which they are offered statements, statements, inferences about which it is not known whether they are false or true, and it is required to establish their truth values and give examples and counterexamples confirming these values. Here are some examples.

**Example 1.** When studying the concept of a prism, it is useful to invite students to answer the question: "Is this definition of a prism correct: a prism is a polyhedron whose two faces are equal polygons with correspondingly parallel sides, and all other faces are parallelograms?"

The answer to the question posed is negative and this is confirmed by Figure 1, which shows a polyhedron that is not a prism, but in which:  $ABCD$  and  $A_1B_1C_1D_1$  are "bases", and all the other faces of the parallelogram. Note that such an erroneous definition of a prism was given earlier in the textbook by A.P. Kiselev.



**Fig.1**

**Example 2.** Prove or refute the judgment: "For any  $x > 0, \sqrt{x} < x$ "

Note that the refutation of a judgment requires the ability to build its negation.

As the experiment has shown, for the development of critical thinking of students, it is advisable to offer them tasks to find errors in problem solutions and theorem proofs. Problems of two types can be proposed:

a) tasks with conflicting information in the condition;



b) problems with conflicting information in the structure of the solution.

Working with problems containing conflicting information in the structure of the solution is structured as follows:

- the problem is proposed together with its solution;
- the error is included in the chain of logical conclusions;
- students are required to find the error in the solution and explain the reason for its occurrence.

The analysis showed that the greatest effect of counterexamples is achieved when two statements are formulated in which the condition and conclusion are interchanged, and the greater effect is achieved if the truth of the statements is unknown to the students.

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## TIME-MANAGEMENT STRATEGY IN THE FORMATION OF STUDENTS' INDIVIDUAL EDUCATIONAL ROUTE

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**Abstract.** The research analyzes the data obtained during the survey, reflecting the degree of familiarity among students about such a concept as time management, the specificities of using this technique for personal time organization with teaching students at a university with the use of distance technologies, as well as issues arising in connection with the need to control time in the educational process.

**Keywords:** time-management, self-organization, efficiency, organization of educational process, individual educational route.

Abstract: "Among the unknown in the nature around us, the most unknown is time, for no one knows what time is and how to manage it." In this statement, Aristotle points to a problem that is more urgent than ever for modern people as the organization of time in human life, as society puts forward more and more requirements for the successful realization of our professional and personal potential. It is especially relevant for students of higher educational institutions, since they have been working with a large amount of information that needs to be acquired in a short time.

A specific feature of modern education can be considered as the need to build an individual educational route in conditions of increasing intensity and density of information flow and a lack of time. Teaching students to consciously and effectively manage the process of self-education, professional and personal growth, the formation of a value attitude to the category of time is proposed to be carried out within the framework of the "Time Management" course in universities of various profiles [4]. In connection with the implement of the distance education format, people are paying more and more attention to the rational use of their time. One of

the different ways of its distribution is time-management – it is not just "physical time-management", but first of all it is the organization and self-organization of a person or a group of people so that in the time, allotted for work or study, the assigned tasks would not only be completed, but also satisfaction with the work performed would be achieved so that there were no subjective obstacles, barriers for work continuation [1]. One of the main distinguishing features of students' time-management (especially while studying online) is a conscious assessment of their work while performing any activity [1]. Time-management can be a significant criterion for assessing the degree of this awareness in a virtual learning format. It should also be noted that disability of managing your time could lead to psychological and emotional overload and burnouts, a low level of quality of life [2]. Time-management should not be associated with such an attitude as to working twenty-four hours a day and not getting tired: it is created for rest to be envisaged correctly into our day so that people have time to restore their powers enough and increase their concentration during working hours. Self-management, as an essential part of time-management, can improve great qualities and human's features: clear, realistic definition of goals, precise creation of a picture of success in your mind (including your material situation, surroundings and other moments), using the «big jump» technique, which implies a quick transition to specific actions, unconditional belief in one's own strength and success, focusing on the main goals and screening of secondary ones, ability to behave in the hands and start again in the event of an unsuccessful experience [5].

Purpose: to find out whether time-management is effective for organizing the time of students in a distance learning format in universities, to assess the degree of self-organization among students, and also to find out whether time-management affects an increase in the level of anxiety (taking into account the increase in computer workload, which is determined by online education).

Materials and methods of research: a survey included students at universities in Volgograd and Moscow was carried out, during which it was proposed to answer questions regarding the use of time-management among students according to the emergence of a distance education format. The survey was conducted using Google Forms.

The object of the research was students of 1–6 courses of universities in Volgograd and Moscow. The survey involved 122 people.

Results: the survey involved several age categories: less than 18 years old – 11.5%, 18–20 – 47.5%, 21–23 – 32.8% and 24 years and more – 8.2%. It is important to note that at the time the survey was done, respondents

had already faced an enforced application of distance learning due to the covid-19 pandemic. Analysis of the responses received showed the following results: despite the fact that most people know what time-management is (86.1% against 13.9% of those who do not know) are confident in its efficiency (88.5% against 11.5% of those who doubt) and 55.7 % of them have a personal schedule, more than half of the respondents (50.8%) do not apply any time-management techniques in a distance learning environment.

At the same time, 30.3% of respondents indicated that they use special timers for study (Forest, Pomodoro), 53.3% do not use it, and 16.4% do not know what it is at all.

According to the survey, almost half of the students (47.5%) reported that they manage to complete more tasks in the hybrid form of education, 38.5% in the fully distance learning format, and only 8.2% preferred the full-time option. Also noted were the comments of some respondents that “the format does not matter, since everything depends on the volume of homework and your own desire” and that “it turns out about the same, because with online learning the number of tasks is increased, and with offline learning a lot of time is constantly spent on the road and getting to the university”.

46.7% of the respondents note that study time-management helps them to reduce the level of stress and anxiety, 18.9%, that it, on the contrary, increases it, and for 34.4% it has no effect.

Also, students were given the opportunity to share their advice and observations, if they have any, allowing them to perform tasks more efficiently. The following answers were offered by the respondents:

- listening and watching lectures at an increased speed. The most common variant of the accelerated format is 2x.

- repetition of the material before going to bed or early in the morning.
- drawing up mental maps.
- reading and repeating material out loud.
- drawing up diagrams, associations and tables, pictures.
- listening to material on the way.
- keeping short notes and making them beautiful.
- retelling of the material.
- silent mode phone.
- good spirits.

Among the various time-management techniques [3], one the most popular is Bullet journal (to-do list maintenance; Instead of blank, lined pages, a bullet journal (or BuJo, for short) contains sections to log daily to-

dos, keep a monthly or weekly calendar, jot down notes, track both physiological and mental health, plus record both short- and long-term goals.) - 41.8%, then ABC analysis - performing tasks according to priorities. In materials management, ABC analysis is an inventory categorization technique. ABC analysis divides an inventory into three categories—"A items" with very tight control and accurate records, "B items" with less tightly controlled and good records, and "C items" with the simplest controls possible and minimal records. - 32%, and then within 5-7% there are such techniques as the Eisenhower matrix (The Four Quadrants. Also referred to as the Urgent-Important Matrix, this visual method of time management splits tasks into four quadrants to help prioritize the order of completion. Boxes are labelled one to four, each with a specific action point: do, decide, delegate or delete), the Pareto method (is a type of chart that contains both bars and a line graph, where individual values are represented in descending order by bars, and the cumulative total is represented by the line. The purpose of the Pareto chart is to highlight the most important among a (typically large) set of factors) , and the "Timekeeping" technique (getting to work early and approaching the work you have to do in good time allows you to plan out what you need to do; You can make a list and prioritize the most important elements of your working days).

Conclusions: the analysis of the results obtained indicates a good awareness of students about time-management and its potential benefits, however, considering modern realities, a much low number of respondents apply it in practice, although the often-enforced application of distance learning encouraged university students to reconsider their approach to learning. However, for many people time-management has no influence on stress resistance, and, in all likelihood, some other factors can change the level of anxiety. For a larger number of students, the transition to partial distance learning is optimal in order to maintain maximum efficiency. Consequently, education at a university using distance technologies for most students does not entail dramatic changes in the organization of their time, although adaptation to such a mode of study occurred in any case.

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**THE USE OF ACTIVE TEACHING METHODS IN THE PROCESS  
OF FORMING GENERAL PROFESSIONAL COMPETENCIES  
OF FUTURE TEACHERS IN THE FIELD OF TECHNOSPHERE  
SECURITY**

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**Abstract.** The article is devoted to the problem of the formation of general professional competences of future teachers in the field of technosphere safety and the use of active teaching methods for these purposes. This category of methods is noted as the most productive, since it is characterized by a high level of involvement in the educational process of students, and also activates cognitive and creative activity in the course of solving the proposed problems.

**Keywords:** formation of general professional competencies of future teachers in the field of technosphere safety, active teaching methods, business game, brainstorming, case studies.

Today, in the context of widespread globalization and digitalization, the issues of ensuring security, including the technosphere, are becoming of paramount importance. So, according to the Federal State Educational Standard of higher education, a future teacher should be formed in the course of training a defense industry complex, among which is: readiness to ensure the protection of the life and health of students (OPK-6) [1].

The priority methods aimed at the formation of general professional competencies of future teachers in the field of technosphere safety are active methods. "They are characterized by a high degree of student involvement in the educational process, activate cognitive and creative activities in solving the assigned tasks" [2]. One cannot but appreciate the contribution, A.M. Matyushkina in the development of active teaching methods in relation to higher education. The author in his works introduces such a concept as dialogical problem learning, this phenomenon best characterizes the essence of the joint active activity of the teacher and students, according to the means of realizing "subject - subject" - relations [3]. Thus,

the learning process with the use of active methods at the university, in addition to general didactic principles, is based on a system of specific principles, which include: the principle of balance between the content and the teaching method, taking into account the preparedness of students and the topic of the lesson; the principle of modeling; the principle of incoming control; the principle of correspondence of the content and methods to the learning objectives the principle of problematicity; the principle of "negative experience" [4].

Today in pedagogical science there are various approaches to the classification of active learning methods. In this direction, research was carried out by such scientists as V.N. Kurglikov, A.M. Smolkin, E.V. Zarukina, V.A. Slastenin, Yu.P. Abramov and others. So, A.M. Smolkin divides the methods of active learning for the university into two areas: imitative and non-imitative. "Simulation methods of active learning, that is, forms of conducting classes in which educational and cognitive activity is based on imitating professional activity, and non-imitative methods are all ways to enhance cognitive activity in the classroom" [5, p. 30]. In turn, simulation methods are classified into play and non-play. So game methods include: business games, didactic games, role-playing games, game design, etc. Accordingly, non-game methods include: analysis of specific situations, solving situational problems, group trainings, etc.

The range of non-imitative teaching methods is also quite extensive, it can be attributed to: problem lecture, lecture with a planned error, heuristic conversation, round table, seminars, brainstorming, etc.

Let us consider the most effective active methods used in the process of forming the general professional competencies of future teachers in the field of technospheric safety, including methods: case studies, business games, brainstorming.

So, the case study method gives a positive result in order to develop the following skills: analytical, practical, creative, communicative, social and introspection. The indisputable advantage of this method when studying subjects related to the field of technosphere safety is the ability to optimally combine theory and practice.

"The case study method or the method of specific situations is a method of active problem-situational analysis based on learning by solving specific problems - situations (solving cases)" [6]. The essence of this method is that the assimilation of knowledge and the development of skills occurs as a result of the active independent activity of students to resolve contradictions, as a result of which creative mastery of professional skills occurs. Also, this method contributes to the formation of students' "ethical and val-



ue attitude to the world, to people, to themselves" [7]. In the course of work on the solution of the case, the student independently formulates goals, finds information, analyzes it, puts forward hypotheses, looks for solutions to the problem, formulates conclusions, substantiates the optimal solution to the situation. In addition, the use of the case method allows you to see the ambiguity of solving problems in real life.

The content of the cases includes such situations that allow students to see their professional goals most clearly and evaluate themselves as a future specialist, as well as analyze their value orientations and personal qualities.

Another method that is effective in the process of forming the general professional competencies of future teachers in the field of technosphere safety is the method of "business games is a complex methodological teaching method, in which students first of all consider the decision-making process" [8]. The famous Soviet psychologists L.S. Vygotsky described this phenomenon, "the kingdom of arbitrariness, freedom and imagination", where, due to the operation of pure meanings and meanings, imaginary situations are created and "an illusory business game takes place as a means of activating cognitive activity and a way of forming students' professional competencies, the realization of unrealizable desires" [9 , p. 203]. Thus, the use of the business game method contributes to an increase in the level of knowledge, the development of logical thinking, the development of skills and the ability to apply theoretical knowledge in practice in future professional activities. It should also be noted the social significance of this method, in the process of completing the task, the skills of group interaction are developed. In addition, the ability to search for answers to the questions posed, the ability to communicate in the process of discussion is developed, as well as the speech etiquette of future teachers is formed.

A special place in the structure of active teaching methods is occupied by the brainstorming method proposed by A. Osborne in the 30s in the USA. In his book "Guided Imagination" the author reveals the principles and procedures of creative thinking, as well as divides in time the processes of forming an idea and a critical assessment of this idea. So, the main "feature of the brainstorming method is collective thought activity to generate new ideas for solving scientific and practical problems through the free expression of opinions by all participants, searching for non-traditional ways of their implementation" [10, p. 59].

Thus, we come to the conclusion: the use of active teaching methods in the process of forming general professional competencies of future teachers in the field of technospheric safety is the most effective. In the future,

we plan to implement the work program of the integrative course "Technosphere Safety in Education" into the teaching process.

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## CATALECTICS OF V.V.NABOKOV'S CLASSICAL VERSE IN THE CONTEXT OF RUSSIAN POETIC TRADITION<sup>1</sup>

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**Abstract.** The article is devoted to the problem of identifying the specificity of the verse of the Russian-language poetry of V.V. Nabokov in the context of the Russian literary verse of the XVIII–XX centuries. For the first time in modern literary criticism, the poet's clause repertoire is investigated: on the basis of the complete corpus of all currently available texts by Nabokov, the ratio of clause variants of classical meters is examined. It is shown that the proportions of catalectic, acatalectic and hypercatalectic forms in the poet's work are not typical for any of the historical eras of the development of Russian literary verse. The results of the study cast doubt on the thesis about the conservatism of Nabokov as a poet, which has become firmly established in literary criticism, and testify to the experimental nature of his work.

**Keywords:** V. V. Nabokov; Russian verse of the XX century; metric of Russian verse; catalectics of Russian verse; quantitative methods of poetry.

Out of the field of vision of the researchers of V.V.Nabokov's verse to the present time remains such an important structural factor as the verse endings. This is partly due to the fact that in Russian syllabotonics the foot is not a real, but a conditional measure of verse; hence the generally accepted idea of the optional role of endings, therefore "the division of rhythmical endings into catalectic, acatalectic and hypercatalectic for Russian verse is only a terminological fiction" [6: 66]. It is no coincidence

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that G. Smith, considering in his article on the Russian-language verse of Nabokov the poet's rhyme, completely neglects the clause forms [see: 3: 109-111]. At the same time, given the fact that almost 96% of the author's poetic heritage is written in classical poetic meters, the nature of the correlation between the meter and the ending is, in our opinion, of particular interest.

The material for the statistical description was all currently available poetic texts by Nabokov (578 works, 18470 lines of poetry, among which 513 works, 17703 lines written in classical meters). Table 1 presents the statistical data on the distribution of acatalectic (**A**), catalectic (**C**) and hypercatalectic (**H**) forms in different meters in Nabokov's works. For comparison, the average statistical data for Russian verse of the XVIII - early XXI centuries are given in parentheses. [5: 254].

**Table 1. The ratio of acatalectic, catalectic and hypercatalectic forms in classical poetic meters (in %)**

	<b>Trochee</b>	<b>Iamb</b>	<b>Dactyl</b>	<b>Amphibrach</b>	<b>Anapest</b>
<b>A</b>	48.6 (45.8)	43.1 (48.9)	4.2 (13.0)	39.7 (46.7)	49.7 (46.4)
<b>C</b>	48.7 (44.9)	–	95.8 (84.2)	53.6 (47.5)	–
<b>H</b>	2.7 (9.3)	56.9 (51.1)	no (2.8)	6.6 (5.8)	50.3 (53.6)

As you can see, the contrast between the data on the verse of Nabokov and the average data on the Russian verse is obvious, although for each of the classical meters it is specific. So, in the trochaic meters, the difference in the proportions between the **A** and **C** endings in Nabokov's works is actually reduced to zero, which is not surprising, since the percentage of trochaic texts in the entire corpus of Nabokov's poems is extremely insignificant, but the statistically significant decrease in the **H** endings (by 6.6%) is symptomatic. And the point is not even that the poet prefers to use exclusively male (**m**) and female (**f**) endings in trochaic lines. Dactylic (**d**) are not only rare in Nabokov's works, they appear just in unusual patterns of verse - as separate inclusions in texts written by a free trochee and mixed trochee, in which the number of feet per line changes according to a set pattern (see: «Temno-siniye oboi...», «Lestnitsa» («Slyshu zvon chasov kholodnyy i razmerenny...»), the first link in the polymetric composition «Vecher na pustyre»). Among Nabokov's poetic models (see about them: [2]), we do not find any of the well-known Russian tradition, such as, for example, the semantically marked trochaic tetrameter **dmdm** [1: 19–32].

In iambic meters, where **A** and **H** are traditionally balanced, the poet per-

ceptibly prefers the **f** endings, which generally prevail over the **m** in his verse, but also uses **d** and even hyperdactylic (**h**) endings. And here, just as in trochaic lines, **d** and **h** endings - as a rule - are found in the composition of the free, mixed iamb, transitional metric forms. Only in two poems does Nabokov refer to the model marked by the symbolist tradition - the iambic tetrameter **dmdm** [see: 1: 33–49] («Pervaya lyubov'» and «Vsyo, ot chego ono szhimayetsya...»).

The specificity of the poet's strategy is even more indicative on the example of ternary meters. It is obvious that **A** dactyl is not found so often in Russian poetry (in 13% of texts), it is no coincidence that M.L. Gasparov calls him “a loser meter” [1: 176]. Significant in this case is not only the fact that the percentage of **d** endings in Nabokov's works is sharply reduced in comparison with the average statistical data on Russian verse, but also the complete absence of **h** endings. Rare **d** endings are found in Nabokov's polymetric structures and free dactyl as separate inclusions. In amphibrach lines, where the percentages of **m** and **f** endings in Russian classical verse are approximately equal, that is, **A**  $\approx$  **C**, in Nabokov's works we observe a sharp redistribution of priorities: **m** endings are found almost 14% more often than **f** (and this despite the general predominance of **f** endings in verse by the author). Finally, in anapest lines the statistically significant predominance of **H** over **A**, which is typical for Russian poetry, is replaced by their almost absolute equality in Nabokov's texts.

The prevailing idea of the conservatism of Nabokov's verse [see: 3; 4; et al.] is resolutely refuted not only by the variety of models he used (structures that imply a specific combination of meter, stanza structure, the order of alternation of rhymes and endings) [see: 2], but also by comparative data on different stages of the development of Russian verse and different preferences for **A**, **C** and **H** forms. Table 2 shows statistical data for the verse of the XVIII, XIX, the end of the XIX - the first half of the XX, the second half of the XX - the beginning of the XXI centuries. [5: 254], as well as the entire corpus of Nabokov's classic verse.

**Table 2. Historical evolution of the catalectics of Russian verse and verse by V.V.Nabokov (in%)**

	XVIII century	XIX century	end of XIX — I half of XX century	II half XX — early XXI century	Nabokov
<b>A</b>	47.7	47.7	46.6	45.2	43.0
<b>C</b>	3.8	8.7	18.5	15.3	6.5
<b>H</b>	48.5	44.7	34.9	39.5	50.5
<b>C + H</b>	52.3	53.4	53.4	54.8	57.0

In general, Russian verse is characterized by the highlighting of the end of the line of verses: this happens even more often than in every second line of poetry due to the use of **C** (truncated) or **H** (additional) syllables, which does not allow leveling the verse vertical (merging neighboring verses into a single metrical-rhythmical line). At the same time, the priorities in the methods of marking the line are historically changing. So, for example, if the **A** forms remain practically at the same level for three centuries, decreasing by 2.5% only in the second half of the XX - early XXI centuries, then the ratio of **C** and **H** fluctuates within tangible and statistically significant limits. In the XVIII century, the percentage of **C** was extremely small, but then it increased by the era of the Silver Age by almost 4.5 times; and on the contrary, the percentage of **H** verse at the beginning of the XX century decreases by almost a third, again slightly increasing in the second half of the XX - beginning of the XXI centuries.

In the work of Nabokov we observe a picture, which is not comparable with any of the epochs of the history of Russian verse. Despite the generally accepted ideas about the "literary conservatism" of the poet's verse, his clause preferences are obviously not comparable with any of the historical eras. Thus, endings, which are contrasting with anacrusis, are 14% more frequent in Nabokov's work than "leveling" ones; in addition, such a high percentage of **H** and a low percentage of **C** does not allow us to correlate his verse with any of the indicated eras.

The reasons for this obvious contrast are explained, in our opinion, by the following circumstances. In contrast to the ancient and a number of new European traditions of syllabic verse, in Russian syllabotonic catalexics acts as a rhythmic, rather than metric, parameter of verse. But it was precisely the searches and conscious experiments in the field of rhythm that especially interested Nabokov, who in his youth was strongly influenced by A. Bely's articles on the rhythm of the iambic tetrameter, published in the collection "Symbolism". Thus, the unusual priorities in the choice of verse endings are on a par with the unusual rhythmic forms of the iambic tetrameter («*Nepravil'nyye yamby*», «*Paskha*», «*Smeyetsya kraska, smeyetsya liniya...*» and many others), ternary meters with variable anacrusis, logaoedic meters, micropolymetry and "complex forms".

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## CIRCADIAN RHYTHM OF MEAN ARTERIAL PRESSURE IN THE ACUTE PERIOD OF CONCOMITANT SEVERE TRAUMATIC BRAIN INJURY

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**Abstract.** In group 1 (aged 19-40 years), combined severe traumatic brain injury (CSTBI) caused a transformation of about-week biorhythms into 5-6 day periods of fluctuations in the first two weeks after the injury. A stress reaction of hemodynamics, increasing on the 18-25th day of the acute period of CSTBI, was revealed in traumatized patients of group 2 (41-60 years old). In group 3 (61-84 years), 5-day cycles of AvBP fluctuations from the very beginning were more constant throughout the acute period of CSTBI. The stress response of the circadian rhythm AvBP prevailed in groups 2 and 3 of patients at a later date and was expressed in an increase in the amplitude of daily fluctuations. Monitoring AvBP in the peri-weekly biorhythm is an additional source of information that allows early detection of deviations, assessment of the effectiveness of intensive care in the acute period of CSTBI.

**Keywords:** circadian rhythm of mean arterial pressure, combined traumatic brain injury

**Relevance.** In the general structure of peacetime injuries, the proportion of combined and multiple injuries ranges from 5 to 12%, and among the most severe - up to 40%. An almost constant component of severe associated injuries is TBI, which occurs in such cases with a frequency of 50-72 to 80-82%. Multiple extracranial injuries in combination with TBI occur in 15% of cases. The positive dynamics of data on the treatment of STBI (a decrease in mortality in the United States and other Western countries with STBI to 30-40%), noted in the last decade, is largely associated with an increase in knowledge of pathophysiology acute STBI and the improvement of intensive treatment technologies during this period [1-3].

Due to the lack of information in the literature on the age-related characteristics of injuries associated with severe traumatic brain injury (STBI),



we tried, based on a retrospective analysis, to identify the features in different age groups of the circadian rhythm of mean arterial pressure (AvBP).

**Purpose.** To study the circadian rhythm of mean arterial pressure in the acute period of combined severe traumatic brain injury.

**Material and research methods.** The indicators of a comprehensive examination of 30 patients with concomitant severe craniocerebral trauma (CSTBI) who were admitted to the ICU of the neurosurgical department of RSCEMA in the first hours after an accident - 28, catatrauma of 2 patients were studied. According to indications, 29 patients underwent invasive mechanical respiratory support (MRS) on admission. Monitoring was carried out by complex hourly recording of body temperature and hemodynamics parameters: Genuine blood pressure (GBP), Pulse blood pressure (PBP), Systolic blood pressure (SBP), Diastolic blood pressure (DBP), respiration. Mechanical respiratory support was initiated with artificial lung ventilation (ALV) for a short time followed by switching to SIMV. The severity of the condition was assessed using scoring methods for assessing the severity of combined injuries - the CRAMS scale, the assessment of the severity of injuries on the ISS scale. On admission, impaired consciousness in 29 injured patients was assessed on the Glasgow Coma Scale (GS) 8 points or less. Patients were considered in three age groups: group 1, 19-40 years old (13), group 2 - 41-60 years old (9), 3 - 61-84 years old (8 patients). Complex intensive therapy consisted in identifying and timely correction of deviations: MRS, after removing from shock anesthetic, anti-inflammatory, antibacterial, infusion therapy, correction of protein and water-electrolyte balance disorders, surgical early correction to the extent possible, stress-protective therapy.

### Result and discussion.

Dynamics of the mesor of mean arterial pressure in the acute period, in mmHg

Days	Group 1	Group 2	Group 3
1	92.1±2.7	90.2±8.0	97.3±6.0
2	88.3±1.8	95.7±3.8	92.0±2.7
3	90.9±2.4	93.3±3.3	90.5±2.3
4	96.6±2.0	94.9±3.9	93.5±2.2
5	93.9±1.7	97.1±2.8	96.4±4.5
6	94.4±1.8	94.3±1.9	95.8±2.4

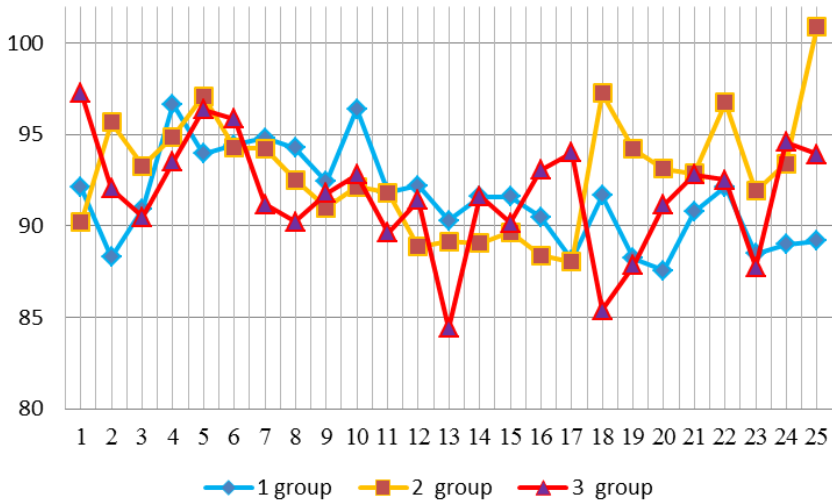
## Process Management and Scientific Developments

7	94.8±1.5	94.2±2.9	91.2±2.3
8	94.3±2.1	92.5±2.2	90.2±4.2
9	92.4±2.7	91.0±3.7	91.8±3.1
10	96.4±2.8	92.1±2.1	92.8±3.5
11	91.8±1.6	91.8±2.2	89.6±3.8
12	92.2±2.1	88.9±3.2	91.4±3.0
13	90.3±2.4	89.1±2.6	84.4±2.5*
14	91.6±2.6	89.0±2.3	91.6±3.3
15	91.6±2.2	89.7±2.3	90.2±3.1
16	90.5±1.5	88.4±2.5	93.1±3.1
17	88.1±3.2	88.0±2.7	94.0±2.8
18	91.6±3.0	97.2±4.9	85.4±3.3*
19	88.2±2.6	94.2±3.8	87.9±3.0
20	87.6±2.4	93.1±5.4	91.2±3.1
21	90.8±2.3	92.9±4.3	92.8±4.5
22	92.1±4.0	96.8±4.9	92.5±5.6
23	88.5±3.1	91.9±3.4	87.7±5.1
24	89.0±2.7	93.4±3.0	94.6±4.8
25	89.2±4.0	100.9±5.8	93.9±5.4

\*- deviation is reliable relative to the indicator in 1 day

On the first day, there were no significant differences depending on age, the mean BP in group 1 was 92.1±2.7. In group 2 - 90.2±8.0 mmHg, in group 3 – 97.3±6.0. In the dynamics of the acute period, a statistically significant change in the AvBP mesor was revealed only in group 3 on days 13 (by 11%,  $p < 0.05$ ) and 18 (by 12%,  $p < 0.05$ ). Fluctuations were observed during continuous vasoactive therapy.

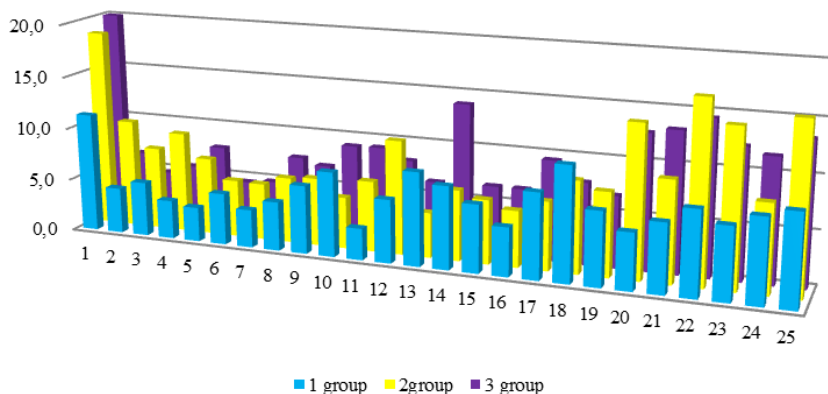
### Dynamics of the mesor of mean arterial pressure in the acute period CSTBI, mmHg



**Fig.1**

In the first group, changes in the AvBP mesoor occurred in waves with periods of fluctuations of 4-5 days. A significant difference in AvBP was revealed on days 2 and 4 of 8 mm Hg ( $p < 0.05$ ), on days 10 and 13 - 6.1 mm Hg ( $p < 0.05$ ), which corresponds to the transformation of about-week biorhythms into 5 -6 daily periods of fluctuation in the first two weeks after injury. In the following days, changes in AvBP were represented by low-amplitude waves with the same wavelength of changes in the mesor of the circadian rhythm AvBP. In group 2, in the first two weeks, there was a tendency to the formation of five-day fluctuations, from 18 to 25 days, an increase in the amplitude of 5-day rhythms was found (up to 9.2 mmHg,  $p < 0.05$ ), which characterizes the stress reaction of hemodynamics, increasing on days 18-25 acute period of CSTBI in patients of group 2. In group 3, 5-day cycles of fluctuations in blood pressure with an amplitude of about 7 mmHg ( $p > 0.05$ ) were more constant from the very beginning throughout the acute period of CSTBI.

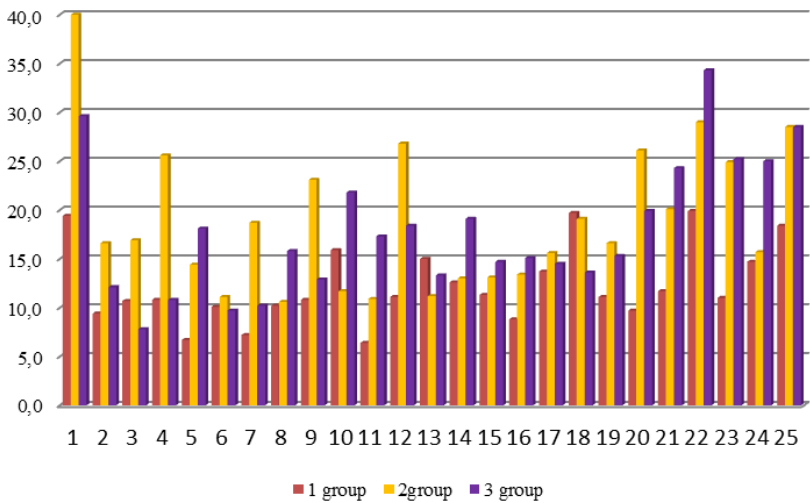
### Dynamics of the amplitude of daily fluctuations in mean arterial pressure



**Fig.2**

Changes in the amplitude of daily fluctuations in AvBP occurred in waves, averaging 7 mmHg in group 1, 13 mmHg in group 2, and 16 mmHg in group 3 with an oscillation period of 5, 4 days (fig. 2). Attention was drawn to the increase in the amplitude of daily fluctuations in AvBP on days 20-25 in group 2 (13-17 mmHg). The highest values of the amplitude of daily fluctuations of the indicator were observed in group 3 on day 1 (20 mmHg), on day 14 (13 mmHg), on days 20-25 (13-14 mmHg). Thus, the stress response of the circadian rhythm of blood pressure predominated in groups 2 and 3 of patients at a later date and was expressed in an increase in the amplitude of daily fluctuations. The latter may have been associated with the limitation of stress-protective sedative therapy in order to restore spontaneous breathing in patients.

Dynamics of the range of daily fluctuations in mean arterial pressure


**Fig.3**

The range of daily fluctuations (the difference between the maximum and minimum AvBP value) in group 1 was 14 mmHg on days 1, 18, 22, in group 2 40 mmHg on day 1, 25 mmHg on day 4, 27 mmHg on days 12, 20, more than 25 mmHg on days 22, 25 (fig. 3). In group 3, the maximum range of daily changes in AvBP up to 34 mm Hg was detected on the 22nd day. The changes were of an oscillatory nature with a wavelength of 4 - 5 days. Thus, the stress response in the acute period of CSTBI was expressed in the transformation of the near-weekly rhythm of AvBP fluctuations into 4-5 days.

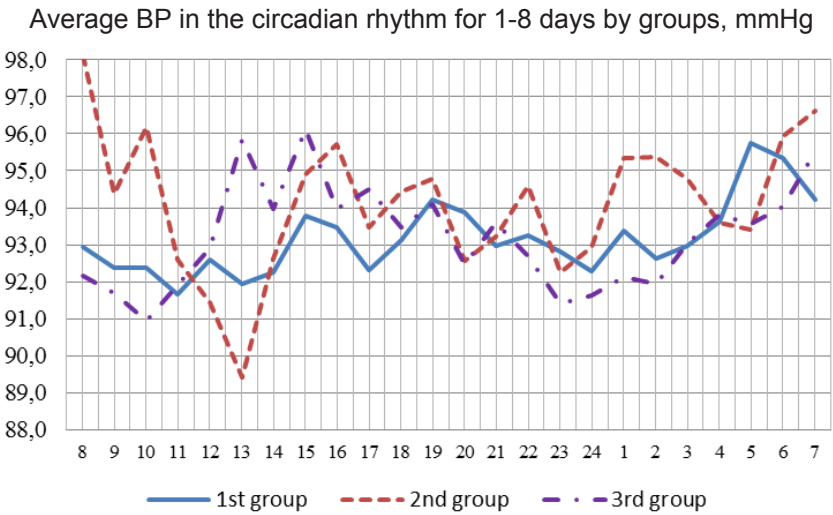


Fig.4

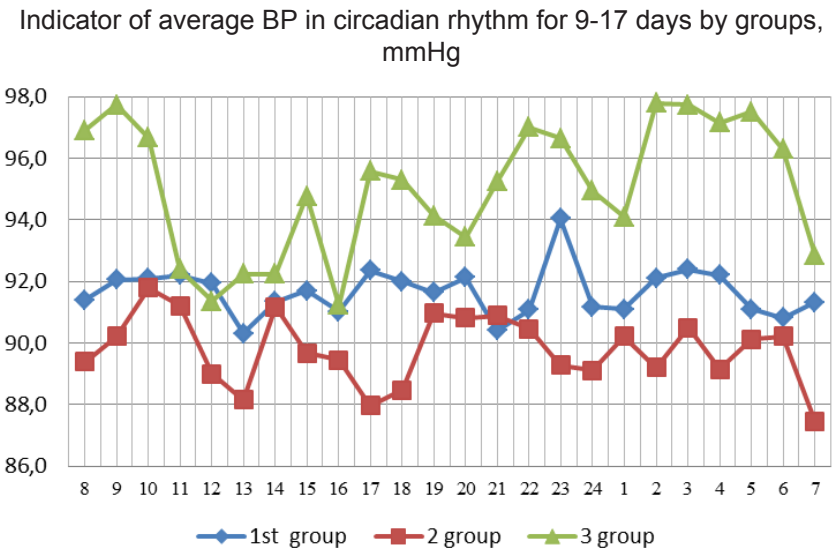


Fig.5

An attempt to differentiate changes in the first 8 days made it possible to reveal that the highest AvBP value was observed on day 1 at 8 a.m. (98 mmHg), which decreased to a minimum (89 mmHg) at 1 p.m. in patients of group 2, remaining at level 94 mmHg with a tendency to rise at night (1-3) hours. In group 2, during the first week after injury, an inversion of the AvBP circadian rhythm was observed in group 2. The tendency to an increase in AvBP at 13-15 o'clock in the afternoon to 96 mmHg, a decrease to 91 mmHg at 23 o'clock, indicating some tendency to maintain the circadian rhythm of AvBP at the physiological level in the first 8 days of intensive therapy. The minimum fluctuations in AvBP (within 1-3 mmHg) in patients of group 1 were most likely due to intensive stress-protective sedative therapy (fig. 4).

In the second week of treatment (9-17 days), the tendency to inversion of the circadian rhythm AvBP in groups 1 and 3 was more noticeable. Oscillations with a 5-6 hour wavelength became more distinguishable (increased amplitude) in group 2 during the daytime, and in group 3 in the evening and night hours, while a single increase by 4 mmHg was observed at 11 pm in group 1 (fig. 5).

Average BP in circadian rhythm for 18-25 days by groups, mmHg

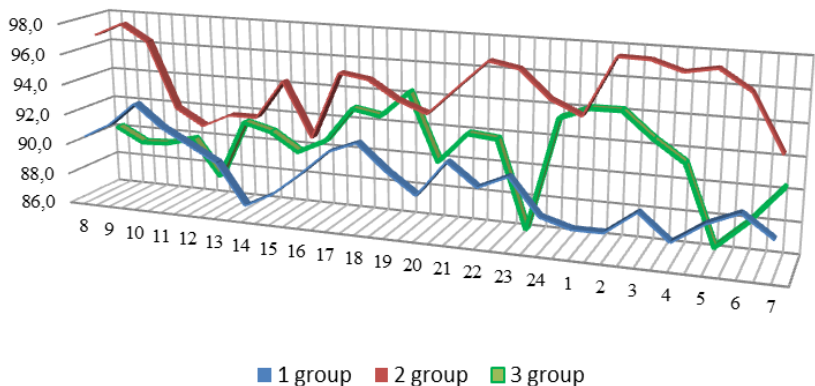


Fig.6

On the 18-25th day of the acute period of CSTBI in group 1, there was a tendency to the restoration of the physiological daily wave AvBP (91.5 mmHg at 9 am, 86 mmHg at 24-2 am). While in groups 2 and 3, the inversion of the AvBP circadian rhythm persisted (97 mmHg at 2-3 hours, 90 mmHg at 9 a.m. in group 2; 94 mmHg at 24-2 a.m., 87 mmHg at 11

a.m. at 3 group) (fig. 6). Thus, the control of hemodynamics in the weekly biorhythm of the studied indicator was an additional source of information allowing early detection of deviations, assessment of the effectiveness of intensive therapy in the acute period of CSTBI.

Correlations of mean arterial pressure indicator in the acute period of CSTBI

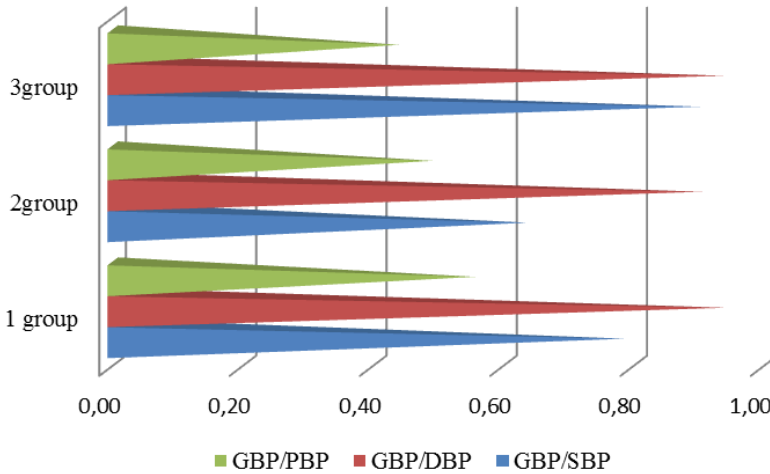


Fig.7

A direct strong correlation between AvBP and DBP (more than 0.8), significant with groups 1 and 3 ( $> 0.7$ ) and slightly less significant AvBP and SBP (0.61) was found in group 2.

As shown in fig. 8, in all age groups, a moderate shift in the acrophase of the circadian rhythm AvBP prevailed, the duration of the inversion of the circadian rhythm AvBP was longer in groups 2 and 3 of the injured.



The severity and duration of displacements of the acrophase

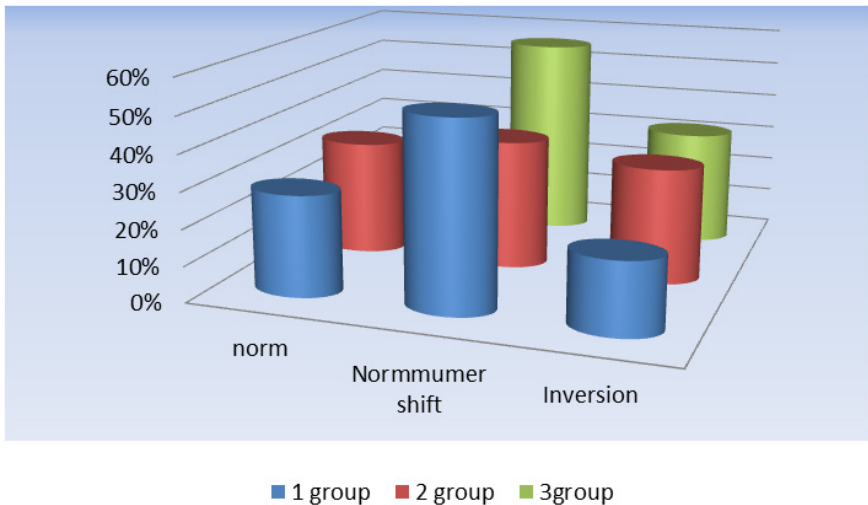


Fig.8

**Conclusions.** In group 1, CSTBI caused a transformation of about weekly biorhythms into 5-6 day periods of fluctuations in the first two weeks after injury. The stress reaction of hemodynamics, intensifying on the 18-25th day of the acute period of CSTBI, was revealed in the injured patients of group 2. In Group 3, the 5-day cycles of AvBP fluctuations from the very beginning were more constant throughout the acute period of CSTBI. The stress response of the circadian rhythm AvBP prevailed in groups 2 and 3 of patients at a later date and was expressed in an increase in the amplitude of daily fluctuations. Monitoring AvBP in the peri-weekly biorhythm is an additional source of information that allows early detection of deviations, assessment of the effectiveness of intensive care in the acute period of CSTBI.

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## **CIRCADIAN RHYTHM OF STROKE VOLUME OF BLOOD CIRCULATION IN THE ACUTE PERIOD OF CONCOMITANT SEVERE TRAUMATIC BRAIN INJURY**

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**Abstract.** In the acute period of combined severe traumatic brain injury (CSTBI), the stress reaction of hemodynamics manifested itself along with an increase in the amplitude, range of diurnal fluctuations, and displacement of the acrophase, as well as a restructuring of weekly biorhythms into 4-5 diurnal fluctuations in the mesor of the SV circadian rhythm. In all age groups, the SV circadian rhythm was an integral value consisting of 3-4-5 hour waves. In older age groups, cardiac output was significantly lower than in group 1 only in the morning hours of the first 8 days, which was probably due not only to more severe trauma in group 1, but also age-related limitations of adaptive stress restructuring of hemodynamics to severe trauma in patients over 41 years old. The most significant instability of myocardial function was found in injured people over 61 years of age.

**Keywords:** circadian rhythm, stroke volume, concomitant severe traumatic brain injury.

**Relevance.** At present, according to the authors' data, mortality in combined STBI reaches 80%, and among survivors - up to 75% of victims remain with severe neurological defects. The positive dynamics of data on STBI treatment (a decrease in mortality in the United States and other Western countries with STBI to 30-40%), noted in the last decade, is largely associated with an increase in knowledge on the pathophysiology of acute STBI and the improvement of intensive treatment technologies during this period. Brain damage in STBI is determined not only by the primary impact at the moment of injury, but also by the action of various damaging factors during the next hours and days, the so-called secondary brain damage (SBD) factors. Secondary brain damage can be influenced by intracranial (intracranial hypertension, dislocation syndrome, cerebral vasospasm, seizures, intracranial infection) and extracranial factors. An increase in heart

rate and a progressive decrease in BP and body temperature are prognostically unfavorable signs. The most dangerous factors of SBD are arterial hypotension, hypoxia and intracranial hypertension (ICH) [1].

The metabolic processes of the brain are adapted to the conditions of rich delivery of oxygen and glucose (with a brain mass of about 2% of body weight, it receives 15-20% of cardiac output), therefore, the brain is practically incapable of anaerobic compensation for a lack of energy, which, under conditions of hypoxia, entails a rapid and irreversible damage to the CNS [2,3]. In this regard, the study, assessment, timely correction of changes in cardiac output always remains one of the priority tasks of intensive therapy for CSTBI in the acute period.

**Purpose of the work.** To study the circadian rhythm of the stroke volume of blood circulation in the acute period of combined severe traumatic brain injury.

**Material and research methods.** The indicators of a comprehensive examination of 30 patients with concomitant severe craniocerebral trauma (CSTBI) who were admitted to the ICU of the neurosurgical department of RSCEMA in the first hours after an accident - 28, catatrauma of 2 patients were studied. Hourly monitoring of the SV (Stroke volume of blood) indicator was carried out by calculating hemodynamic parameters according to the formula:  $SV = PBP \cdot 100 / AvBP$  in ml, where PBP (PP) is the pulse arterial pressure; AvBP (MBP) - average arterial pressure.

According to indications, 29 patients underwent invasive mechanical respiratory support (MRS) on admission. Mechanical respiratory support was started with artificial lung ventilation (ALV) for a short time, followed by transfer to SIMV. The severity of the condition was assessed using scoring methods for assessing the severity of concomitant injuries - the CRAMS scale, the severity of injuries using the ISS scale. On admission, impaired consciousness in 29 injured patients was assessed on the Glasgow Coma Scale (GS) 8 points or less. Patients were considered in three age groups: group 1 - 19-40 years old (13), group 2 - 41-60 years old (9), 3 - 61-84 years old (8 patients). Complex intensive therapy consisted in identifying and timely correction of deviations: MRS, after removing from shock anesthetic, anti-inflammatory, antibacterial, infusion therapy, correction of protein and water-electrolyte balance disorders, surgical early correction to the extent possible, stress-protective therapy.

**Results and discussion.** As shown in tab. 1, on the first day after injury, the SV mesor of the circadian rhythm did not differ from the normative data. In the first group, on day 3, a significant increase in the mesor of the SV circadian rhythm by 13% ( $p < 0.05$ ) was revealed. In group 2, an

increase in the mesor of the SV circadian rhythm was revealed on the 17th and 21st days by 21%, 31% ( $p < 0.05$ , respectively). In group 3, there were no significant deviations of the SV circadian rhythm mesor in the acute period of CSTBI.

**Table1**  
**Dynamics of the mesor of the circadian rhythm SVB in the acute period of CSTBI, ml**

Days	Group 1	Group 2	Group 3
1	55.7±3.9	50.3±4.0	57.0±4.3
2	60.9±2.3	50.9±2.9	53.6±2.8
3	63.2±2.1*	52.1±2.2	59.5±2.5
4	59.7±2.8	54.8±4.1	50.9±3.8
5	56.6±2.4	54.8±3.6	54.6±3.3
6	58.1±3.6	54.9±2.6	54.8±2.5
7	59.7±3.8	54.3±3.6	62.0±4.1
8	54.4±3.0	57.3±2.9	57.0±4.1
9	56.9±2.7	57.5±2.5	56.8±4.4
10	55.3±2.4	54.4±3.5	54.1±5.0
11	56.3±3.0	57.3±4.0	51.4±2.9
12	56.8±2.2	57.3±3.2	60.3±5.6
13	61.4±6.3	56.7±2.5	56.4±5.3
14	55.6±2.9	54.8±2.9	55.0±3.4
15	56.3±3.0	55.6±3.2	59.8±3.9
16	55.7±4.0	55.0±2.9	54.3±3.7
17	58.3±6.1	61.0±4.1*	59.7±5.9
18	54.1±3.8	53.7±5.4	60.3±2.9
19	52.7±2.6	56.2±4.3	59.1±8.0
20	55.3±3.0	55.8±4.7	52.0±5.8
21	59.1±3.0	66.1±6.1*	52.9±6.2
22	59.4±3.8	57.2±4.7	58.9±9.5
23	59.1±2.0	58.5±4.8	60.5±6.4
24	60.0±3.1	58.9±4.2	59.0±5.1
25	55.1±3.2	59.7±5.1	57.4±6.4

\*-reliably relative to the indicator on the first day

Changes in the mesor of the SV circadian rhythm during the acute period occurred in the form of oscillations with a wavelength of 5-4 days, which were repeated and were more ordered in group 1 (fig. 1). While in group 2, the first weekly fluctuation was replaced by 4-5 day cycles with an increase in amplitude by 17, 21 days. In group 3, more distinct 4-5 daytime fluctuations of the mesor of the SV circadian rhythm were observed. Thus, the stress reaction of hemodynamics noted in the acute period of CSTBI also included the restructuring of about-weekly biorhythms into 4-5 daily fluctuations in the mesor of the SV circadian rhythm.

Dynamics of the mesor of the circadian rhythm SVB in the acute period of CSTBI, ml

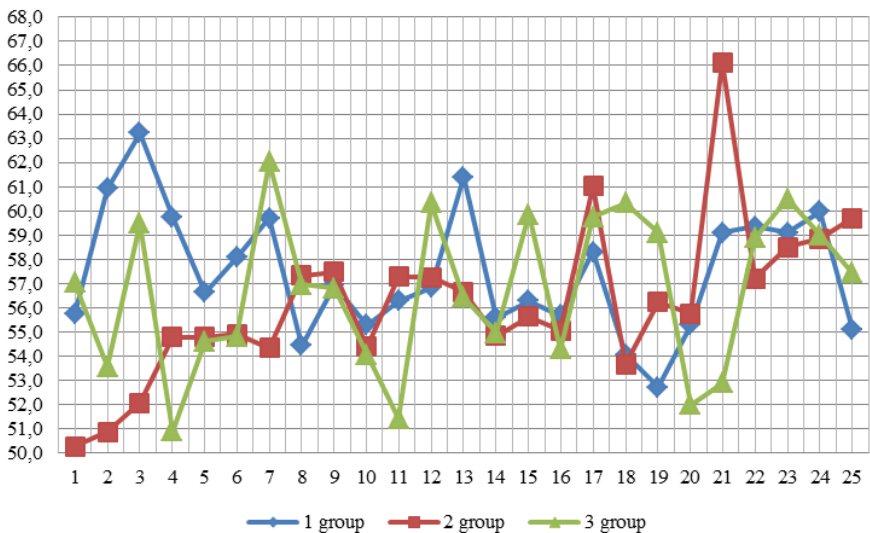


Fig.1

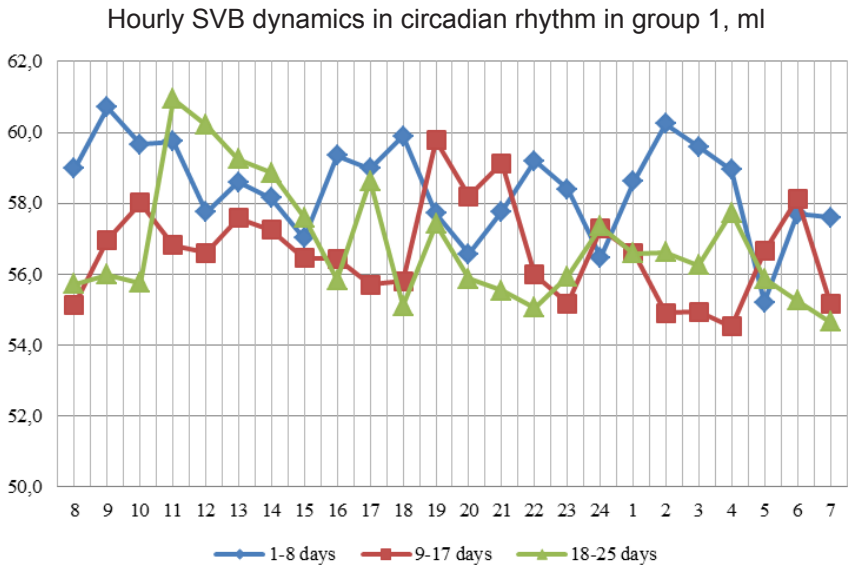
**Table 2**  
**Comparative assessment of hourly changes in SV in circadian rhythm at 1, 2, 3 weeks of the acute period of CSTBI, ml**

Hours	SVB index 1-8 days after injury			SVB 9-17 days after injury			SVB 18-25 days after injury		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
8	59±2	52±4*	54±2*	55±2	54±2	55±3	56±3	56±1	58±8
9	61±3	50±5*	56±3	57±3	56±3	57±4	56±4	56±3	56±8
10	60±3	50±2*	57±5	58±3	55±4	54±6	56±4	58±7	60±6
11	60±3	55±3	53±4	57±3	57±3	57±3	61±7	59±3	60±4
12	58±5	52±1	54±3	57±2	58±5	56±5	60±3	57±5	61±7
13	59±5	53±3	56±5	58±3	56±2	55±5	59±4	60±3	58±4
14	58±5	54±4	58±6	57±2	55±3	58±6	59±2	62±6	60±7
15	57±3	53±4	57±4	56±2	56±2	60±5	58±4	55±7	59±5
16	59±3	54±4	58±5	56±2	56±2	55±9	56±3	58±5	57±4
17	59±4	52±3	57±5	56±3	57±3	58±5	59±2	61±5	55±5
18	60±4	53±5	55±5	56±5	58±3	57±6	55±3	59±4	55±9
19	58±4	55±3	55±3	60±5	57±4	55±5	57±5	59±4	57±5
20	57±3	53±5	58±6	58±5	57±4	54±6	56±6	54±4	55±6
21	58±2	55±3	55±4	59±4	58±1	54±4	56±5	61±3	58±5
22	59±3	54±3	56±4	56±3	56±4	56±4	55±2	58±6	60±6
23	58±5	54±5	55±4	55±3	56±4	58±5	56±3	58±7	62±7
24	56±3	55±4	56±3	57±3	56±3	57±7	57±4	59±3	54±4
1	59±4	55±3	56±5	57±2	58±3	58±5	57±4	62±6	53±8
2	60±5	55±4	55±4	55±3	59±3	58±4	57±4	56±6	52±5
3	60±2	55±3	57±3	55±4	56±4	56±5	56±3	57±4	53±4
4	59±3	54±3	60±5	55±3	58±4	55±5	58±3	57±7	51±8
5	55±4	55±2	59±5	57±3	57±4	57±5	56±5	57±5	61±6
6	58±3	55±4	57±4	58±3	57±3	56±2	55±3	60±7	57±5
7	58±3	55±5	52±5	55±2	54±3	57±6	55±4	58±8	55±7

\*-reliably relative to the indicator in group 1

As shown in Table 2, in the first week of intensive care after trauma, the SV indicator in group 2 at 8.9.10 a.m. was lower than in the first by 11%, 9%, 16% ( $p < 0.05$ , respectively). In group 3 patients SV was less than in

group 1 at 8 hours by 8% ( $p<0.05$ ). Thus, only in the morning hours of the first 8 days in older age groups, cardiac output was significantly lower than in group 1, which was probably due not only to more severe trauma in group 1, but also age-related limitations of adaptive stress restructuring of hemodynamics to severe trauma. in patients over 41 years old.



**Fig.2**

The circadian rhythm of SV in group 1 consisted of three to 4 hour components, and at night, 5 hour periods of fluctuations in the indicator in 1 week of treatment. In the second week, the wavelength increased to 4-6 hours. In the third week of the acute period, three, four, six-hour fluctuations were observed with a maximum amplitude of 11 hours (fig. 2). In group 2 (fig. 3), in the first week of the acute period of CSTBI, fluctuations were low-amplitude with a tendency to a decrease in SV, on days 9-17 more ordered 4-hour waves prevailed. On days 18-25, with the same oscillation period, there was a tendency to an increase in the amplitude of the four hourly waves.

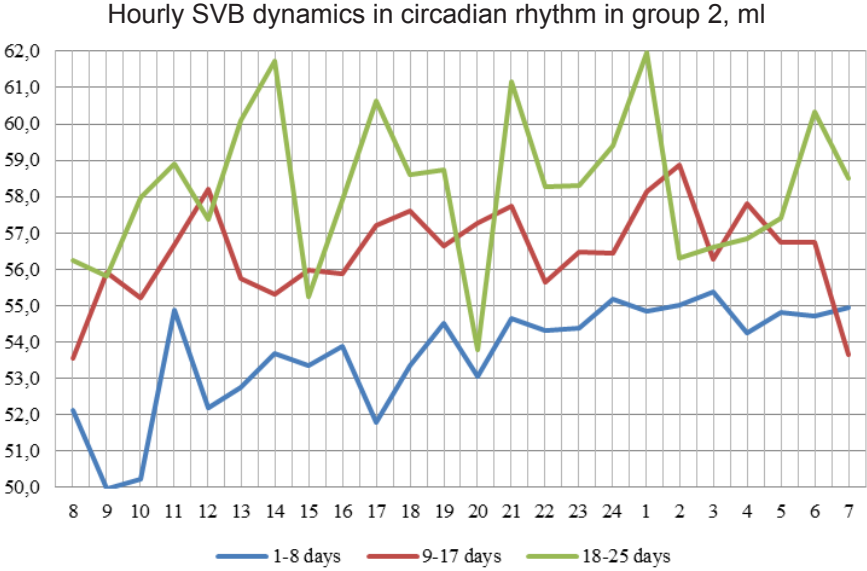


Fig.3

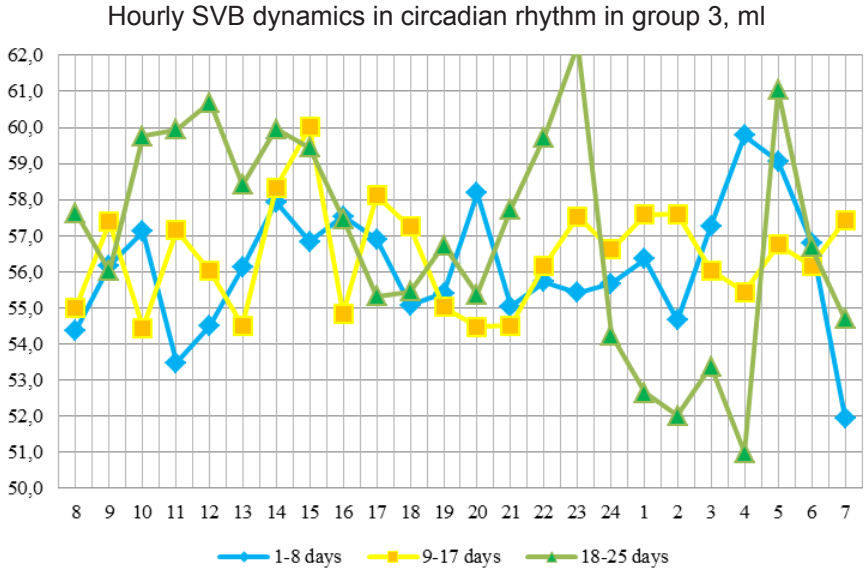
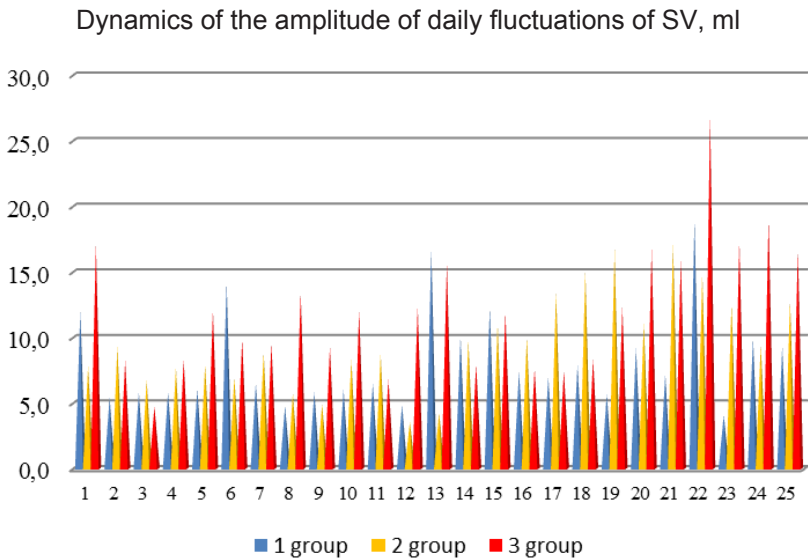


Fig.4



In group 3 (fig. 4) in 1 week, the daily wave consisted of 3-, 4-hour waves, at 2 weeks there was a tendency to an increase in the amplitude. An even greater tendency to increase the amplitude of 5-4 hour waves was noted on the 18-25th day. Thus, in all age groups, the SV circadian rhythm was an integral value, consisting of 3-4-5 hour waves. The amplitudes of these SV ultradianic rhythms, apparently, depend on both the severity of the injury and, perhaps to an even greater extent, on the reserve capacity of the body for the implementation of the stress response in the process of adaptation to new conditions, caused by the severity of the injury and the volume of intensive therapy CSTBI.



**Fig.5**

The change in the amplitude of diurnal SV fluctuations occurred in waves with maximum values in group 1 at 1,6,13,22 days. In group 2, the most significant increase in the amplitude of diurnal SV fluctuations was on days 17,18,19,21,22. In group 3, the corresponding changes were recorded at 1,5,8,13,22,23,24,25 days. In groups 2 and 3, an increase in the amplitude of the SV circadian rhythm after 17 days was revealed (fig. 5).

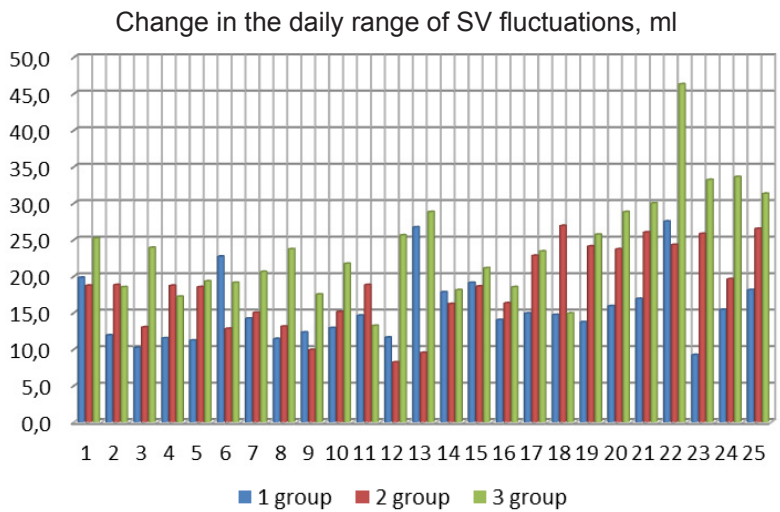


Fig.6

Attention was drawn to the significant prevalence of daily changes in SV in group 3 patients throughout the observation period (fig. 6). The latter characterizes the most significant instability of myocardial function in injured people over 61 years of age.

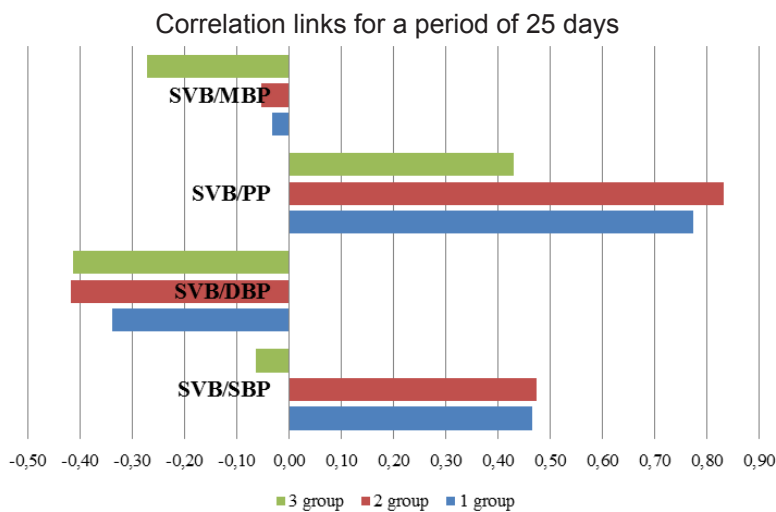


Fig.7

A strong direct relationship between SV and PBP was found in traumatized patients of groups 1 and 2 (0.77; 0.83, respectively). While in group 3, the correlation between SV and PBP turned out to be significantly less (0.43) (fig. 7). The study of SV correlations in the peri-weekly rhythm did not reveal any significant differences depending on the duration of intensive therapy.

**Conclusion.** In the acute period of CSTBI, the stress reaction of hemodynamics was also manifested by the restructuring of about-weekly biorhythms into 4-5 daily fluctuations in the mesor of the SV circadian rhythm. In all age groups, the SV circadian rhythm was an integral value consisting of 3-4-5 hour waves. In older age groups, cardiac output was significantly lower than in group 1 only in the morning hours of the first 8 days, which was probably due not only to more severe trauma in group 1, but also age-related limitations of adaptive stress restructuring of hemodynamics to severe trauma in older patients. 41 years old. The most significant instability of myocardial function was found in injured people over 61 years of age.

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## THE ROLE OF IMMUNOMETABOLIC PROCESSES IN PERIODONTAL TISSUES FOR REPEATED ENDODONTIC TREATMENT IN PATIENTS WITH CHRONIC FORMS OF PERIODONTITIS

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**Annotation.** In clinical practice, the study of the immunometabolic processes in periodontal tissues of patients with chronic forms of periodontitis makes it possible to assess the nature of the course of the process and objectively assess the effectiveness of treatment. An immunological study of 65 patients with chronic forms of periodontitis and 65 donors was carried out, which showed the maximum deviation of the immunological parameters of peripheral blood in chronic granulating periodontitis. The patients of the main groups change in the immunological parameters of the oral fluid were revealed: a decrease in the concentrations of IgG, sIgA, fibronectin, IL-4, IL-8, IL-10, IFN- $\gamma$ ; an increase of levels of proinflammatory cytokines IL-1 $\beta$  and TNF- $\alpha$ . The maximum deviation of the immunological parameters of peripheral blood was noted in chronic granulating periodontitis. The patients of the main groups, changes in the immunological parameters of the oral fluid were revealed: a decrease in the concentrations of IgG, sIgA, cytokines IL-1 $\beta$  and TNF- $\alpha$ . In this regard, the violation of immunometabolic processes in the tissues of the root area of the tooth is the basis for repeated endodontic treatment in patients with chronic forms of periodontitis.

**Keywords:** immunometabolic processes, humoral and cellular factors of the immune system, chronic forms of periodontitis, repeated endodontic treatment.

### **Relevance**

Chronic forms of periodontitis are characterized by a protracted development of the inflammatory process in the root area of the tooth with the subsequent development of destruction of the surrounding tissues [1,2,3].

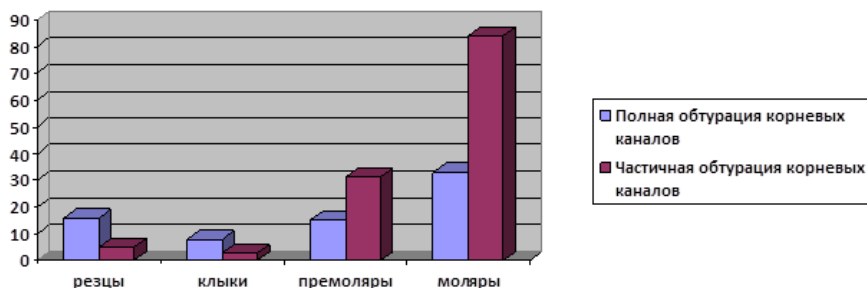
The study of the role of the immunometabolic processes in periodontal tissues is a priority in the pathogenesis of chronic periodontitis. In clinical practice, the study of the cytokine status makes it possible to assess the nature of the course of the process and objectively assess the effectiveness of treatment. Cytokines are a group of polypeptide mediators involved in the formation and regulation of the body's defense reactions [4, 5, 6, 7]. Features of the biosynthesis and regulation of cytokines are determined in the circulating blood. The diagnostic significance of assessing the level of cytokines lies in its increase or decrease in a patient with chronic forms of periodontitis, but to assess the severity and predict the course of this pathology, it is advisable to determine the concentration of pro- and anti-inflammatory cytokines in the dynamics of the process.

Chronic forms of periodontal disease are proposed to be considered as diseases in the pathogenesis of which cellular and humoral autoimmune reactions against periodontal tissues play an essential role. It has been proven that the presence of long-standing multiple foci of infection in the periodontal tissues of the teeth leads to sensitization of the body and secondary immune deficiency [8, 9]. Cytokines play an important role in maintaining normal tissue homeostasis and in inflammation. The study of the role of proinflammatory cytokines in the immune and inflammatory response is an important area of modern immunology in dentistry [10]. In this regard, impaired immunometabolic processes in patients with chronic forms of periodontitis are relevant.

**The aim of the work is** to evaluate the immunometabolic processes in periodontal tissues in patients with chronic forms of periodontitis

### **Materials and research methods**

130 patients were examined, including 65 patients requiring repeated endodontic treatment based on complaints and analysis of root canal obturation by orthopantomograms (Figure 1) and 65 donors from the Samara Regional Blood Transfusion Station.



**Figure 1. Analysis of obturation of root canals of teeth of different group affiliation**

The age of patients who do not have a history of somatic pathology ranged from 18 to 60 years. The patients were randomized into three main groups: Group 1 - patients with a diagnosis of chronic fibrous periodontitis - 12 people (18.5%); Group 2 - patients with the diagnosis: chronic granulating periodontitis - 26 people (40.00%); Group 3 - patients with a diagnosis of chronic granulomatous periodontitis - 27 people (41.5%). The control group (comparison group) was represented by 65 donors with immunological parameters of the cytokine profile. Donors have a sanitized oral cavity, and a history of no background pathology.

Immunological research methods included the determination of lymphocyte subpopulations using monoclonal antibodies of the LT series. The percentage of the total population of cells expressing CD3 +, CD4 +, CD8 +, CD19 +, CD16 +, CD25 +, CD95 +, CD4 / CD8 was calculated. At the same time, a clinical blood test was performed to determine the absolute number of cells.

The levels of cytokines IL-1 $\alpha$ , IL-1 $\beta$ , IL-4, IL-8, TNF- $\alpha$ , IFN- $\gamma$ , total IgE and fibronectin in blood serum and oral fluid were determined using enzyme-linked immunosorbent assay. The concentration of total IgE in blood serum in patients was determined using DIA-plus kits (Switzerland) and NPF Hema Medica (Russia).

The content of immunoglobulins of classes A, G, M in blood serum was determined by the method of radial immunodiffusion according to Mancini (1965). To assess the state of peripheral blood neutrophils, latex produced by the Institute of Biological Instrumentation (Russia) was used. Hemolytic units CH50 were calculated from the standard hemolysis curve and correction factors. The level of myeloperoxidase was determined using a medium consisting of 50 ml of water, 60 mg of ortomedin.

For statistical analysis, we used the PSIMAGO 4.0, IBMSPSS Statistics 24 software package (license No. 5725-A54). The arithmetic mean (M) and its standard error (m) or the median with quartiles are given as descriptive statistics.

To analyze the characteristics of the quality of treatment in dynamics, the paired Wilcoxon test was used.

### **Results and discussion**

In all forms of periodontitis, the content of leukocytes and lymphocytes is significantly higher than in the control group. Their maximum number was found in patients with chronic granulating periodontitis.

The results of the study of the characteristics of systemic immunity revealed in chronic forms of periodontitis a decrease in the phagocytic activity of neutrophils, the level (relative and absolute) of the main populations and subpopulations of lymphocytes - T-lymphocytes, T-helpers, B-lymphocytes, NK (natural killer cells).

Studying the state of cellular immunity factors by the ratio of lymphocyte subpopulations CD3, CD4, CD8, CD16, CD19, CD25 +, CD95 +, CD4 / CD8, depending on the form of chronic periodontitis, the following was found. The absolute content of CD3 + cells tended to decrease more significantly in chronic granulating periodontitis ( $0.2 \pm 0.1$  cells / ml) than in other forms of periodontitis and in the control group. The level of cells with helper functions (CD4 + lymphocytes) is significantly reduced in all forms of periodontitis, but especially significantly in granulating periodontitis ( $0.1 \pm 0.05$ ). A decrease in the level of these indicators, reflecting the cellular link of immunity, indicates the presence of a defect in cellular immunity.

At the same time, the absolute level of cells with suppressor activity (CD8 + lymphocytes) in patients with granulating periodontitis is significantly higher than in patients with other forms of periodontitis and in the control group. The number of CD19 + cells is higher in patients with chronic fibrous and chronic granulomatous periodontitis compared with the control group. In the group of patients with chronic granulating periodontitis, their content is minimal -  $0.09 \pm 0.04$ . The same picture was observed in relation to CD16 + lymphocytes: the minimum content was found in granulating periodontitis ( $3.1 \pm 1.2$ ). Immunoregulatory index, i.e. the ratio of the number of cells expressing markers CD4 + and CD8 + on their surface has significant differences. The CD4 + / CD8 + ratio is minimal in patients with chronic granulating periodontitis ( $0.2 \pm 0.08$ ). The maximum was found in the control group -  $2.6 \pm 0.4$ .

There were no statistically significant differences in the quantitative content of CD95 + in the studied groups of patients and in the control. The

level of CD25 + lymphocytes was slightly increased in all patients with periodontitis. The content of HLA-DR + cells was significantly higher in all patients with periodontitis. There were no differences in this indicator among groups of patients with various forms of the studied pathology.

The study of humoral immunity factors showed that the level of myeloperoxidase was significantly increased in all patients with periodontitis in comparison with the control group. The maximum indicator was found in patients with granulomatous periodontitis -  $60.9 \pm 1.0\%$  and fibrous periodontitis -  $59.4 \pm 1.4\%$ . The level of fibronectin, which is a marker of inflammation, was increased in all patients with periodontitis: the maximum level was observed in patients with fibrous ( $579.4 \pm 11.4$  ng / ml) and in patients with granulomatous forms ( $504.7 \pm 6.5$  ng / ml).

The CH50 level was significantly lower in all patients with periodontitis, especially in patients with granulating forms ( $37.6 \pm 0.8$ ). The indicators of phagocytic activity of neutrophils were significantly reduced in all patients with periodontitis, especially in patients with granulating periodontitis ( $42.4 \pm 2.0\%$ ). Apparently, the decrease in phagocytic activity indicates the dominant place of phagocytosis disorders along with T-system defects in the pathogenesis of chronic periodontitis.

The levels of serum IgA, IgM, IgG were the highest in patients with granulating periodontitis -  $3.2 \pm 0.2$  g / l,  $1.8 \pm 0.1$  g / l,  $18.1 \pm 0.9$  g / l, respectively ... The maximum level of total IgE was found in patients with granulomatous form ( $142.3$  ng / L) and fibrous form of periodontitis ( $139.6 \pm 7.5$  ng / L). The increase in the levels of total IgE in the blood serum in all examined groups of patients is characteristic of allergic sensitization.

The levels of IL-8, IL-1 $\alpha$ , IL-1 $\beta$  are significantly higher in all forms of periodontitis in comparison with the control group. Thus, IL-8 in patients with chronic granulating periodontitis was found at a concentration of up to  $84.6 \pm 2.0$  ng / ml. The level of IL-1 $\alpha$  in this group of patients reached  $30.6 \pm 1.0$  ng / ml, while this interleukin was not detected in the control group. The concentration of IL-1 $\beta$  was maximal in patients with granulating and granulomatous periodontitis -  $64.9 \pm 1.0$  ng / ml and  $54.5 \pm 1.1$  ng / ml, respectively. IFN- $\gamma$  was significantly reduced in all patients with periodontitis. The most significant decrease in this indicator was observed in patients with granulating ( $46.4 \pm 1.0$  ng / ml). The level of TNF- $\alpha$  was most elevated in patients with granulating and granulomatous periodontitis -  $128.0 \pm 2.8$  ng / ml and  $71.2 \pm 1.0$  ng / ml, respectively. The level of IL-4 was significantly reduced in all patients with periodontitis, especially in patients with granulating periodontitis -  $6.8 \pm 0.6$  ng / ml.



As you know, there is a close relationship between oral fluid and blood. The blood-salivary barrier, by changing the permeability and activity, provides a balanced redistribution of biologically active substances between blood and saliva.

A comparative analysis of the concentration of cytokines in the blood serum in patients with chronic forms of periodontitis revealed a dependence on the form of the disease. In chronic granulating periodontitis, the production of pro-inflammatory cytokines (IL-1, TNF- $\alpha$ , IL-8) is significantly increased, and anti-inflammatory cytokines (IFN- $\gamma$ ) are reduced.

Determination of cytokines in blood serum and oral fluid in healthy people showed that there is a balance of pro- and anti-inflammatory cytokines. In inflammatory processes in the periapical region, an increase of 2.5-3 times in the indices of pro-inflammatory cytokines (IL-1, TNF- $\alpha$ , IL-8) was noted in comparison with healthy individuals.

According to the results of the studies, it can be assumed that the sharply increased concentration of IL-1, TNF- $\alpha$ , IL-8 is the result of the attraction and activation of macrophages in the inflammation focus, which are the main producers of these cytokines.

In chronic forms of periodontitis, immune mechanisms are suppressed at the level of the oral mucosa - the phagocytic activity of neutrophils is reduced, there is an imbalance in the cytokine system in blood serum and saliva, the production of pro-inflammatory cytokines - IL-1, TNF- $\alpha$ , IL-8 is increased and the level of anti-inflammatory cytokine IFN- $\gamma$ .

From the analysis of indicators of proinflammatory cytokines, it follows that in patients with chronic granulating periodontitis, compared with the control group, there is an increase in the concentration of IL-1 $\alpha$ , TNF- $\alpha$  and IFN- $\gamma$  both in the blood serum and in the oral fluid. The content of pro-inflammatory cytokines and the nature of the inflammatory process are interrelated. There is a direct relationship between the level of proinflammatory cytokines and the type of chronic periodontitis.

The revealed disorders in patients with chronic fibrous, granulating, granulomatous periodontitis indicate a significant cytokine imbalance in all forms of chronic periodontitis. Based on the studies carried out, the severity and individual prognosis of a patient with chronic periodontitis are determined by the severity of immunological disorders - a defect in cellular immunity factors and an imbalance in the cytokine profile. Consequently, when examining a patient, it is necessary to establish which link of the immune response suffers in certain forms of chronic periodontitis.

### **Conclusion**

According to the results of the immunological studies in patients of the

main groups with chronic forms of periodontitis and in the control group (indicators of cellular, humoral immunity factors, cytokine profile), it can be concluded that there is an imbalance of the cellular immune response and cytokines in this pathology, as well as a low level of local immune response.

In fibrous and granulomatosis forms of periodontitis, humoral immunity factors (myeloperoxidase activity, fibronectin, immunoglobulins) and phagocytic activity of neutrophils play a leading role in immunopathogenesis; in chronic granulating periodontitis, the most significant is a defect in cellular immunity factors (lymphocytes and their associated subpopulations), impaired immune regulation of the inflammatory process.

Thus, the violation of the immunometabolic processes in the tissues of the root region of the tooth is the basis for the justified conduct of repeated endodontic treatment in patients with chronic forms of periodontitis.

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## CLINICAL PICTURE AND TREATMENT OF MAXILLARY FRACTURES

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**Abstract.** The article is devoted to the study of the clinic and peculiarities of the postoperative period of patients with maxillary fractures depending on the method of treatment. We treated 32 patients with maxillary fractures of different severity and clinical picture. Of these, 11 patients had an upper jaw fracture according to Le-For III, where an orthopedic method of treatment with an intermaxillary Tigerstedt splint was used. In 21 patients, there was a combined fracture of a more complicated clinical picture, with concomitant traumas of the cranial brain, where open surgical treatment was applied using osteosynthesis with titanium miniplates. Thus, the patients were conventionally divided into two groups. The aim of the study was to study the peculiarities of the course of the postoperative period and peculiarities of a particular method of treatment. In the course of treatment, we studied the peculiarities of clinical manifestations in each case and compared them with each other. We took into account the data obtained using each method and drew some conclusions. Thus, after a complete analysis of the results and comparisons, it was established that the use of open osteosynthesis with the use of titanium miniplates proved to be successful in treating jaw fractures. This is due to the fact that this method of treatment causes much fewer complications during bone fracture healing,

patients can eat and gradually put weight on their jaws, and oral hygiene is carried out without any problems. The bone wound heals much faster due to the absence of mobility of the bone fragments. The accompanying symptoms disappear more quickly than with the orthopedic method, so that the surgical method with miniplates proves to be more effective.

**Keywords:** maxillofacial surgery, jaw fractures, upper jaw fracture, Le-For, jaw injuries.

**Introduction:** Patients with facial skeletal fractures account for 30-32% of inpatients. The annual growth rate of injuries to the maxillofacial region is increasing. The number of facial bone fractures is increasing by 12-15%, which should be taken into account when organising inpatient and outpatient surgical care. It should be emphasized that jaw fractures are a significant and social problem, since the majority of this category of patients are men aged 20-40 years. This is the most able-bodied part of the population and, therefore, the issues of their treatment and rehabilitation are of great practical importance [1,2,3,4,5].

**The aim of this study** is to analyse the results of upper jaw fracture treatment over the last 5 years (from 2016 to 2020) and to substantiate the effect of the applied method.

### **Materials and Methods**

We analysed case histories of 32 patients treated at the Oral Surgery Department of the Osh Interregional Joint Clinical Hospital with traumatic upper jaw injuries. We analysed cases of isolated fractures of the maxilla only, fractures of the nasal bone and zygomatic arch were not analysed. There were 26 males and 6 females and the age distribution was as follows: 16 to 20 years old 3 persons, 21 to 30 years old 15 persons, 31 to 40 years old 9 persons, 41 to 50 years old also 3 persons, 51 and older 2 persons. Data shows that traumas of upper jaw most frequently occurred at the age of 16 to 40 years (27 patients), i.e. 84.3% of cases, the most able-bodied part of population. Patients presented to the Clinic in various states: in 21 patients anamnesis was noted: loss of consciousness with marked retrograde amnesia, nausea, vomiting, severe headaches, which described the clinical picture of craniocerebral trauma; injuries of soft tissues of various degrees of severity were registered, contusion of eye on the injured side was noted. In 11 patients the condition on admission was of moderate severity. Orthopaedic treatment in the form of fixation of the jaws with a Tigerstedt splint was used in 11 patients with a mild condition. In 21 patients who had multiple combined fractures and a relatively severe condition, surgical treatment with titanium miniplates was used. The

patients were thus conventionally divided into two groups to compare the efficacy of the treatment performed and the manifestation of clinical symptoms depending on the method. In diagnosis, we were guided by well-known techniques based on objective data: presence of wounds, traumatic edema, hematomas of soft facial tissues, severity of facial fractures, the so-called "spectacle symptom", elongation and flattening of the face, mobility of fractures in different parts, bleeding from the nose, external auditory canal, and changes in the oral cavity. The most pronounced symptom was a change in the bite, which was manifested by displacement of the fractures to the back and side, especially in patients with bilateral fractures of the maxilla. An orthopantomogram and computed tomography were used to clarify the diagnosis.

### **Results and discussion**

The scope of treatment measures, as well as their sequence was mainly determined by the patient's clinical condition, the presence of concomitant diseases and concomitant injuries, the severity of signs of craniocerebral trauma and its complications. In 11 patients, the condition was of medium severity, where an upper jaw fracture according to Le-For III (lower type) was diagnosed, emergency hospitalization in the maxillofacial surgery department was performed, and at the same hour a Tigerstedt or Vasiliev splint with intermaxillary traction was applied. Particularly severe patients (21 patients) were immediately transferred to the intensive care unit with concomitant craniocerebral injuries, skull base fractures, grade I-II shock and contusion of the eye on a particular side. Such patients were treated by the joint efforts of other specialists (intensive care specialist, neurosurgeon, ophthalmologist, etc.) to improve their general condition after 3-5 days, and they had already been treated for fractures of the upper jaw. Out of 21 severe cases, 7 patients had maxillofacial fractures of Le-For I (upper type) and 14 patients had maxillofacial fractures of Le-For II (medium type). Mini-plate osteosynthesis was used in these patients after the general condition had improved. In recent years the method of osteosynthesis with mini-bone fixation plates made of titanium, which provide rigid fixation of fractures and the possibility of functional loading in early postoperative period, has become widespread in the treatment of fractures of the jaws. The proposed plates have different design features and are made from different materials, but the way they are applied is fundamentally the same: the plates are fixed on two levels in order to eliminate the tensile forces and prevent the occurrence of diastema and violations of dental occlusion. Biomechanical, morphological and clinical techniques have shown that the use of miniature bone plates is one of the most effective ways to treat jaw fractures.

In the category of patients with splinting, the clinical picture was slightly worse due to several factors. Thus, the healing of the fracture was slightly more difficult in these patients compared to patients who used the surgical method. Clinical symptoms in 11 patients with an intermaxillary splint were evident up to 10 days after fixation of the fracture. Soft tissue swelling persisted at discharge and during follow-up examination 10 days later. There was little tenderness on palpation. Body temperature was maintained at 37.0°C for a long time, due to the presence of mobility in the treatment of fractures with splints. At the same time, the patients were unable to maintain proper oral hygiene, which also impaired wound healing.

In the 21 patients with combined maxillary fractures and severe cases, the postoperative period was much milder in terms of symptoms and jaw function. In this category of patients, where osteosynthesis was performed with titanium mini plates, the clinic was relatively mild. After the swelling had resolved, the patients were able to exert some chewing pressure on their jaws. Body temperature normalised by day 3 and there was no mobility of the maxilla. The patients were fully able to observe oral hygiene.

In the postoperative period all patients underwent antibiotic therapy, symptom therapy individually, irrigation of the oral cavity with antiseptic solutions.

Thus, here are clinical examples of the postoperative period of patients from each group for comparison.

Clinical example of patient from the group with intermaxillary splint.

Patient B. 35 years old, admitted to the Department of Oral and Maxillofacial Surgery after an accident. His condition was relatively satisfactory and he was walking.

Local status: edema on the face, asymmetry of the face due to the position of the lower jaw and bite disorder. On the left side there is a haematoma around the eye, painful on palpation, symptom of upper jaw stress is positive. The fracture line cannot be palpated. On the oral side the bite is disturbed, the alveolar process of the upper jaw is mobile. There is a tear of the mucosa at the level of the transitional fold on the left side.

The patient was referred for further examination and after a CT scan he was diagnosed with an upper jaw fracture according to LeFort III and it was decided to apply an orthopaedic treatment with an intermaxillary Tigerstedt splint. After the splint was applied, the bite was fixed and a sling was used.

The patient had subfebrile body temperature from day one to day three, which was controlled with medication, and from day three to day seven, the body temperature was in subfebrile values. The temperature normalised only on the seventh day after the partial termination of antibiotic therapy.

At the time of discharge, the patient also had mobility of the upper jaw, and the patient was scheduled for a follow-up examination in 2 weeks to assess the condition and analyse fracture healing. After 14 days there was no swelling or soreness at the follow-up examination. Oral hygiene was poor and a radiograph was taken to assess the condition of the bone wound, where there were no particular changes and the fracture line was clearly visualised. The splint was removed one month after it had been applied.

A clinical example of a patient from the group with the surgical method, osteosynthesis with miniplates.

Patient A., 28 years old, was admitted urgently to the emergency department in a moderate condition; after X-ray examination, examination and consultation with a neurosurgeon and a traumatologist, it was decided to admit the patient to the maxillofacial surgery department. The patient had a history of domestic trauma. He was diagnosed with an upper jaw fracture according to LeFor II.

Local status of the patient: On examination he had swelling of the soft tissues of the face, positive spectacle symptom, nasal bleeding. On palpation of the right lower eyelid and anterior wall of the sinus, painful, positive loading symptom, crepitation of fragments, fracture line is not palpable due to swelling. On the oral side there is no mucosal trauma, the upper jaw is slightly mobile and there is sharp pain on loading.

After a few knocks after hospitalisation and normalisation of the patient's condition, intra-oral osteosynthesis of the upper jaw was performed using titanium mini-plates. Standard postoperative therapy with medication was administered, and the treatment prescribed by the neurosurgeon was carried out in parallel.

The patient had subfebrile body temperature from day one to day three and then normalised completely. On the fifth day postoperatively, the swelling had gone down and mouth opening had relatively improved, he was eating soft food and putting some weight on his jaw. On the oral side, the wound healed with primary tension without any complications. There was no palpation mobility of the jaw. Oral hygiene was observed without any problems. The sutures were removed on day 8 and the patient was discharged home two days later. A follow up examination 20 days after discharge was recommended.

At the time of the follow-up examination one month later, the swelling and haemorrhages had completely disappeared, periosteal phenomenon in the area of the placed plates was noted on palpation. On the radiograph, the fracture lines were visualised, no displacement was detected, no secondary deformities, and the bite was normal. The plates can optionally be



removed after one year from the date of surgery.

**Conclusions:** Thus, analysis of clinical results of surgical treatment of the upper jaw made it possible to determine the following main points of bone osteosynthesis with mini plates: when using the plates as fixators, due to their design and definition of zones of their application, there is no need to create compression; in all cases, with mini-bone osteosynthesis, an extremely accurate repositioning of fractures and intimate adhesion of fractured surfaces is necessary; the metal, from which plates and screws are made is titanium of BT-5, BT1-0, BT1-00 grades. Titanium is a material ideally suited for implants, so it can remain in the body indefinitely without causing adverse effects. If the patient has no desire to have the retainer removed, it remains implanted.

The fixed fracture fixation allows the bone to heal much more rapidly and without complications. Secondary deformities after surgery are prevented, thus eliminating the need for a second surgical intervention.

Thus, based on the analysis of clinical experience, we believe that osteosynthesis with miniplates is a more sparing method with respect to the soft tissues surrounding the bone. Its use is less likely to disrupt the extra-osseous blood supply, which plays a particularly important role in jaw fracture healing.

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## PROSPECTS IN THE TREATMENT OF ISCHEMIC STROKE

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**Abstract.** Stroke is an acute violation of the cerebral blood supply, which leads to ischemia and death of brain cells. According to the National Stroke Registry, 31% of stroke patients are unable to take care of themselves, 20% are unable to move independently and only 8% of surviving patients can return to their previous lifestyle. The ratio of ischemic to hemorrhagic strokes was 5:1, and the average age of stroke development was 66.7 years (63.7 years for men and 69.4 years for women). According to the results of population studies, the incidence of atherothrombotic ischemic stroke is 16%, cardioembolic-29%, lacunar-16%, stroke due to rarer causes-3%, stroke of unknown etiology-36% of cases. The risk of recurrent stroke during the first 30 days of the disease is higher in atherothrombotic stroke compared to other pathogenetic variants. This pathology, due to its prevalence, leads to persistent disability in about 80% of the adult population, so early treatment of acute ischemic stroke is crucial.

**Key words:** stroke, cerebral circulation disorder, ischemia.

### **Introduction**

At the moment, thrombolysis using recombinant tissue plasminogen activator (rtPA) is the only effective remedy indicated for use during the first six hours after a stroke, as well as endovascular thrombectomy are still

the main methods of revascularization in acute ischemic stroke. It should also be taken into account that intravenous thrombolysis therapy is contraindicated in patients who are in a state of hypocoagulation, given that the half-life of new oral anticoagulants in patients with normal renal function does not exceed 17 hours. In addition, ischemic reperfusion injury after revascularization therapy can worsen neurological symptoms and worsen the prognosis. Also, secondary neuroinflammation after a stroke stimulates further cell damage, which leads to ischemic death of brain cells and, as a result, disability and even death. An early increase in the level of pro-inflammatory cytokines and chemokines from the onset of brain ischemia may be associated with the severity of stroke and, accordingly, a worse prognosis. The presence of this inflammation is diagnosed using computed tomography, but there is no direct connection between these objective indicators and the patient's symptoms, which makes it difficult to treat a stroke. Some studies have reported that higher levels of C-reactive protein and interleukin-6 are associated with a worse prognosis after an ischemic stroke.

Interestingly, the triggering receptor expressed on myeloid cells-1 (TREM-1) is involved in their activation and the formation of innate immunity. TREM-1 is an orphan receptor and is associated with toll-like receptor 4 (TLR4). The TREM-1 receptor is also involved in the development of non-infectious and non-inflammatory neurological diseases, such as cerebrovascular atherosclerosis, ischemia, stroke, and others. It is assumed that during an acute ischemic stroke, endogenous molecules from damaged ischemic brain tissues activate the TREM-1 signaling pathway and trigger the inflammatory process. These data provide a reason for further in-depth study of the role of the post-stroke immune response and the development of a modern optimal method for the treatment of acute cerebral circulatory disorders based on this theory.

No less interesting in recent years is the study of a new promising therapy based on stem cells, which is based on cell replacement and induction of paracrine effects to replace damaged cells, reduce cell death and provide trophic support for host cells. At the same time, it is known that only less than 1% of cells can remain viable for 4 weeks after transplantation due to the harmful effects of damaged tissues. Recent studies have established the connection of paracrine signals with extracellular vesicles, which are produced by all living cells and include microvesicles and exosomes, which in turn play a key role in the regulation of immune responses. Exosomes are released into extracellular fluids and contain proteins, lipids and genetic materials (mRNA, ncRNA, etc.). Updated data

showed that exosomes were successfully tested in preclinical models of stroke, myocardial infarction/reperfusion injury and hind limb ischemia. Antitumor treatment methods based on the use of extracellular vesicles have also entered phase II of human clinical trials. The unexpected role of exosomes and their numerous advantages over stem cells in the treatment of ischemic stroke of the brain are of great interest and require further study in order to develop a modern optimal pharmacotherapy for this pathology.

### **The results obtained**

We focused our scientific interest on the role of markers of neuroinflammation, namely, on the relationship of interleukin-6 with the development of acute cerebral blood supply disorders (ischemic stroke). The study group included 32 patients aged from 54 to 72 years: 19 male patients, which was 59%, and 13 female patients, which was 41%. The control group included 10 people, including 5 men and 5 women aged from 54 to 72 years. On the first day after the onset of the disease, the levels of five common inflammatory markers were measured: leukocytes, neutrophils, lymphocytes, C-reactive protein and interleukin-6 (IL-6) in the blood serum. The results were obtained: interleukin-6 increased in patients with stroke compared to the control group. In all 32 patients with acute ischemic stroke, high values of interleukin-6 were recorded, in the control group of 10 people, 1 woman had an increased level of interleukin-6. The average level of circulating interleukin-6 in patients with acute stroke was 27.7 [6.5; 163.4], which is 6.5 times higher than in the control group of 4.1 [2.2; 5.8] ( $p < 0.0001$ ). The levels of C-reactive protein and interleukin-6, neutrophils and leukocytes were significantly higher in the subtype of atherosclerosis of large arteries, while the number of lymphocytes was significantly higher in occlusion of small arteries. In our study, the level of interleukin-6 was significantly increased in the first 24 hours after the onset of an ischemic stroke. This fact confirms the hypothesis that the production of interleukin-6 is an inflammatory response to acute hypoxic ischemic damage.

After analyzing the results obtained, we can conclude that the levels of pro-inflammatory cytokines (and in our example, this is interleukin-6) increase in patients with ischemic stroke compared to the control group. These results support the evidence that interleukin-6 inhibition may offer a therapeutic approach for the prevention of ischemic stroke.

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**THE ROLE OF MARKERS OF FIBROSIS AND IMMUNE  
INFLAMMATION IN THE DEVELOPMENT OF POST-STROKE  
DEPRESSION IN ELDERLY PATIENTS WITH CHRONIC KIDNEY  
DISEASE AND ACUTE ISCHEMIC STROKE**

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**Abstract.** Stroke continues to be the most important medical and social problem due to its high share in the structure of morbidity and mortality. Neuroinflammation is characterized by increased levels of proinflammatory cytokines in the brain parenchyma. An increase in the level of MMP-9 in peripheral blood correlates with the severity of depression. **Purpose of the study** – to determine the features of the concentration of fibrosis markers (MMP-9) and immune inflammation (TNF- $\alpha$ , IL-1 $\beta$ , INF- $\gamma$ ) in the blood serum of elderly patients with chronic kidney disease and ischemic stroke, depending on the development of post-stroke depression. **Material and research methods.** The study included 98 people, of whom 78 patients with chronic kidney disease (CKD, C2, A2) with acute ischemic stroke (IS) and 20 people in the control group, comparable in age without chronic kidney disease and ischemic stroke in history. The average age of the patients was  $68 \pm 6$  years. Post-stroke depression during follow-up developed in 34 people. (43.6%), 44 people (56.4%) did not show signs of PSD. The average NIHSS score was  $8 \pm 5$ , which corresponded to mild (20 people, 25.6%) and moderate (58 people, 74.4%) severity. The concentration of MMP-9 in serum was determined by ELISA using the Human MMP-9 kit (ELISA Kit, USA), the level of IL-1 $\beta$ , TNF- $\alpha$ , INF- $\gamma$  - using a set of reagents for ELISA CJSC "Vector-Best", Russia. **Results.** The level of IL-1 $\beta$  in the blood serum of patients with CKD, IS with PSD was 1.3 times ( $p < 0.001$ )

higher, TNF- $\alpha$  was 1.6 times higher ( $p < 0.001$ ), INF- $\gamma$  was 1.3 times higher than in the group of patients with CKD, IS without PSD ( $p < 0.001$ ). The level of MMP-9 in CKD, IS patients with PSD is 1.4 times higher than in the group of CKD, IS patients without PSD ( $p < 0.01$ ). **Conclusion.** Thus, the addition of the determination of the serum level of markers of fibrosis (MMP-9) and immune inflammation (IL-1 $\beta$ , TNF- $\alpha$ , INF- $\gamma$ ) can improve the prediction of the risk of post-stroke depression in elderly patients with chronic kidney disease and ischemic stroke. In addition, the results obtained can help in identifying elderly patients with CKD with IS, who need special attention for the early detection of post-stroke depression.

**Keywords:** ischemic stroke, kidney disease, depression

Stroke continues to be the most important medical and social problem due to its high share in the structure of morbidity and mortality [1]. Patients with chronic kidney disease have multiple risk factors that provoke vascular endothelial damage, oxidative stress, inflammation, fibrosis of the extracellular matrix, which leads to the progression of atherosclerosis, arterial hypertension, and aggravation of neurodegeneration. Chronic kidney disease, influencing the pathogenetic mechanisms of stroke development, worsens the results of recovery, causing cognitive impairment, anxiety, and depression. In addition, sudden onset of functional deficits, emotional instability, fear of death, and the need for rehabilitation can lead to stress and depression. Post-stroke depression (PSD) is the most common emotional disorder after stroke, affecting about 1/3 of patients, and has an important impact on the course, recovery and prognosis of stroke [2, 3]. Depression symptoms are most common in the first 3–6 months after a stroke, which leads to a decrease in the effectiveness of rehabilitation therapy, difficulties in physical and cognitive recovery, especially in older age groups [4, 5]. Enache D et al (2019) showed that patients with depression have neuroinflammation, which is characterized by an increased level of proinflammatory cytokines in the brain parenchyma [6]. In addition, studies by Beroun A (2019) showed an increase in the level of matrix metalloproteinase-9 (MMP-9) in the peripheral blood in patients with depression, and their correlation with the severity of depression [7]. Thus, MMP-9, interleukins are significantly involved in the pathogenesis of post-stroke depression (PSD - PSD) and may be possible biomarkers for predicting the risk of PSD development.

**Purpose of the study** – to determine the features of the concentration of fibrosis markers (MMP-9) and immune inflammation (TNF- $\alpha$ , IL-1 $\beta$ , INF- $\gamma$ ) in the blood serum of elderly patients with chronic kidney disease

and ischemic stroke, depending on the development of post-stroke depression.

### **Material and research methods**

The study was carried out on the basis of the neurological department of the emergency hospital № 8 in Voronezh. The study included 98 people, of whom 78 patients with chronic kidney disease (CKD, C2, A2) with acute ischemic stroke (IS) and 20 people in the control group, comparable in age without chronic kidney disease and ischemic stroke in history. The inclusion criteria for the study were elderly patients with chronic kidney disease (C2, A2) who were admitted to the hospital in the acute period of the first cerebral stroke. Exclusion criteria - refusal to participate in the study. The average age of the patients was  $68 \pm 6$  years. Post-stroke depression during follow-up developed in 34 people. (43.6%), 44 people (56.4%) did not show signs of PSD. The diagnosis of stroke was established on the basis of anamnesis, clinical criteria (severity of cerebral and focal symptoms); additional laboratory and instrumental research methods. The severity of the patients' condition was assessed using the NIHSS scale, the mean score was  $8 \pm 5$ , which corresponded to mild (20 people, 25.6%) and moderate (58 people, 74.4%) severity. Upon admission, the concentration of MMP-9 was determined by ELISA using highly sensitive Human MMP-9 kits (ELISA Kit, USA). Determination of the level of IL-1 $\beta$ , TNF- $\alpha$ , INF- $\gamma$  was carried out using a set of reagents for ELISA CJSC "Vector-Best", Russia. Registration of neurological and mental status was carried out on days 1-3 and 90 days ( $\pm 2$  days) after the stroke. Depressive disorders were diagnosed based on the DSM-V criteria [8]. All patients received identical complex therapy aimed at correcting central and cerebral hemodynamics, normalizing homeostasis, and improving perfusion of brain tissue.

Statistical processing was carried out using the "Microsoft Excel 2016" software package. Quantitative indicators are presented as median (Me), interquartile ranges (Q25%; Q75%), continuous quantitative values were expressed as mean  $\pm$  SD. Comparison of quantitative variables with a normal distribution of the trait was carried out using the Student's t-test, the differences were considered significant at a significance level of  $p < 0.05$ .

### **Results and its discussion**

Within three months, 5 people (6.4%) dropped out of the study, 3 of them due to refusal to follow-up, 2 people with a recurrent stroke. Thus, an assessment of the studied indicators was carried out in 73 people. (93.6%).

Table 1 presents the clinical and laboratory characteristics of the studied groups of CKD patients with ischemic stroke, depending on the development of post-stroke depression.

**Table 1 Clinical and laboratory characteristics of patients with chronic kidney disease with ischemic stroke included in the study, depending on the development of post-stroke depression**

Indicators, units of measurement	IS without PSD, (n=40, people)	IS with PSD (n=34, people)
Men/women, people	28/12	24/10
AH, people. (%)	30 (75%)	32 (94.1%)*
IHD, people. (%)	10 (25%)	10 (29.4%)
DM 2 types, people. (%)	5 (12.5%)	6 (17.6%)
AO, people. (%)	12 (30%)	12 (35.3%)
Age, years	64 (61; 67)	70 (65; 74)*
BMI, kg/m <sup>2</sup>	29.7 (27.0-32.1)	30.2 (27.3-33.8)
Glucose, mmol/l	5.4 (4.7-7.2)	5.9 (5.2-7.4)*
TG, mmol/l	1.96 (1.54-2.37)	2.84 (2.09-3.37)**
LDLP, mmol/l	2.80 (2.45-3.17)	3.47 (2.88-3.87)**
NIHSS	5 (3; 7)	7 (3; 9)**

Note: AH – arterial hypertension; AO- abdominal obesity, IHD – ischemic heart disease; IS – ischemic stroke, BMI – body mass index, LDLP – low density lipoproteins, PSD – post-stroke depression, DM – diabetes mellitus, TG – triglycerides; \*  $p < 0.05$ ; \*\* $p < 0.01$  – between the studied groups of patients

Elderly patients with CKD and ischemic stroke who developed post-stroke depression were significantly older ( $\Delta 8.6\%$ ,  $p < 0.05$ ) than without PSD, more often had arterial hypertension ( $\Delta 20.3\%$ ,  $p < 0.01$ ), hyperglycemia ( $\Delta 9.3\%$ ,  $p < 0.05$ ), hypertriglyceridemia ( $\Delta 31.0\%$ ,  $p < 0.01$ ), higher LDLP values ( $\Delta 19.3\%$ ,  $p < 0.05$ ), higher score for NIHSS ( $\Delta 28.6\%$ ,  $p < 0.01$ ).

Recently, the occurrence of neuroplastic changes in the brain is associated with an increased production of pro-inflammatory cytokines (IL-1, IL-6, IL-8, TNF- $\alpha$ ), which inhibit the indolamine-2,3-dioxygenase involved in the synthesis of serotonin, which helps to inhibit the synthesis neurotransmitters. In this regard, we have studied the content of IL-1 $\beta$ , TNF- $\alpha$  and INF- $\gamma$  in blood serum. When analyzing the results obtained, it was revealed that in elderly patients with CKD and ischemic stroke, the indicators of inflammation were significantly higher than in the control group. Thus, the level of IL-1 $\beta$  in the blood serum in the control group (CG) was 20.9 (14.9; 27.1) pg/ml, in patients with CKD, IS without PSD 55.1 (47.9; 65, 2) pg/ml, which is 2.6 times higher than in CG ( $p < 0.001$ ), in patients with



CKD, IS with PSD 71.2 (58.3; 83.3) pg/ml, which is higher than CG in 3.4 times ( $p < 0.001$ ), and 1.3 times than in the group of patients with CKD, IS without PSD ( $p < 0.001$ ). The serum TNF- $\alpha$  content in the control group was 5.2 (3.4; 6.8) pg/ml, in patients with CKD, IS without PSD 12.1 (9.9; 14.8) pg/ml, which is 2.3 times higher than the CG ( $p < 0.001$ ), in patients with CKD, IS with a PSD of 19.5 (13.0; 24.2) pg/ml, which is 3.8 times higher than the CG ( $p < 0.001$ ) and 1.6 times than in the group of patients with CKD, IS without PSD ( $p < 0.001$ ). The content of INF- $\gamma$  in blood serum in the control group was 14.62 (13.04; 16.80) pg/ml, in patients with CKD, IS without PSD 19.87 (15.19; 23.08) pg/ml, which is 1.4 times higher than CG ( $p < 0.001$ ), in patients with CKD, IS with PSD 26.45 (19.06; 32.27) pg/ml, which is 1.8 times higher than CG ( $p < 0.001$ ) and 1.3 times than in the group of patients with CKD, IS without PSD ( $p < 0.001$ ).

The ischemic cascade is triggered after the onset of a stroke, and an immune response is initiated in the damaged tissue. Microglial cells are activated, which, along with other pro-inflammatory mediators, lead to a violation of the integrity and an increase in the permeability of the blood-brain barrier, which contributes to the inflammatory process and aggravates the death of neurons. Neuronal damage can also occur through the humoral pathways due to the release of inflammatory mediators such as INF- $\gamma$ , TNF- $\alpha$  [9]. Our study revealed a significant increase in the serum levels of INF- $\gamma$ , TNF- $\alpha$ , IL-1 $\beta$  in elderly patients with CKD during the acute stage of ischemic stroke, while post-stroke depression developed in elderly patients with higher values of these cytokines.

Serum MMP-9 levels in the acute stage of stroke are a possible biomarker for predicting outcomes in patients with IS [10]. In this regard, our study determined the level of fibrosis marker in patients with CKD in the acute stage of IS, depending on the subsequent depression. The level of MMP-9 in CG subjects was 41 (28; 54) pg/ml, in patients with CKD, IS without PSD 117 (90; 144) pg/ml, which is 2.9 times ( $p < 0.001$ ) higher than in CG, in patients with CKD, IS with PSD 159 (123; 194) pg/ml, which is 3.9 times higher than CG ( $p < 0.001$ ) and 1.4 times higher than in the group of patients with CKD, IS without PSD ( $p < 0.001$ ).

Matrix metalloproteinase-9 belongs to the family of zinc-containing endopeptidases capable of destroying extracellular matrix compounds. MMP-9 is localized and released from neurons, astrocytes and microglia, where its expression is regulated by growth factors, cytokines and free radicals. In a study by Che B. et al (2019), the relationship between the level of MMP-9 in patients with acute ischemic stroke and the development of PSD was studied. A multivariate adjusted analysis showed that high se-

rum MMP-9 levels (odds ratio 4.36, 95% CI 2.49–7.65) were an independent predictor of PSD within 3 months of stroke onset [10]. We found that elderly CKD patients with ischemic stroke had higher serum MMP-9 values compared with CG individuals. At the same time, post-stroke depression developed in elderly patients with CKD who had higher MMP-9 values during the acute stage of ischemic stroke, which is consistent with the results of the CATIS multicenter cohort study [10].

### Conclusion

Thus, the addition of the determination of the serum level of markers of fibrosis (MMP-9) and immune inflammation (IL-1 $\beta$ , TNF- $\alpha$ , INF- $\gamma$ ) can improve the prediction of the risk of post-stroke depression in elderly patients with chronic kidney disease and ischemic stroke. In addition, the results obtained can help in identifying elderly patients with CKD with IS, who need special attention for the early detection of post-stroke depression.

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## QUANTITATIVE ASSESSMENT OF PECTIN CONTENT IN THE PULP OF MOUNTAIN ASH FRUITS (FRUCTUS SORBIA)

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**Abstract.** In the course of the analysis of mountain ash fruit pulp of fruits collected from wild and cultivated plants the content of pectin substances was established. It ranged from 2.1 to 2.7%, depending on the sample under study. Given the wide distribution of mountain ash in the Russian Federation, it seems appropriate to use mountain ash fruits (*Fructus Sorbia*) as an additional source of pectin substances.

**Keywords:** fruits, mountain ash, pectin, gravimetric analytical method.

Pectin is one of the most common polysaccharides accumulated in various plant raw materials. Pectin is widely used in many industries. For example, in Russia the food industry needs up to 10,000 tons of pectin per year [1]. A slightly smaller amount of pectin is required for therapeutic and prophylactic purposes.

In medical practice pectin is used as an enterosorbent, as well as an excipient and corrigent in different medical prescriptions [2]. It was also found that pectin substances have a marked antimicrobial effect on test-strains of microorganisms. *E. coli* and *S. Aureus* colonies seem to be the most sensitive to pectin substances [3]. Despite its considerable presence in many plant-based products, the cost of food pectin is 25-35 US dollars per 1 kg, whereas 1 kg of medical pectin costs 60-120 US dollars, depending on the purity of the finished product.

Nowadays up to 80% of pectin in Russia is imported, so the search for cheap domestic sources is thought to be a relevant and promising direction. In Russia pectin is produced by processing apple or citrus pomace in compliance with the requirements of GOST 29186-91 pectin (technical specifications).

Previous studies [4, 5] analysed pectin content in fruits of the following plants: viburnum, blackberry, dogwood, blackthorn, rosehip, hawthorn,

oriental wild apple and blueberry. In the course of this research the content of pectin substances in the studied samples was established. Also, the prospects of using them as an additional source of pectin were highlighted [6, 7]. As one of the sources of pectin is an apple fruit pulp, we considered it appropriate to make a quantitative assessment of pectin content of the pulp of fruits of mountain ash, that belongs to the same family Rosaceae.

### **The aim.**

An analysis of the quantitative content of pectin in mountain ash fruit pulp for estimating the prospects of this raw material use as a source of pectin for medical purposes.

### **Materials and methods.**

The objects of the study were wild mountain ash fruits collected in the underbrush of broad-leaved forests in Moscow Oblast (Istra District and Chekhov District) and Tver Oblast, cultivated mountain ash fruits (Michurinskaya Desertrnaya variety) and the fruits of cultivated plants of hybrid mountain ash (Burka variety, a hybrid obtained by crossing alpine sorbaronia and mountain ash, and Granatnaya variety, a hybrid obtained as a result of crossing mountain ash and large-fruited hawthorn).

For a preliminary assessment of the presence of natural polysaccharides Pharmacopoeia method was used. It included the following procedures: grinding the plant raw material to a particles enabling to pass through sieves with a hole diameter of 2mm, extraction of hydrophilic substances with water purified by heating for 30 minutes, filtration of the extracts, and adding 30 ml of alcohol 96% to 10 ml of the filtrate that was accompanied by flocculent sedimentation.

For quantitative assessment of the content of pectin substances we used sample preparation, including mechanical squeezing of juice, followed by drying and grinding the pulp to particles enabling to pass through sieves with a hole diameter of 2mm. Pectins were quantified by the gravimetric analytical method. The pH value of the solutions of obtained pectins was found after dissolving samples of 0.1 gram mass (accurately weighed) in water distilled with a help of an automatic high-precision potentiometric titrator ATP-02 with Aquilon software. The analysis of pectin samples was performed in accordance with the requirements of GOST. Organoleptic and physicochemical properties of pectin such as moisture content, etherification degree, gel strength, weight ratio of nitrates and particles of the fibrous fraction larger than 0.5 mm in size were determined and assessed.

### **Discussion and results.**

To assess the quantitative content of pectin substances prepared ac-

cording to the method described above, mountain ash fruits pulp was treated with 0.5% oxalic acid solution at 65° C and a weight ratio of 1:5 for 4 hours, followed by coagulation with 95% ethyl alcohol, separation of the finished product by centrifugation, isothermal drying, and gravimetric determination of pectin.

The results of the quantitative assessment of pectin content in the samples of fruits collected from wild and cultivated mountain ash plants, as well as hybrid varietal mountain ash plants, are presented in *Table 1*. Also, the table shows the pH value of aqueous pectin solutions of obtained samples.

**Table 1. Assessment of pectin content in the plant raw materials**

Plant raw material	Collecting area	Quantitative content of pectin, %	pH of aqueous pectin solutions
Pulp of mountain ash fruits (wild plants)	Underbrush of broad-leaved forests in Moscow Oblast (Chekhov District)	2.7±0,05	2,4
Pulp of mountain ash fruits (wild plants)	Underbrush of broad-leaved forests in Tver Oblast	2,6±0,01	2,3
Pulp of mountain ash fruits (wild plants)	Underbrush of broad-leaved forests in Moscow Oblast (Istra District)	2,4±0,03	2,1
Pulp of hybrid mountain ash fruits (Burka variety)	Garden Community «Sunrise»	2,2±0,03	3,0
Pulp of hybrid mountain ash fruits (Granatnaya variety)	Nursery garden «Ecoplant»	2.3±0,03	3,2
Pulp of cultivated mountain ash fruits (Michurinskaya Desertnaya variety)	Botanical Garden of Moscow State University	2,1±0,01	2,5

*Table 1* shows that all the analysed samples have similar content of pectin substances, from 2.1 in the cultivated mountain ash fruits pulp of Michurinskaya Desertnaya variety to 2.7 in wild mountain ash fruits pulp.

The analysis of the pH values of the aqueous pectin solutions suggests its highest content in wild mountain ash fruits pulp (Istra District). An increase in the pH value in the varietal fruits samples may be explained by a larger amount of monosaccharides, which predetermine better taste characteristics.

The obtained pectin samples were examined in accordance with the requirements of GOST 29186-91 Pectin. The organoleptic parameters of the studied samples are presented in *Table 2*.

**Table 2. Organoleptic parameters of pectin obtained from the pulp of wild and varietal fruits of mountain ash**

Sources of pectin	Aggregate state	Taste	Odor	Color
Pulp of mountain ash fruits (wild plants)	Fine grinding powder without foreign impurities	Slightly sour, tasty	No	Yellowish
Pulp of mountain ash fruits (wild plants)	Fine grinding powder without foreign impurities	Slightly sour, tasty	No	Yellowish
Pulp of mountain ash fruits (wild plants)	Fine grinding powder without foreign impurities	Sour	No	Yellowish
Pulp of hybrid mountain ash fruits (Burka variety)	Fine grinding powder without foreign impurities. Pectin flakes fractions can be found.	Slightly sour with pronounced berry flavor	No	Reddish
Pulp of hybrid mountain ash fruits (Granatnaya variety)	Fine grinding powder with separate fibre fractions	Slightly sour, tasty	No	Cream-colored
Pulp of cultivated mountain ash fruits (Michurinskaya Desertnaya variety)	Fine grinding powder without foreign impurities	Slightly sour, tasty	No	Cream-colored

Physicochemical parameters of the pectin samples are presented in *Table 3*.

**Table 3. Physicochemical parameters of pectin**

Sources of pectin	Moisture content, %	Degree of etherification, %	Gel strength, Farr-Baker degrees	Weight ratio of nitrates, %	Weight ratio of particles of the fibrous fraction larger than 0.5 mm in size, %
Pulp of mountain ash fruits (wild plants)	3,4	69	185	0,04	4,5
Pulp of mountain ash fruits (wild plants)	3,1	71	180	0,12	5,0
Pulp of mountain ash fruits (wild plants)	3,6	70	179	0,06	5,5
Pulp of hybrid mountain ash fruits (Burka variety)	2,4	82	190	0,14	12,5
Pulp of hybrid mountain ash fruits (Granatnaya variety)	5,6	76	186	0,08	16,0
Pulp of cultivated mountain ash fruits (Michurinskaya Desertnaya variety)	3,7	68	182	0,06	6,0

As can be seen from *Tables 2 and 3*, all the pectin samples are in line with the requirements of GOST for industrial pectin. Physicochemical parameters of pectin obtained from wild mountain ash plants and cultivated mountain ash plants of Michurinskaya Desertnaya variety are close to each other, while physicochemical parameters of hybrid varieties differ. All samples have a fairly high degree of etherification (>65%). Considering all the information above, we suggest using mountain ash fruit pulp as a promising source of pectin, particularly for medical purposes [10, 13, 15, 16].



### Conclusion.

The study carried out the quantitative assessment of the content of pectin substances in the fruits of mountain ash pulp collected in different areas, as well as of hybrid varieties. The results show that pectin content ranges from 2.1% (pulp of cultivated mountain ash fruits of Michurinskaya Desertnaya variety) to 2.7% (pulp of wild mountain ash fruits). Given the significant reserves of mountain ash in the Russian Federation, this type of raw material can be used as an additional source of pectin for medical purposes.

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## PROTEIN METABOLISM AND LIVER FUNCTION (NEW IDEAS)

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*In gratitude to A. Verghese for the  
book of the century "Cutting for  
Stone"*

**Abstract.** The main goal is to investigate the role of the liver in protein metabolism. Venous blood counts are the only way to study liver function. For practical purposes this is sufficient, but for understanding liver function it is wrong. It is known that the blood of the portal vein and the hepatic artery flows to the liver, and the blood of the hepatic vein and the hepatic lymph, which is completely unknown in its composition, flows from the liver. The biochemical composition of the lymphatic system, which is not known at all, has never been taken into account in the study of this function.

For this, in an experiment on 23 dogs, the function of the liver in the inflowing and outflowing blood and lymph was investigated. The difference in the summed amount in the inflowing and outflowing blood and lymph should be determining the function of the liver.

It draws attention to the fact that there is more protein and protein fractions in the inflowing blood, which shows the regulating (sometimes leveling) role of the liver.

The quantitative composition of the liver lymph differs markedly from the general lymph.

**Keywords:** Blood from the portal vein and hepatic artery flowing to the liver, blood flowing from the liver through the hepatic vein and hepatic lymph. The general and hepatic lymphatic system.

**Proteins** – are high molecular weight natural substances, consisting of a chain of amino acids that are linked by a peptide bond. The most important role of these compounds is the regulation of chemical reactions in the body (enzymatic role).

Albumin is synthesized in the liver and reflects the functional state of

the liver. The half-life (half-life) of albumin is about 20 days.

The liver plays a major role in the production of proteins. All albumin, 75-90% of  $\alpha$ -globulins and 50% of  $\beta$ -globulins are synthesized by hepatocytes.

$\gamma$ -globulins are synthesized by macrophages, they include stellate reticuloendotheliocytes (Kupffer cells). Basically,  $\gamma$ -globulins are synthesized outside the liver.

Note that important proteins are synthesized in the liver — prothrombin, fibrinogen, proconvertin, and proaccelyrin.

Determination of the composition of the liver is of diagnostic and prognostic significance. The pathological process in hepatocytes sharply reduces the synthetic capabilities, which leads to a decrease in plasma albumin, which reduces the plasma oncotic pressure and leads to the development of edema and ascites.

It is known that a decrease in the level of total protein in blood plasma to 45 g/l indicates severe endogenous intoxication and an unfavorable outcome of the disease; a decrease in the concentration of total protein due to the albumin fraction reflects the use of albumin as the most important factor in plasma detoxification, binding and removal of toxins;

- an increase in alpha-2-globulins twice reflects the activity of the process with impaired deamination; an increase in gamma globulins indicates an increase in the production of coarse proteins;

- a decrease in the albumin-globulin coefficient (the ratio of the number of albumin to the amount of globulins) causes, in case of severe intoxication, the transition of albumin into the tissue as a result of impaired permeability of the vascular walls, a decrease in the intensity of albumin synthesis in the liver tissue, acceleration of their decay and transformation into other proteins, partly into globulins, as well as increased synthesis of alpha - 2 and gamma - globulins. Normally, the albumin-globulin coefficient ranges from 1.5 to 2.3. This is the first part of the article with well-known facts, without which it is impossible to understand what follows, they are all from books (2 and 4).

In everyday clinical practice, we use biochemical data obtained from venous blood parameters to determine liver protein metabolism, but this only indirectly shows liver function and is practically incorrect. This practice exists in all laboratories in the world, there is no other way. However, it is known that blood flows to the liver through two vessels - the portal vein and the hepatic artery, and blood flows through the hepatic vein and hepatic lymph. This in itself dictates a different approach in determining protein metabolism and the value in this liver.

Based on this, an attempt was made in an experiment on dogs to find

out the role of the liver in protein metabolism from different positions, for this we took for the study of protein and protein fractions the blood flowing to the liver from the portal vein and hepatic artery and, finally, the indicators of blood flowing from the liver in the hepatic vein and completely unknown in terms of its qualitative and quantitative composition of hepatic lymph (3).

We will consider each component of the inflowing and outflowing blood and lymph separately. There is a very important point here, we do not know what indicators should be taken as the norm. Naturally, the indicators of protein and protein fractions in venous blood cannot be the norm!

The norm should be considered indicators in the blood and lymph flowing from the liver. The difference between the flowing and flowing blood is an indicator of liver function.

In an experiment on 23 dogs, the function of the liver in the inflowing and outflowing blood and lymph was investigated. The biochemical composition of the lymphatic system has never been taken into account in the study of this function, and its composition is not known at all.

This is only a part of a large study of liver function, presented in a large number of articles (about 20).

The study of blood and lymph for protein and protein fractions was carried out in the laboratory of the Department of General Surgery. The composition is given in g/l (gram per liter).

**Lymph.** To obtain lymph, at present, the only possible method is drainage of the thoracic lymphatic duct (TLD) on the neck, which is possible with certain indications, but by the nature of the lymph it is mixed - hepatic lymph flowing from the liver simultaneously and flowing down the lumbar and intestinal trunks (1). Due to these circumstances, it is impossible to say which part of the lymph is determining the exchange of protein and protein fractions of the liver.

To differentiate lymph, an attempt was made in an experiment on dogs to obtain pure hepatic lymph. For this purpose, the TLD cistern was ligated in a certain way, and as a result, clear hepatic lymph was obtained. The method of obtaining hepatic lymph is described and an application for an invention is filed.

Organ and mixed lymph are different in their biochemical composition. We present the comparative results of the characteristics of the composition of protein and protein fractions from the general bed - the general lymph and from the lymph of the liver.

The quantities are shown in the table and graph. We present the composition of the protein and protein fractions in the lymph flowing from the liver in the general lymph and separately in the hepatic lymph.

Table.1.

Protein	alb.	a1	a2	b1	b2
43	38	5.2	7.7	16.4	21.5

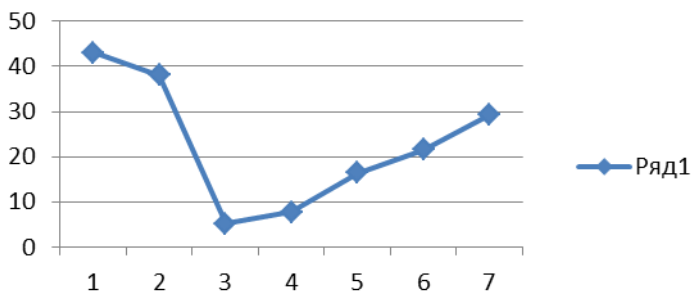
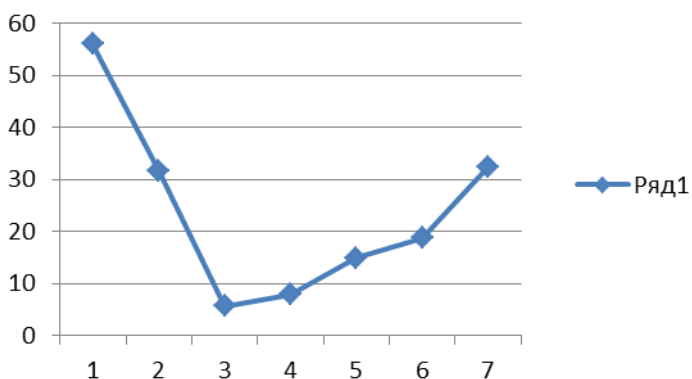


Table.2.

Protein	alb.	a1	a2	b1	b2
56	32	5.7	7.9	15	19



We see that the amount of protein in the hepatic lymph is 1.3 times higher, the fractions are higher for albumin a1 and albumin a2; the gamma globulin is 1.1 times higher.

All this, as indicated above, is presented in tables and graphs.

**Liver function.** The gradient of the difference between the inflowing and outflowing blood and lymph from the liver should be normal. The table below shows the summary data for each parameter in numbers.

**Table 3. Protein metabolism of the liver is normal**

		<b>Protein</b>	<b>alb.</b>	<b>a1</b>	<b>a2</b>
Vein	Numb 22	47	23.3	4.1	6.7
Infl.					
Port.vein	23	77	37.1	4.2	9.2
Artery	22	65	23.4	2.7	8
		142	60.5	6.9	17.2
total		71	30.2	3.4	8.6
Edema.					
Liv.vein	13	69	23.2	4.7	7.2
Lym.total	19	43	38	5.2	7.7
		112	61.2	9.9	14.9
total		56	30.6	4.9	7.4
Liv.vein	13	69	23.2	4.7	7.2
Lym.liv.	9	56	31.6	5.7	7.9
		125	54.8	10.4	15.1
total		62	17.4	5.2	7.5

At first glance, in the outgoing blood, in total, all indicators should be higher, but this turns out to be not the case, the main parameters of protein and albumin are lower. Here the regulating role of the liver is manifested. "Excess" protein flowing to the liver is not deposited in the body, unused proteins are broken down to nitrogenous compounds, carbon dioxide and water.

For greater clarity, let us consider separately the average content of protein components and fractions.

It is known that the range of blood protein levels in a healthy adult ranges from 65 to 85 g/l. Total blood protein is the sum of all types of proteins circulating in plasma.

The main fractions are albumins and globulins. Albumin is formed in the liver, its fraction is homogeneous in its structure and makes up about 60% of the total amount of proteins.

Consider first these two indicators - protein and albumin.

**Table 4. The amount of protein and albumin in the blood and lymph of the liver is normal**

		<b>Protein</b>	<b>alb.</b>
Vein	Numb22	47	23,3
Infl.			
Port.vein	23	77	37.1
Artery	22	65	23,4
		142	60,5
total		71	30,2
Edema.			
Liv.vein	13	69	23,2
Lym.total	19	43	38
		112	61,2
total		56	30,6
Liv.vein	13	69	23,2
Lym.liv.	9	56	31,6
		125	54,8
total		62	17,4

Conclusions: The inflowing blood contains the largest amount of protein and albumin in total.

At the same time, there is less protein (1.1 times) and albumin (1.7 times) in the outflowing lymph. In the hepatic lymph, in comparison with the total amount of protein, there is more, and less albumin.

I repeat the explanation of this fact, the "extra" protein is not deposited in the liver, and the excess amount of proteins is broken down to nitrogenous compounds, carbon dioxide and water.

Albumin and globulins of the blood and lymph of the liver are normal.



**Table. Albumin and globulins of blood and lymph of the liver are normal**

06.05.21		a1	a2	b1	d2	y
Vein	Numb 22	4.1	6.7	11.9	19.5	24.2
Infl.						
Port.vein	23	4.2	9.2	17	21.3	25.8
Artery	22	2.7	8	10	12.5	19.8
		6.9	17.2	27	33.8	45.6
total		3.4	8.6	13.5	16.9	22.8
Edema						
Liv.vein	13	4.7	7.2	12.3	14.2	21.9
Lym.total	19	5.2	7.7	16.4	21.5	29.2
		9.9	14.9	28.7	25.7	51.1
total		4.9	7.4	14.3	12.8	25.5
Liv.vein	13	4.7	7.2	12.3	14.2	21.9
Lym.liv.	9	5.7	7.9	14.9	18.7	32.3
		10.4	15.1	31.3	40.2	61.5
total		5.2	7.5	15.6	20.1	30.7

The albumin indicators in the outflowing blood and lymph are predominantly higher. There are also more globulins, but they are formed in the liver and the reticuloendothelial system (lymphocytes and plasma cells). and we do not take them into account.

Globulins are represented by a heterogeneous composition, because they are formed in the liver and the reticuloendothelial system (lymphocytes and plasma cells).

**Table 5. Albumin-globulin coefficient**

	Albumin globulin ratio		
Vein	23.3	24.2	0.96
Port. vein/artery	30.6	22.8	1.3
Liv.vein/liv. total	30.6	25.5	1.2
Liv.vein/lymph liv	17.4	27.1	0.6

The ratio of albumin to globulins is the albumin-globulin coefficient.

I assume that the albumin-globulin coefficient (tab. 5) in the peripheral blood does not characterize liver function. Follows the norm to take the indicator in the hepatic vein and hepatic lymph. As well as among other indicators, the coefficient of albumin and globulins is slightly higher in the blood flowing to the liver.

Conclusions:

1. For the study of various functions of the liver, the comparative nature of the inflowing and outflowing blood is acceptable. Flowing through two vessels - the portal vein and artery and outflowing blood - the hepatic vein and lymph. In this case, the organ hepatic lymph should be taken into account. The difference between inflowing and outflowing blood and lymph characterizes liver function.

2. The norm should be considered the indicators available in the flowing blood and lymph. Digital indicators should be made up of the sum of indicators from two vessels - hepatic vein and hepatic lymph.

3. The difference between the flowing and flowing blood from the liver is an indicator of liver function.

4. When comparing these ingredients, the level of indicators in the inflowing blood is higher than in the hepatic blood and hepatic lymph flowing out on average (total protein, albumin and globulins).

5. The albumin-globulin gradient in the inflowing and outflowing blood and lymph slightly predominates in the inflowing blood.

6. Attention should be paid to  $\gamma$ -globulin, which is very high in venous blood.  $\gamma$ -globulins are synthesized outside the liver.

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## VICIOUS CIRCLES IN THE PATHOGENESIS OF SCHIZOPHRENIA (NEW PRINCIPLES OF PATHOGENESIS AND TREATMENT OF SCHIZOPHRENIA)

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Clinic for pathology of higher nervous activity

**Abstract.** Long-term observations of patients who underwent cytokine therapy in our clinic allowed us to create a fundamentally new concept of the pathogenesis of schizophrenia and to find a number of instrumental examinations capable of confirming or rejecting the diagnosis of F 20. We came to the conclusion that neural networks suffer secondarily. The main reason for the onset and development of schizophrenia is the genetic vulnerability of astroglial syncytium. We believe that the greatest success of the use of cytokines is not a long-term stable remission, but a complete recovery of patients F 20, which was confirmed socially, clinically and instrumentally.

**Keywords:** Cytokines, Astroglial networks, Tripartite synapse, Delta sleep, New concept of schizophrenia pathogenesis, New principles of schizophrenia treatment.

**Schizophrenia – a disease based on the self-poisoning of the brain, as an organ, by the products of its own metabolism.** The genetic vulnerability of astroglia reduces the drainage function of the glymphatic system. The growing toxicity of the cerebrospinal fluid leads to the degeneration and death of a number of glial cells, which in turn triggers a chain of pathophysiological processes developing according to the laws of a “vicious circle”. Neurons are deprived of the energy support of astrocytes. Tripartite synapses change sensitivity to most neurotransmitters (GABA, dopamine, serotonin, etc.), and they change in different directions. In the toxic cerebrospinal fluid, oligodendrocytes die en masse, depriving axons of myelin isolation. Decreased energy potential, distortion of emotional space, impaired attention and thinking, delirium, pseudo-hallucinations are just various **consequences** of this progressive autointoxication process. **"Consequences"** are depicted in the form of shadows from the patho-

physiological processes going on in the central nervous system of patients F 20 (Fig. 2).

Agree, our idea of F 20 is fundamentally different from everything that you have ever read about this disease [7.]. For practicing psychiatrists, the definition is not familiar, but it reveals the pathophysiological mechanism of the development of schizophrenia correctly. Pathologist-psychiatrist Pavel Evgenievich Snesev, in the fifties of the last century, gave a shorter definition of schizophrenia: **"Toxic - anoxic encephalopathy"** [1.]. Eighty years ago, his instrument was only a microscope, hellish patience and the most complex methods of staining the gliosis tissue of the brain he himself developed... Who knows, if it were not for the young AV Snezhnevsky, who for political reasons took his place - what heights could Soviet psychiatry have reached? The scientific views of Pavel Evgenievich were formed by the school of V.M.Bekhterev, where the experiment and the close connection of pathomorphology with clinical observations were always the basis. Unfortunately, Snezhnevsky, for all his merits, took Soviet psychiatry in a completely different direction and doomed it to the role of a "servant" of the political regime.

If we consider pathogenesis as an alternating sequence of events, then the first event that triggers the schizophrenic process, we assume a shift in the cytokine balance towards the prevalence of the group of cytokines **Th2>Th1**. This is followed by an autoimmune attack of cytokines of the **Th2** group on the "legs" of astrocytes lining the perivascular space. The consequence of this attack is a violation of the coordinated coordination of the changing volume of the "legs". The mechanism that provides enhanced movement of the cerebrospinal fluid along the glymphatic system breaks down during slow wave sleep [2,10.]. An autoimmune attack on the "legs" of astrocytes becomes the cause of the launch of the main vicious circle in the pathogenesis of schizophrenia, But! Just an incentive. Schizophrenia should not be classified as an autoimmune disease, despite the severe immunological imbalances observed in patients. The main pathological mechanism that determines the entire course of schizophrenia is the genetic vulnerability of astroglial syncytium, which actually organizes the drainage of the cerebrospinal fluid through the glymphatic system in slow sleep. We have written a lot about this in previous articles [2,3,5,9,10.]. Moreover, due to the breakdown of this drainage mechanism, it is impossible to compensate for slow-wave sleep after its deprivation. Patient F 20 is unable to "sleep off" after a sleepless night. Even a small "lack of sleep" is destructive for him. This is a serious provoking factor capable of independently launching the main vicious circle, accelerating the

degradation of astroglia. (Fig. 1, blue circle in the center.) It happens in the following way; A shift in the cytokine balance **Th2> Th1** adversely affects the domain-coordinated, sequential change in the volume of astrocyte legs [2,10]. Astroglial syncytium ceases to provide increased flow of cerebrospinal fluid during slow sleep and metabolic products accumulate in the cerebrospinal fluid. Astrocytes in both directions pass through all the toxins that the stagnant cerebrospinal fluid contains and gradually degrade. Within three to five years, this process leads to the appearance of defective symptoms. Defective symptomatology, as a rule, appears before psycho-production, and sometimes even grows without psycho-production (simple form F20) Astrocytes suffering in toxic cerebrospinal fluid are not able to energetically support neurons. The energy potential is steadily declining. Astrocytes cease to adequately provide sensitivity to mediators in tripartite synapses. In different parts of the brain, the sensitivity to neurotransmitters changes in different directions, but basically it increases to dopamine and decreases to serotonin.

### **Our understanding of the pathogenesis of schizophrenia** (Fig. 1.2.)

The central nervous system (CNS) is made up of individual cells, but the brain functions harmoniously as a single organ. Almost all the cells present in the brain matter conditionally divide into two large interdependent network structures that are organized in different ways; 1. **Neural** networks are united by the electric action potential and neurotransmitters moving in the space of the synaptic cleft. Neurons hardly reproduce. In the growing autointoxication of the cerebrospinal fluid, they suffer, but almost never die. Therefore, **the intellect of the patient F 20 remains intact**, even in conditions of attention deficit, distortion of emotional space and a significant drop in energy potential. ***This feature allows patients to consider themselves mentally healthy, and to assert this, ignoring the other opinion of relatives and doctors.***

2. **Astroglial networks** are organized differently, according to the syncytium principle, where there is no electrical action potential, and individual cells proliferate intensively. Astrocytes constantly multiply, renew themselves, combine into domains and communicate with each other with molecules completely different from neurotransmitters. The increasing inconsistency of fluctuations in the volume of astrocytic "legs", which tightly surround the entire perivascular space, reduces the velocity of the cerebrospinal fluid in the glymphatic system of the central nervous system. It is now well known that only in slow sleep occurs the most intensive disposal of the brain, as an organ, from the products of its own metabolism. Until the invented psychotropic drug capable of restoring the physiological structure

of night sleep. All types of schizophrenia, including some types of autism, share a lack of drainage function of slow wave sleep, although to varying degrees.

All therapeutic efforts of psychiatrists and pharmacologists are aimed at correcting the action of neurotransmitters in interneuronal synapses. (Fig. 1. Yellow circle on the right) In this case, the pathology of astroglial syncytium, the main reason for the increasing deficit of slow wave sleep, is ignored (Fig. 1. Central blue circle). For psychotropic drugs, there is no point of application. We argue that the main reason for the development of schizophrenia lies precisely in the pathology of astroglial syncytium. Any failure in its well-coordinated work upsets many of the brain functions closely related to it. Increasing, according to the principle of a vicious circle, intoxication of the cerebrospinal fluid modifies astrocytes, inhibits their proliferation. Usually, the pathological process in astroglial networks is slow. Intoxication with the products of one's own metabolism builds up gradually, over the course of three to five years, and only then leads to a tangible defect. But there is also an avalanche-like increase in the process (toxic, hyperthermic schizophrenia). In any case and always, the development of schizophrenia is based on a decrease in the draining function of delta sleep, the only organizer of which is astroglia. Astrocytes are reborn and gradually **lose the ability to energetically support neurons**, cease to adequately **regulate tripartite synapses**. The process leads to a drop in the energy potential, a change in the sensitivity of interneuronal tripartite synapses to dopamine, serotonin, gamma aminobutyric acid (GABA) and other mediators.

The increasing toxicity of the cerebrospinal fluid triggers at least two more vicious circles. **The second vicious circle** (Fig. 1. Yellow on the right) was defined and became clear only after the discovery of tripartite synapses. Astrocytes, which have changed their properties in the toxic cerebrospinal fluid, in different parts of the brain, modulate the work of tripartite synapses in different directions. As a result, the usual concentration of dopamine, serotonin and other mediators in certain areas of the brain works as excessive, and in other areas, as insufficient. All modern psychopharmacology is engaged in correcting the sensitivity of these synapses, with varying success. Antipsychotics, by their presence, balance the activity of neurotransmitters in interneuronal synapses, without affecting astrocytes in any way - the main reason that disrupts the balance of mediators. The selection of antipsychotics, antidepressants and other psychotropic drugs in practice occurs according to the **ex juvantibus** principle (if it helps means it is prescribed correctly) and depends entirely on the clinical experience of the doctor.

**The third vicious circle** (Fig. 1, red circle left), - is triggered by the growing intoxication of the cerebrospinal fluid and begins with the mass death of oligodendrocytes. The lack of myelin manifests itself in a slow-down in the speed of the impulse through Ranvier's interceptions. The myelin of axons is thinning (up to the complete absence in some areas). This leads to a dispersion of the impulse, the so-called "worn out wires symptom" and causes many clinical symptoms interpreted as pathology of thinking (Fig. 2, left shadow). It is with these symptoms that psychiatrists try to substantiate the diagnosis. Each doctor in a conversation with a patient evaluates the "found" symptoms subjectively - hence the confusion in the interpretation of "findings" and disputes about the diagnosis up to the denial of the very presence of schizophrenia, as a disease with a single pathogenesis, but very different symptoms.

In our studies, we used three objective diagnostic techniques that allow us not only to substantiate or reject the diagnosis of schizophrenia, but also quantitatively, digitally and on a graph (instrumentally) to observe the dynamics of the recovery of our patients. We recommend these methods for early and objective diagnosis of schizophrenia.

**1. Pre-pulse inhibition. (PPI).** This method is used to confirm the diagnosis of schizophrenia in laboratory rats and mice. The presence of the "mouse model of schizophrenia" has made it possible to defend more than one doctoral dissertation. In fact, this test measures the amount of "attention" and expresses it in numbers. Physiologically, attention is provided by sufficient myelination of axons, a normal rate of potential conduction through Ranvier's interceptions, which indicates a good state of oligodendrocytes, the only sources of myelin. If oligodendrocytes suffer, myelin becomes low. Isolation of axons is disturbed - the impulse is not channeled, but scattered, then it is difficult to keep attention. The diagnosis of schizophrenia is always accompanied by degeneration and death of oligodendrocytes. Thinning of the myelin sheath of axons, up to the complete absence of myelin in certain areas, makes it impossible to maintain attention. In our case, the insulating sufficiency of myelin on the axons of the auditory areas of the brain is being investigated. Anatomically, the auditory (temporal) zones are drained by the cerebrospinal fluid more difficult than other zones, therefore, the death of oligodendrocytes in the temporal regions occurs earlier than in the occipital, visual zones. But on the axons of the visual zones, it is also possible to determine the sufficiency of myelin, for example, by the nature of eye movement.

The **PPI** procedure on a person looks like this; the subject is comfortably seated in a comfortable armchair in a room well insulated from extra-



neous sounds. The eyes are closed. In high-quality headphones, a special device generates "white noise" (reminiscent of the noise of rain). Sensors are fixed under the eye and on the forehead that register the subject's reaction to clicks heard in the headphones. The clicks are loud, and anyone who hears such a click against the background of "white noise" involuntarily shudders and blinks. The flinch is registered by the sensors. It is impossible to forge a test. It has been experimentally proven that a mentally healthy subject, if 60 milliseconds before the main loud click, give a barely audible, quieter pre-click, does not flinch. A subject with a lack of attention ignores the pre-click and always flinches at the next loud noise. Lack of attention is often recorded in blood relatives of the patient, although to varying degrees. Expressed in numbers - attention deficit allows with a high probability to assume from which parent the patient inherited a predisposition to schizophrenia. In our experiment, immediately after inhalation of a mixture of cytokines, the PPI numbers slightly changed towards improving attention. This allowed us to more accurately select the combination of cytokines. In the course of cytokine therapy, the "attention numbers" gradually increase, until they approach the norm. The therapeutic mixture of cytokines has not only a cumulative effect, but also slightly and briefly improves attention immediately after the procedure. We use this feature to correct the ratio of cytokines in the inhaled mixture.

The F 20 diagnosis test is simple and excellent. It can be used to test people whose profession requires high responsibility and absolute mental health (pilots, train drivers, military specialists in rocket launchers, individual leaders and politicians).

In 2012, Scottish scientists at the University of Aberdeen discovered that people with schizophrenia are unable to track moving objects smoothly. The device created by them records the lag of the gaze of patients with F 20 from the object of observation. The diagnostic accuracy is close to 98%. This method does not require sound insulation, a "white noise" generator, sensor stickers, a special cabinet and takes only a few minutes. This is in theory. In practice, there are no such simple and inexpensive devices in Russian hospitals, and given the current state of medicine, one should not expect them to appear...

**2. Dynamics polysomnography.** Polysomnography has been around for a long time and is mainly used to prevent respiratory arrest during sleep (apnea) and to combat snoring. The realization that this method can be used to accurately diagnose schizophrenia has come recently. Why a person spends a third of his life on sleep - it became clear only a few years ago. **In schizophrenia, there is always a deficit in "slow wave sleep".** This

is the main instrumental diagnostic criterion. It cannot be detected without polysomnography. Only and exclusively in slow sleep is the flow of the cerebrospinal fluid through the glymphatic system seriously accelerated. Any decrease in the time or depth of slow wave sleep leads to the accumulation of metabolic products and self-poisoning of the brain as an organ. Autointoxication of the cerebrospinal fluid causes the death of two of the four types of microglial cells involved in the organization of REM sleep. (Fig. 1: red circle on the left) As a result, REM sleep suffers, but this is not as critical as NREM sleep deficit. When getting rid of metabolic products is difficult, toxicosis increases. In a toxic environment, oligodendrocytes die and the morphology of astrocytes changes. The morphology of astrocytes changes according to the laws of a vicious circle. The more intoxication, the more astrocytes change; they lose ribosomes, increase in size. The more the morphology of astrocytes changes, the worse they cope with organizing the movement of the cerebrospinal fluid along the glymphatic system. The proliferation of astrocytes slows down, and the ability to accelerate the movement of cerebrospinal fluid in slow sleep decreases (Fig. 1. The main blue circle in the center). Astrocytes are interconnected in astroglial networks according to the syncytium principle. **It is very likely that these connections are much more complex than neural networks.** There are no mediators on which psychotropic drugs could act, but astrocytes are sensitive to any changes in the ratio of cytokines. Actually, **all our therapy is aimed at restoring the cytokine balance.** We determine the effectiveness of cytokine therapy by the dynamics of restoration of the depth and duration of slow wave sleep. The polysomnography procedure takes place at the institute at night, although it is more informative to carry out it continuously, for two to three days, like Holter monitoring. Such devices already exist without wires and work perfectly within a radius of 30-50 meters. The quality and quantity of slow wave sleep shows not only the momentary severity of the schizophrenic process, but also the approximate duration and intensity of the disease. We have written a lot about this in previous articles. [2,3,5,6.] Slow sleep should normally be at least 26%. If the percentage is less, this indicates a low drainage function of the glymphatic system and is an important sign of schizophrenia.

**3.Three Tesla MRI.** We conduct this expert examination at the entrance, before starting cytokine therapy and then every six months. We pay close attention to the dynamics of the Virchow - Robin perivascular spaces. So - the less the depth and duration of the delta sleep - the slower the cerebrospinal fluid flows, the higher its toxicity, the greater the pressure in the glymphatic system! This causes expansion of the ventricles, coarsening of the intraventricular vascular plexuses, the appearance of

microhemorrhagic changes on them, an increase in the number and size of Virchow-Robin spaces. Under such conditions, the degeneration of astrocytes is more intense. They lose ribosomes, slow down proliferation, and some increase in size [4]. In the case of a well-chosen combination of cytokines and a rapid restoration of a full night's sleep, the Virchow-Robin spaces decrease and return to normal within a year or two. Sometimes they disappear completely [3,10.]. We are not satisfied with the written conclusions of radiologists and without fail every six months we compare the control parts of the brain (with the enlarged perivascular spaces). So we manage to instrumentally observe the dynamics of restoration of the drainage function of the glymphatic system.

### **Follow-up of real patients who underwent a course of treatment with cytokines.**

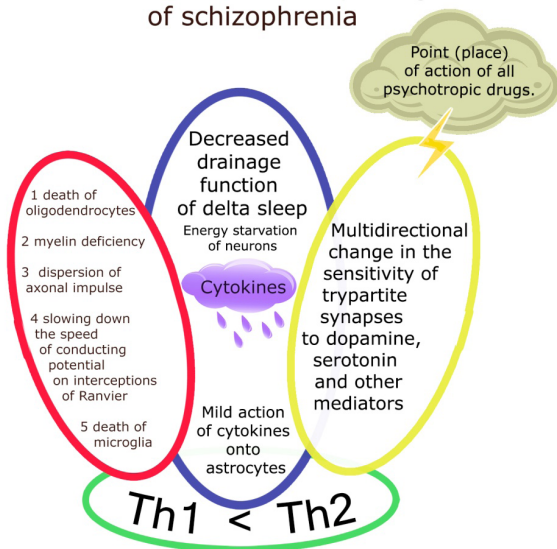
1. Patient "L" The disease began in winter 2009. The debut within a month was stopped by drip parenteral administration of cytokines. In the spring of 2010 she entered the medical institute (see the appendix to the patent). In the winter of 2010, during the winter session, she was admitted to the psychiatric hospital №2 of Novosibirsk. Diagnosed with paranoid schizophrenia. In a state of catatonic excitement, in mating, at high doses of haloperidol, she was in the hospital for more than two months without visible improvement. At the request of the parents, treatment with cytokines was started again. The course is three months. She was discharged in a state of stable remission. In the fall of 2011, she entered a medical school and graduated from it with excellent results. Got married. By July 2021, she gave birth to three children, married for the second time. Additionally, he is raising a child of a new husband. Graduated by correspondence from the Novosibirsk University of Railway Engineers. Mentally completely healthy. Follow-up for 11 years. [5.8.]. Monitoring continues.

2. Patient "Carol". She fell ill in 2010 at the age of 14. She was hospitalized in psychiatric hospitals twice in 2011 and 2012. She was treated with haloperidol, clopixol, antidepressants. For ten months she was treated exclusively with cytokines. It is described in great detail in the journal [6.10]. By July 2021, the follow-up is 11 years. She got married, graduated from the Institute of Railway Engineers, and got a prestigious job in Moscow. Mentally completely healthy.

3. Patient "I" is 29 years old. He has been suffering from schizophrenia since 2008. Two hospitalizations. He was treated with neuroleptics: riset, sonapax, haloperidol. The second group of disability. We underwent a course of cytokines in the winter of 2015. Follow-up for 6 years. Mentally healthy. Married. Raises two children [9.].

The volume of the article does not allow for other examples. In general, we can summarize the following: the patients described above were treated only with cytokines, without the use of antipsychotics (Fig. 1, blue circle in the center). Against the background of treatment with cytokines, the use of antipsychotics is quite possible and often justified. Cytokines and antipsychotics have different points of application and, apparently, do not interfere with each other too much. We use antipsychotics very rarely and only in the initial period of treatment, since almost all patients come for maintenance therapy with two and sometimes three antipsychotics. Successful treatment results are still around 70%.

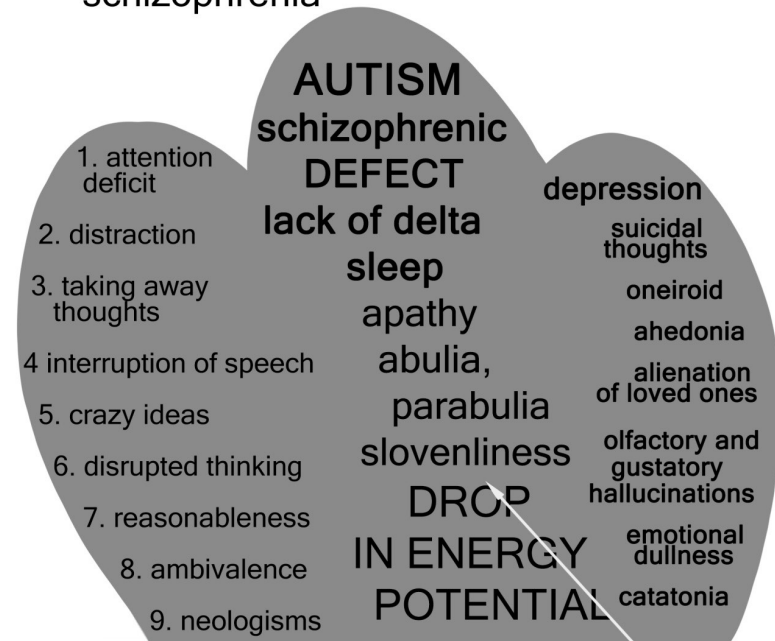
### Three vicious circles of the pathogenesis of schizophrenia



The blue circle in the center represents the astroglial networks. The genetic vulnerability of astrocytes in response to a change in the cytokine balance (green circle below) - reacts with a progressive deceleration of the general CSF dynamics in the glymphatic system of the brain. In the clinic, this looks like a reduction in the time and depth of delta sleep. The increasing toxicity of the cerebrospinal fluid modifies the astrocytes of the tripartite synapses and launches a second vicious circle symbolizing neural networks (yellow on the right) - this in different directions changes the sensitivity of neuroreceptors to dopamine, serotonin and other mediators. The red circle on the right symbolizes the death of oligodendrocytes and microglia in conditions of increasing autointoxication due to defective astroglial networks (blue circle in the center). All psychopharmacology is capable of acting only on interneuronal synapse (yellow circle on the right). Cytokines act on astrocytes and solve the therapeutic task of completely curing schizophrenia.

Picture 1

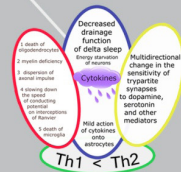
## Clinical symptoms of schizophrenia



The pathophysiological processes presented in three vicious circles in the cast shadows look like clinical symptoms and syndromes of schizophrenia.

Until now, these non-obvious and varied manifestations of schizophrenia have served as the basis for diagnosis.

Picture 2



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## **ORGANOLEPTIC AND PATHOLOGICAL-MORPHOLOGICAL EXAMINATION OF FISH GROWN IN PONDS OF A FISH FARM**

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**Abstract.** The article evaluates the grown fish on the basis of external examination, organoleptic and pathological-morphological studies of fish and internal organs. The results of studies of mirror carp and trout grown in a fish farm are analyzed, conclusions are drawn that the meat of the fish grown according to the conducted examination meets the requirements of GOST and the rules of the fish grown in a pond farm. The raised fish (carp and trout) in the pond farm met the requirements of the Technical Regulations of the Eurasian Economic Union.

**Keywords:** fish breeding, helminths, organoleptic, pathological-morphological method, runway, consistency.

**Introduction.** Humanity receives about 20% of protein food of animal origin from aquatic organisms, mainly from fish, which contains about the same amount of protein substances as beef and pork, but they are much better absorbed by the human body. It is no coincidence that this is why fish and products from it occupy an essential place in the diet of people, and are considered dietary food. Over the past decade, the production of live fish has significantly increased in our country.

The ichthyofauna of the Russian Federation numbers 269 freshwater semi-anadromous and anadromous species, and at least 400 species are found in coastal sea waters. In total, this represents about 2% of the



world's diversity of the fish class. Most of the fish products (about 100 million tons), mankind receives from the World Ocean. In recent decades, aquaculture has played an increasing role in supplying the population with fish products. The annual increase in fish production from aquaculture is 1 million tons. In 2018, the volume of aquaculture production amounted to 111 946 623 tons [3].

In modern conditions, the founders of pond fish farming (A.N. Eleonsky, F.G. Martyshev, F.M. Sukhoverkhov and many others) rank fish farming as one of the areas of beef farming, since it is based on rational animal husbandry principles, and provides a system of targeted measures maximum receipt of fish from the water area of reservoirs in the desired assortment of the best quality. This involvement in agriculture has arisen since the time when people moved from hunting to fish farming in ponds and other reservoirs for agricultural and other purposes [7].

**Purpose of the study.** Evaluate the quality of fish grown in ponds of a fish farm.

Tasks:

- a) to conduct an organoleptic examination of fish grown in a pond farm;
- b) conduct pathological and morphological studies of the meat of the grown carp
- c) assessment of the compliance of the farmed fish with sanitary and epidemiological rules and regulations.

**Material and research methods.** The veterinary and sanitary examination of fish was carried out in accordance with the Rules for the veterinary and sanitary examination of freshwater fish and crayfish. M.: Agropromizdat, 1989, and the reference book "Veterinary and sanitary examination of freshwater fish". M.: Agropromizdat, 1989. [1,6].

Physicochemical studies of fish were carried out in accordance with GOST 7631-2008 - Fish, non-fish objects and products from ...docs/entd/ru document 1200066618 Internet source [2];

Evaluation of fish and fish products izron>aricles...nauk.... usloviyakh...i...06-04-01... Internet source [5].

Organoleptic and bacterioscopic method for assessing the quality of live fish during veterinary and sanitary examination. Subbotina Yu.M. Educational workshop for bachelors in the discipline "Sanitation and environmental safety": teaching aid. – M.: Publishing house MSUFP, 2021. – 106 P. [8].

**Research results.**

Two and three-year-old specimens of carp and crucian carp, as well as three-year-old trout raised in the ponds of the "Biserovskiy Rybokombinat" were examined.



A study of the organoleptic properties of carp has been carried out. The scales of the fish adhere tightly to the skin, the fins are intact and not deformed, the abdomens are within normal limits, the eyes are somewhat sunken. The color of the skin, scales and meat on the cut is normal, the gills are red. The consistency of the muscle tissue is dense. The smell matches the smell of raw pond fish. There are bruises under the scales of two-year-old carps (fig. 1).

The abdomen has a characteristic shape for this fish species, not swollen. The anal opening is tightly closed, not protruding, without the flow of mucus. In the section, the muscle tissue is elastic, tightly attached to the bones; in the cross section, the dorsal muscles have a characteristic color for the carp species of fish. The internal organs are well expressed, of natural color and structure, without the presence of tumors, the intestines are not swollen, without a putrid odor.

The study carp was boiled and 100 g of fish without internal organs, cleaned of scales, was taken, filled with a double volume of pure water and boiled for 5 minutes.



**Figure 1 – The appearance of the studied carp**

The broth of benign live fish is transparent, on the surface there are large glitters of fat and brown flakes of coagulated blood, the smell is specific, the meat is well divided into muscle bundles. The taste of broth and

fish is pleasant, without bitterness and mustiness [8].

Trout was also examined organoleptically. Fish without mechanical damage, signs of disease and external parasites were not found. The gills are red, the eyes are transparent without damage, the smell is typical of live fish. In fresh fish, stiffness of the muscles is well pronounced (when pressed with a finger, the fossa in the region of the dorsal muscles quickly disappears). The scales, slightly pale with a pearlescent tint, fit tightly to the body; the mucus is transparent, without blood impurities and foreign smell. There are no tumors on the body. The skin is elastic, without extra-neous spots, has a natural color, fits snugly to the carcass (fig. 2).

Solid fins of natural color. The operculums tightly cover the branchial cavity. The eyes are slightly sunken, the cornea is transparent, there are occasional hemorrhages in the anterior chamber of the eyes. The abdomen is characteristic of a trout, not swollen. The anal opening is tightly closed, not protruding, without the flow of mucus. On the cut, the muscle tissue is elastic, fits tightly to the bones; on the cross section, the dorsal muscles have a characteristic color for trout. The internal organs are well expressed, of natural color and structure, without the presence of tumors, the intestines are not swollen, without a putrid odor. Trout broth is transparent, has not large glitters of fat on the surface, a specific fishy smell; meat is well cut into muscle bundles.

The studied fish comply with the sanitary and epidemiological rules and regulations [4,6].



**Figure 3 - Appearance of the studied trout**

Pathological and morphological studies of internal organs were carried out, the studies were carried out in the following order [8].

**Liver.** Determined the shape, size, color, consistency of the organ (dense, soft, flabby), hyperemia or anemia, the presence of hemorrhages. No helminths were found.

**Gall bladder.** Determined the degree of its filling, the nature of bile (color, transparency, consistency), the state of the wall of the swim bladder and its inner shell, noted that the walls of the bladder are hyperemic, the vessels are dilated.

**Spleen.** Determined the grandeur, shape, consistency (dense, soft, flabby) color, the presence of overlays, scars. After external examination, the spleen was cut and the state of the pulp, its color, the presence of necrotic areas, hemorrhages, purulent and cheesy foci were not found.

**Gastrointestinal tract.** The intestine was carefully removed together with the adjacent internal organs, then freed from the liver and adipose tissue, straightened in a separate cuvette and opened with scissors. At the same time, attention was paid to the width of the lumen, the amount and nature of the contents of various departments, the presence of food mass, mucus, its color, smell, and the presence of parasites.

After that, the intestines were washed in water and the mucous membrane was thoroughly examined: color, the presence of swelling, edema, thinning, hemorrhages, ulcers, scars, perforations. Was made from the intestinal mucosa for microscopic examination for the presence of small parasitic forms. No helminths were found.

**Sex glands.** The shape, size, color, consistency, stage of maturity, hemorrhages, and the presence of parasites were determined.

**Swimming bladder.** Attention was drawn to its shape, size, the ratio of the volumes of the anterior and posterior chambers, deformation, the condition of the membranes, their thickness, opaque walls, the presence of hemorrhages and overlaps, as well as pigmentation. The nature of the contents was determined: the amount, color, transparency, consistency, odor, as well as the presence of parasites visible to the naked eye.

In our case, the carp showed inflammation of the posterior chamber of the swim bladder (fig. 3, 4, 5).



**Figure 3 - External view of the internal organs and inflamed swim bladder of carp**



**Figure 4 - Pathological and morphological studies of mirror carp**



**Figure 5 - Swimming bladder mouth guard with severe inflammation**

The scaly skin was evaluated. The body surface of carp and trout is clean, natural coloration, covered with a thin layer of mucus. scales are shiny, with a mother-of-pearl tint, tight to the body, transparent mucus. The skin is firm, the fins are solid. The toads are bright red, the gill covers tightly close the gill cavity. The eyes are convex, the cornea is transparent, dirty gray in color. The abdomen is not swollen, the anus is not protruding. On the cut, the muscle tissue is elastic and tight.

The consistency of the fish was determined by pressing lightly with the fingers. To determine the consistency of the fish, an oblique cut was made with a scalpel in the most stable part of the fish.

The consistency is dense, if, when pressing on the edges of the cut, the meat is very springy, and the traces of deformation quickly disappear.

The consistency is weakened, if the fish meat springs weakly, the traces of deformation disappear slowly but completely.

The consistency is soft, if the meat does not spring, the resulting grooves do not completely disappear.

The consistency is smeared if, when rubbed between the fingers, the muscle tissue is easily smeared.

The muscular part is elastic, fits tightly to the bones, in the section the dorsal muscles of a characteristic color. The smell is fishy. The consistency is dense, when pressed on the edges of the cut, the meat is very springy, traces of deformation quickly disappear.



**Conclusions.** The nutritional value, in general, of the meat of the farmed fish corresponded to the requirements for the fish grown in the pond farm. Microbiological indicators met the requirements of SanPiN. In the pond economy, the technology and regimes of fish rearing are fully observed, including the creation of optimal temperature and gas regimes, and zoohygienic conditions for rearing fish.

The fish grown (carp and trout) in the pond farm met the requirements of the Technical Regulations of the Eurasian Economic Union "On the safety of fish and fish products" 040/2016", which confirms the safety of products for the consumer [4].

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**SYNTHESIS AND CHARACTERIZATION OF NANOSCALE  
MAGNESIUM OXIDE  
BY USING CO-PRECIPITATION METHOD**

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**Abstract.** This research paper concerns the study on the nanoscale magnesium oxide production from magnesium nitrate hexahydrate ( $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ ) by using co-precipitation method. Magnesium nitrate hexahydrate ( $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ ) and sodium hydroxide ( $\text{NaOH}$ ) were selected as synthesis materials. There are four main processes used to produce nanoscale magnesium oxide. They are preparation of magnesium nitrate and sodium hydroxide solution, co-precipitation of magnesium hydroxide, filtration of magnesium hydroxide, washing and calcination of nanoscale magnesium oxide. The produced nanoscale  $\text{MgO}$  was characterized by using Scanning Electron Microscope (SEM) method and X-ray diffraction (XRD).

**Keywords:** Magnesium Oxide; Co-precipitation method; Nanoparticles;

## **1. INTRODUCTION**

Human dreams and imagination often give rise to new science and technology. Nanotechnology, a 21<sup>st</sup>-century frontier, was born out of such dreams. Nanotechnology is defined as the understanding and control of matter at dimensions between 1 and 100 nm where unique phenomena enable novel applications [1]. Although human exposure to nanoparticles

has occurred throughout human history, it dramatically increased during the industrial revolution. The study of nanoparticles is not new. The concept of a “nanometer” was first proposed by Richard Zsigmondy, the 1925 Nobel Prize Laureate in chemistry. He coined the term nanometer explicitly for characterizing particle size and he was the first to measure the size of particles such as gold colloids using a microscope. Modern nanotechnology was the brain child of Richard Feynman, the 1965 Nobel Prize Laureate in physics. During the 1958 American Physical Society meeting at Caltech, he presented a lecture titled, “There’s Plenty of Room at the Bottom”, in which he introduced the concept of manipulating matter at the atomic level. Almost 15 years after Feynman’s lecture, a Japanese scientist, Norio Taniguchi, was the first to use “nanotechnology” to describe semiconductor processes that occurred on the order of a nanometer [2].

In a timeframe of approximately half a century, nanotechnology has become the foundation for remarkable industrial applications and exponential growth. For example, in the pharmaceutical communities of practice, nanotechnology has had a profound impact on medical devices such as diagnostic biosensors, drug delivery systems, and imaging probes [3]. In the food and cosmetics industries, use of nanomaterials has increased dramatically for improvements in production, packaging, shelf life, and bio-availability [4]. Some of the potential benefits of medical nanomaterials include improved drug delivery, antibacterial coatings of medical devices and detection of circulating cancer cells.

### **2. METRIALS**

In this research work, magnesium nitrate hexahydrate was used as precursor material and sodium hydroxide was used as precipitant. All the reagents used in this experiment, magnesium nitrate hexahydrate, sodium hydroxide, ethanol were analytical grade and were used without any others purification.

The nanoscale magnesium oxide was produced from magnesium nitrate hexahydrate by using co-precipitation method. Magnesium nitrate hexahydrate ( $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ ) and sodium hydroxide ( $\text{NaOH}$ ) were purchased from local market.

### **2. METHODS**

There are many available methods for synthesis of nanoparticles. Some of them are-

1. Co-precipitation
2. Hydrothermal
3. Inert gas condensation
4. Microwave



5. Sol-gel
6. Biological
7. Microemulsion, etc.,

Among them the co-precipitation method had been selected for my research work. Because of the advantages of co-precipitation method, nanoscale metal oxide can be obtained the high yield, high product purity, low cost, easy control of particle size ,and composition and low temperature. In this section, nanoscale magnesium oxide production was described as follows.

#### **A. Raw Sample**

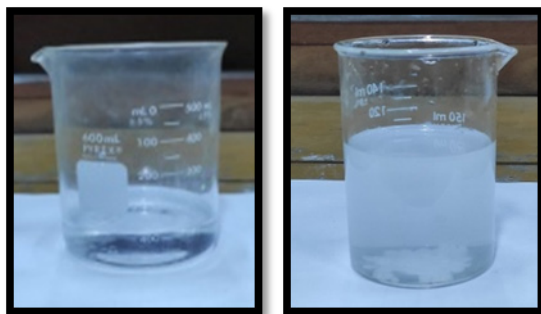
Magnesium nitrate hexahydrate ( $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ ), sodium hydroxide ( $\text{NaOH}$ ), DI water and ethanol were used for my research work. Magnesium nitrate hexahydrate ( $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ ) was used as starting material and sodium hydroxide ( $\text{NaOH}$ ) was used as precipitant. Ethanol and DI water were used for washing. Magnesium nitrate hexahydrate ( $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ ), sodium hydroxide ( $\text{NaOH}$ ) and ethanol were purchased from local market. The prepared raw samples are shown in figure1.



**Fig. 1. ( $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ ) and ( $\text{NaOH}$ )**

#### **B. Magnesium Oxide Nanoparticles Preparation**

Magnesium nitrate hexahydrate solution (0.6M) and sodium hydroxide (2M) were separately prepared with deionized water. Instantly, the solution was stirred on stirring by means of magnetic stirrer for 2 hours.



**Fig.2. Dissolution of  $(\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O})$  and  $(\text{NaOH})$  in DI water**

In this time, sodium hydroxide solution was slowly added into the above stirred magnesium nitrate solution drop by drop within 2 hours. And then, precipitated magnesium hydroxide was settled at the bottom of the beaker.



**Fig.3. Precipitation of Magnesium Hydroxide**

The precipitated magnesium hydroxide was filtered with filter paper. The filtrated precipitates were washed firstly with DI water and subsequently washed with ethanol 3 times.



**Fig.4. Washing and Filtration of Magnesium Hydroxide Precipitate**

After washing step, the washed magnesium hydroxide was dried at 100°C for 2 hours at muffle furnace and calcined at 500°C for 4 hours at carbolite to get sample of MgO powder.



**Fig.5. Drying and Calcination Magnesium Hydroxide Precipitate**

Eventually, the Magnesium oxide nanoparticles were obtained. The obtained MgO is a white powder.



**Fig.6. Final Product Magnesium Oxide Nanoparticles Powder**

### 3. Results and Discussion

#### 3.1 Structural Analysis

X-ray powder diffraction pattern of MgO nanoparticle was illustrated in Fig.7. The results show that, the purity of the MgO nanoparticle. The sharp diffraction peaks showed in the figure indicate good crystallinity of MgO and no characteristic peaks of any other phase of MgO or any impurity were observed.

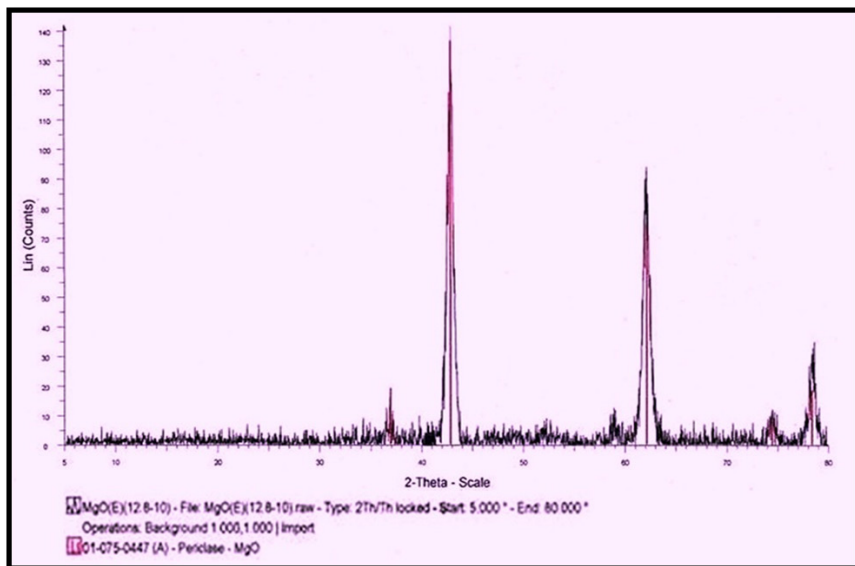


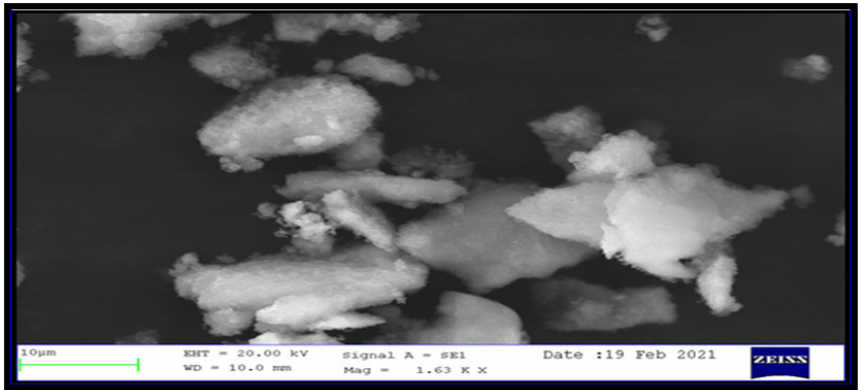
Fig.7. XRD pattern of the product sample.

The size of the particle was determined by means of the X-ray line broadening method using the Scherrer equation. From XRD result, the crystallite size can be described by using the Scherrer's formula,  $D = 0.9 \lambda / \beta \cos \theta$  Where, D = Crystallite size,  $\lambda$  = Wavelength (0.1541 nm),  $\beta$  = Full maximum half width and  $\theta$  = Diffraction angle.

By comparing XRD pattern of the produced nanoscale magnesium oxide in Figure, the diffraction peaks of the produced nanoscale MgO are analogous to JCPDS card number 45-0946. The matched  $2\theta$  angles are 36.96, 42.92, 62.25, 74.50 and 78.45° respectively and there is no peaks were detected in the pattern. It shows that the formation of the MgO nanoparticles was cubic structure and the average crystallite size of ~14 nm was obtained.

### 3.2 Surface Morphological Analysis

The surface morphology of the produced metal oxide nanoparticles were characterized by SEM. The SEM image of synthesized nanoscale magnesium oxide was illustrated in figure 8. The nanoscale magnesium oxide powder can be perceptibly observed from the image. The SEM result shows that the structure of MgO crystallites is spherical shape. Moreover, MgO nanoparticles are spongy and agglomerated.



**Fig.8. SEM images of MgO Nanoparticles**

### 4. CONCLUSION

Magnesium oxide nanoparticles were successfully synthesized by using  $(\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O})$  as precursors. In this research work, sodium hydroxide ( $\text{NaOH}$ ) was used as precipitant and ethanol and deionized water were used for washing. In the nanoscale metal oxide production, 1:3 molar ratios of magnesium nitrate and sodium hydroxide for MgO is appropriate to produce the MgO nanoparticles. The optimum calcinations temperature for the MgO nanoparticles was  $500^\circ\text{C}$ . The produced nanoscale MgO was determined by using X-ray Diffractometer (XRD) and Scanning Electron Microscope (SEM). The SEM result shows that the structure of MgO crystallites is spherical shape. Furthermore, MgO nanoparticles are spongy and agglomerated. According to the XRD result, the average crystallite structure of nanoscale MgO is  $\sim 14$  nm.

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## DYNAMICS OF CHANGES IN SURFACE AIR TEMPERATURE IN THE NORTH CAUCASUS

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**Annotation.** Climate warming studies are attracting a lot of attention from researchers around the world. In recent years, warming has been noted both throughout Russia and in some of its regions. This article analyzes temperature changes in the North Caucasus region. The research was carried out on the basis of data from 16 weather stations in the region. Changes are considered both at individual w/stations and in the region as a whole.

It was found that in the region as a whole, since 1976, there has been an increase in the rate of growth of the average annual temperature to  $0.41^{\circ}\text{C}/10$  years. The maximum growth rate is observed in the summer season, while since the mid-90s of the XX century, exceptionally positive anomalies of the average summer temperature have been observed.

The highest growth rate of average annual temperatures is observed in the foothill zone, followed by a plain zone, then a mountain zone. The high-mountain zone is distinguished by the stability of average annual temperatures, where the rate is  $0.09^{\circ}\text{C}/10$  years.

**Keywords:** average annual temperatures, absolute maximum, absolute minimum, rate of change, weather stations, North Caucasian region.

Climate change is a factor that has a significant impact on atmospheric processes, on the natural and climatic characteristics of almost all regions of our planet and is the main cause of many extreme weather events. The problems of modern climate changes, especially the rapid ones in recent decades, are of increasing concern to the world community. They are constantly discussed in scientific publications, at international forums and in the media [1-3].

Climate change studies, as well as the determination of possible consequences, have long been scientific problems that attract a lot of attention of researchers around the world. Along with the general trend of increasing average temperatures, there is an increase in the amplitude of short-term temperature fluctuations and the recurrence of anomalous phenomena associated with severe frosts and high positive temperatures, storm winds, snowfalls, heavy rains, etc. [4].

In recent years, warming has been noted both throughout Russia and in some of its regions.

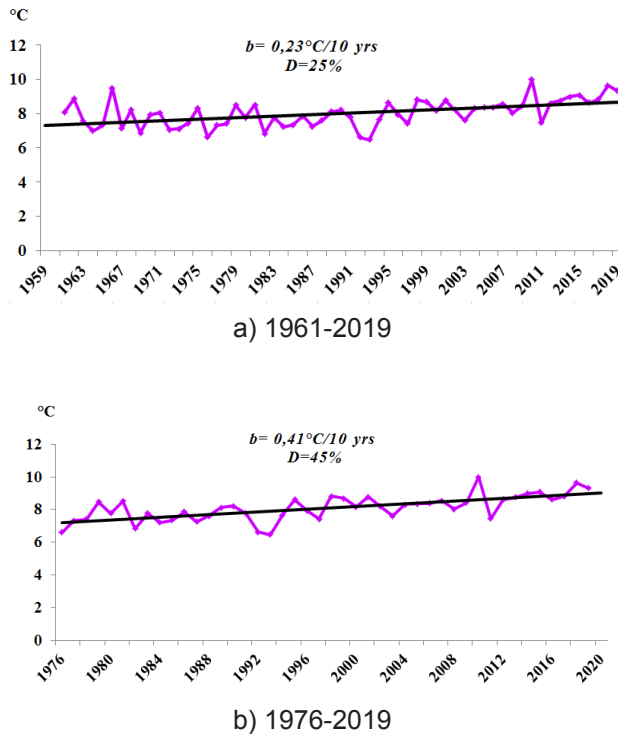
This paper examines the change in the temperature regime on the territory of the North Caucasus region for the period 1961-2019. The North Caucasus is a region rich in diverse natural landscapes and climatic diversity in the south of the Russian Federation.

Based on the data from the series of climatic variables of the 16 weather stations (w/stations) studied, averaged series of average temperatures were obtained for the territory of the North Caucasus region.

Characteristics of linear trends for the full study period from 1961 to 2019 and from 1976 to 2019 are presented in terms of the slope  $b$  and characterize the rate of change of the investigated meteorological parameter ( $^{\circ}\text{C}/10$  years). Significance of the trend for the studied period 1961-2019 was determined by the value of the contribution to the explained variance ( $D, \%$ ). In the course of the study, the stability of climatic changes was assessed. An indicator of fractal properties of time series, the so-called Hurst exponent ( $H$ ), was used as its integral characteristic [5,6].

According to our estimates, the warming trend in the territory of the North Caucasian region of Russia corresponds to the general direction of the global temperature change in the second half of the 20th century and the beginning of the XXI century. The growth rate of the average annual air temperature since 1961 was  $0.23^{\circ}\text{C}/10$  years, since 1976 the growth rate of the average annual temperature increased to  $0.41^{\circ}\text{C}/10$  years (Fig. 1 and Table 1). The value of the contribution to the explained variance increased from  $D=13\%$  (1961-2019) to  $D=45\%$  (1976-2019). The Hurst exponent  $H=0.91$ , obtained for the series of average annual temperatures in the period 1961-2019, demonstrates the high trend stability of the series.





**Figure 1 – The rate of growth of the average annual air temperature in the North Caucasus**

Table 1 shows the seasonal characteristics of the average air temperature in the North Caucasus region.

**Table 1. Characteristics of the dynamics of the average air temperature in the North Caucasus**

Temperature, °C	Year	Winter	Spring	Summer	Autumn
Average temperature 1961-2019	8.0	-2.1	7.3	18.1	8.7
Climatic norm 1961-1990	7.7	-2.3	7.1	17.5	8.5
Standard deviation 1961-2019	0.8	1.5	1.0	1.0	1.0

Anomalies 1961-2019	0.3	0.3	0.3	<b>0.6</b>	0.2
Slope of the trend 1961-2019, <i>b</i> , °C/10 yrs. ( <i>D</i> %)	0.23 (25%)	0.2 (4.7%)	0.2 (12%)	<b>0.38 (23%)</b>	0.15 (6.2%)
Slope of the trend 1976-2019, <i>b</i> , °C/10 yrs. ( <i>D</i> %)	0.41 (45%)	0.36 (11.7%)	0.35 (21%)	<b>0.58 (53%)</b>	0.34 (16%)

On the time interval 1961-2019 there is an increase in the average air temperature in all seasons and the year as a whole. Table 1 show that the average winter temperature has increased since 1961 by 0.2°C/10 years, and since 1976 its growth rate has reached 0.36°C/10 years. The growth rate of the average spring air temperature increased from 0.2°C/10 years in the period 1961-2019, to 0.35°/10 years in the period 1976-2019. The rate of increase in air temperature in the summer season at these time intervals was 0.38°C/10 years and 0.58°C/10 years, respectively. The rate of increase in air temperature in the autumn season also increased significantly: from 0.15°C/10 years to 0.34°C/10 years for the corresponding periods.

Thus, the maximum value of the averaged anomalies in the considered time interval is observed at summer temperatures (0.58°C/10 years). Since the mid-90s of the 20th century, extremely positive summer temperature anomalies have been observed (Fig. 2).

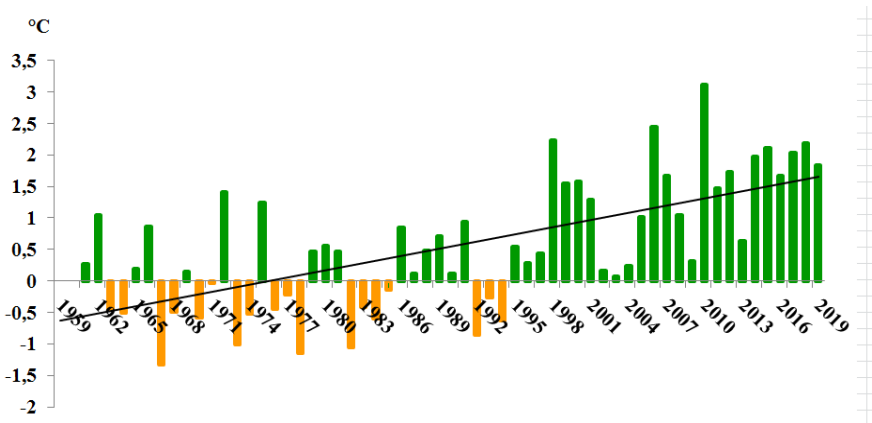


Figure 2 – Average-summer anomalies in the North Caucasus for the 1961-2019

It should be noted that the North Caucasus region is rich in various natural landscapes and climatic diversity. According to climatic conditions, the region is subdivided into plain (<500 m above sea level), foothill (from 500 to 1000 m above sea level), mountain (> 1000 m above sea level) and high mountain (> 2000 m above sea level) climatic zones.

The analysis of the temperature regime of different climatic zones of the region showed approximately the same (synchronous) changes in average annual temperatures. Apparently, this can be explained by the influence of one dominant factor, namely, the same large-scale atmospheric circulations.

The magnitude of the range of air temperature values obtained at meteorological stations of different climatic zones and the rate of their change are determined by the regional features of the air temperature regime. Table 2 shows that the average annual temperature is maximum in the plain zone,  $t_{av}=11.8^{\circ}\text{C}$  and minimum in the high-mountain zone (Terskol),  $t_{av}=2.6^{\circ}\text{C}$ .

**Table 2. Average climatic parameters of the region 1961-2019**

Weather stations	Average annual temperature, °C	Absolute maximum temperature, °C	Absolute minimum temperature, °C
<b><i>Plain stations (&lt;500 m a. s. l.)</i></b>			
Izobil'nyi (Stavropol region)	11.0	36.2	-18.7
Mozdok (Republic of North Ossetia - Alania)	10.8	37.7	-20.9
Prokhladnaya (Kabardino-Balkaria)	10.6	37.0	-19.4
Derbent (Dagestan)	13.2	33.8	-8.4
Kizlyar (Dagestan)	12.1	36.4	-18.5
Makhachkala (Dagestan)	12.4	35.0	-14.3
Izberg (Dagestan)	12.5	32.6	-10.9
<b><i>Foothill stations (500-1000 m a. s. l.)</i></b>			
Stavropol (Stavropol region)	9.6	35.0	-19.5
Cherkessk (Karachay-Cherkessia)	9.4	34.1	-20.5
Kislovodsk (Stavropol region)	8.3	32.0	-18.4

Nalchik (Kabardino-Balkaria)	9.8	34.1	-18.9
Vladikavkaz (Republic of North Ossetia - Alania)	9.1	33.5	-19.0
Buinaksk (Dagestan)	10.5	35.9	-16.5
<b>Mountain stations (1000-2000 m a. s. l.)</b>			
Teberda (Karachay-Cherkessia)	6.9	34.7	-19.4
Akhty (Dagestan)	9.6	32.9	-15.9
<b>Alpine station (&gt;2000 m a. s. l.)</b>			
Terskol (Kabardino-Balkaria)	2.6	23.9 (2006-2019)	-16.8 (2006-2019)

In the plain zone, the highest value of average annual temperatures was observed at w/station Derbent (Caspian) 13.2°C, and the minimum value of average annual temperatures at w/station Prokhladnaya was 10.6°C. The largest scatter of the absolute maximums and minimums of annual temperatures was noted at weather station Mozdok with values of 37.7°C and -20.9°C, respectively.

In the foothill zone, the highest value of the average temperature and absolute maximums for the entire study period from 1961 to 2019 took place at weather station Buinaksk 10.5°C and 35.9°C, respectively. The smallest values of the absolute minima for the period under study were observed at w/station Cherkessk -20.5°C.

In the mountainous zone, the maximum value of the average temperature was noted at w/station Akhty 9.6°C. The highest values from the absolute maximums and minimums at the Teberda w/station with values of 35.9°C and -19.4°C, respectively.

The alpine zone is represented only by the 1st meteorological station Terskol, where the average annual temperature is 2.6°C. Data on absolute maximums and minimums have been available only since 2006. During this period, the average value of the absolute maximum and minimum was 23.9°C and -16.8°C, respectively.

The average annual air temperature according to the data of the mountain station Akhty (1054 m above sea level,  $t_{av}=9.6^{\circ}\text{C}$ ) and the stations of the foothill zone are approximately the same. Apparently, this can be explained by the fact that the mountainous climate of Akhta is mitigated by the proximity of the Caspian Sea.

Further, Table 3 shows the characteristics of the temperature regime

of the surface air and the rate of their change in the climatic zones of the North Caucasus region.

**Table 3. Characteristics of the temperature regime of surface air in the climatic zones of the North Caucasus**

<b>Average annual temperature, 1961-2019</b>	<b>Plain zone</b>	<b>Foothill zone</b>	<b>Mountain zone</b>	<b>High-mountain zone</b>
Average temperature, °C	11.8	9.5	8.3	2.6
Standard deviation, °C	0.9	<b>1.0</b>	0.8	0.7
Upper limit*	13.6	<b>11.4</b>	9.8	4.0
Bottom line*	10.0	<b>7.4</b>	6.6	1.2
Slope of the trend $b$ , °C/10 yrs. ( $D$ ,%)	<b>0.27</b> (27%)	<b>0.32</b> (33%)	0.25 (27%)	0.09 (4.8%)

\* Upper (lower) limit of average temperature ( $t_{av} \pm 2$  sigma) at 95% confidence interval

In all climatic zones of the region, with the exception of the high mountain (Terskol), for the period 1961-2019 an increase in the average annual air temperature was observed: in the plain zone by 0.27°C/10 years, in the foothill zone by 0.32°C/10 years, in the mountain zone by 0.25°C/10 years, in the high-mountain zone (Terskol) 0.09°C/10 years.

Table 3 shows the upper and lower boundaries of the intervals of the mean annual air temperature; at a 95% significance level, its values are in the range of  $\pm 2\sigma$ . The lower and upper boundaries of the ranges of the confidence intervals of the average annual temperature according to the data of the plain, foothill and mountain weather stations intersect. The average annual temperature in Terskol is significantly lower than the rest (2.6°C, taking into account the interannual variability from 1.2°C to 4.0°C), which is explained by the altitudinal zonality. This station is also distinguished by the stability of changes in the annual temperature (0.09°C/10 years).

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## INVESTIGATION OF THE PROPERTIES OF LENTIL CHEESE AS A NEW FOOD SOURCE IN RUSSIA

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**Abstract.** In this work, research has been carried out to obtain vegetable cheese from sprouted lentil grains. The conditions for enrichment of the protein clot with iodine were established when adding potassium iodide during the germination of lentil grains. Some indicators of the structure formation of the protein clot were determined, laboratory testing of the vegetable cheese technology was carried out. For the prevention and treatment of diseases, a physicochemical and organoleptic assessment of the finished experimental product was given.

**Keywords:** lentils, germination, potassium iodide, lentil cheese, coagulant, endemic diseases

The state policy of Russia is aimed at providing the population with high-quality food products. The main objectives of the strategy include improving nutritional value, preventive methods to prevent diseases, development and circulation of food of appropriate quality on the market. When analyzing the nutritional structure of the population of Russia, it was revealed that food products consumed by humans do not fully correspond to modern trends in the development of nutritional science. The reasons lie in the increased calorie content, deficiencies and imbalances in macro- and microelements in foods. Changes in the lifestyle of most of the population caused a decrease in the need for energy costs and, as a result, in food consumption, but human needs for micronutrients have practically not changed [1].

The activities of domestic and foreign scientists are actively aimed at the development of food products enriched with vitamins, mineral compo-

nents, dietary fiber. Currently, the development of protein products from plant raw materials, especially legumes (soybeans, lentils, peas, chick-peas, etc.), is very popular.

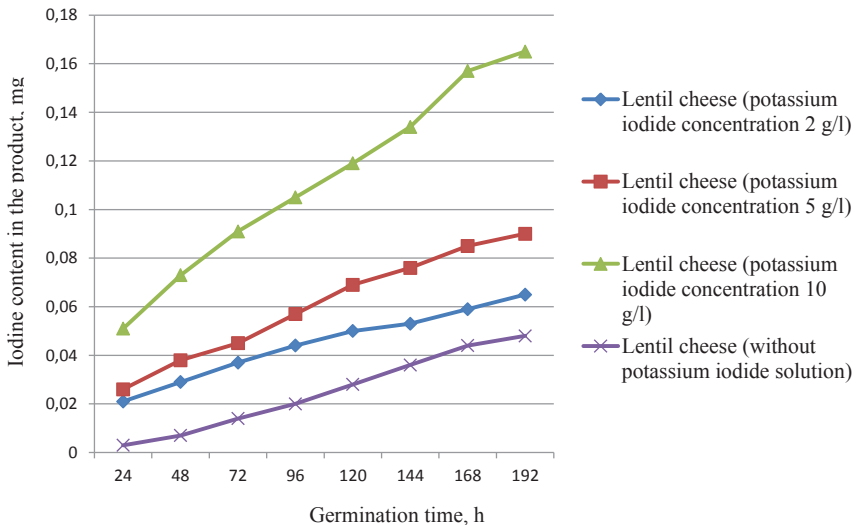
The aim of the work is to assess the possibility of creating a protein product from a domestic vegetable source of raw materials that meets the needs of the population in high-grade proteins, vitamins, fiber, and is also able to replenish the iodine level in the human body to prevent the onset and development of thyroid diseases.

Lentils, known since the time of Tsarist Russia as a healing culture, were selected as a raw material source. Lentil grains were bioactivated by germination in a modified nutrient medium using potassium iodide. To obtain lentil cheese, seeds of sprouted red lentils were used. It is known that the germination process enriches lentil seeds with a large amount of nutritional ingredients, increases antioxidant activity, and also decreases the oligosaccharide fraction while increasing the proportion of vitamins.

The technology for obtaining lentil cheese consists in the following operations. Lentil seeds are germinated in cold conditions of 4-6°C, while irrigating with a nutrient solution with the addition of potassium iodide. In the process of germination of lentil grains, inorganic iodine in the nutrient medium is converted into an organic bioavailable form, which is better absorbed in the body and helps prevent the occurrence of endemic diseases. Then lentil seeds are crushed to a puree state with the addition of flavoring components and spices. Then the prepared mixture is added to the prepared agar-agar, mixed and poured into molds, cooled to 4-6°C and sent to maturation [2, 3].

As you know, the human body constantly needs to obtain the necessary minerals for the normal functioning of vital organs. Iodine is a chemical element that promotes the synthesis of thyroid hormones (triiodothyronine and thyroxine), thereby improving the growth and development of cells, regulating the exchange of vitamins, hormones, maintaining a stable functioning of the nervous and immune systems, etc. To determine the quantitative content of iodine in lentil cheese, a titrometric method was used. In the process of germination in various variations used the concentration of potassium iodide 2 g/l, 5 g/l, 10 g/l (figure 1) [4].

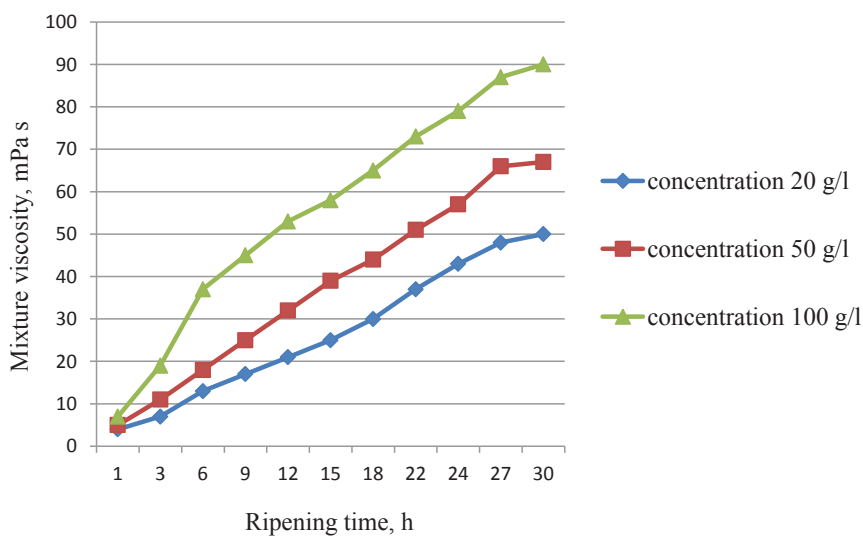




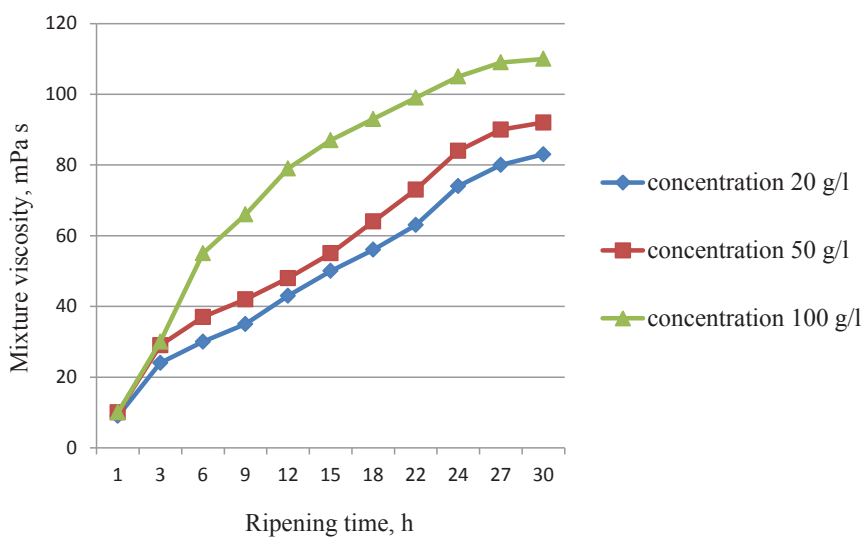
**Figure 1. Diagram of iodine content in vegetable cheese from sprouted lentil seeds**

It was found that the recommended daily intake of iodine for a healthy adult is 0.150 mg. The optimal dose of fortification of germinated lentil seeds is 10 g/l, since the iodine content in the final product is 0.165 mg.

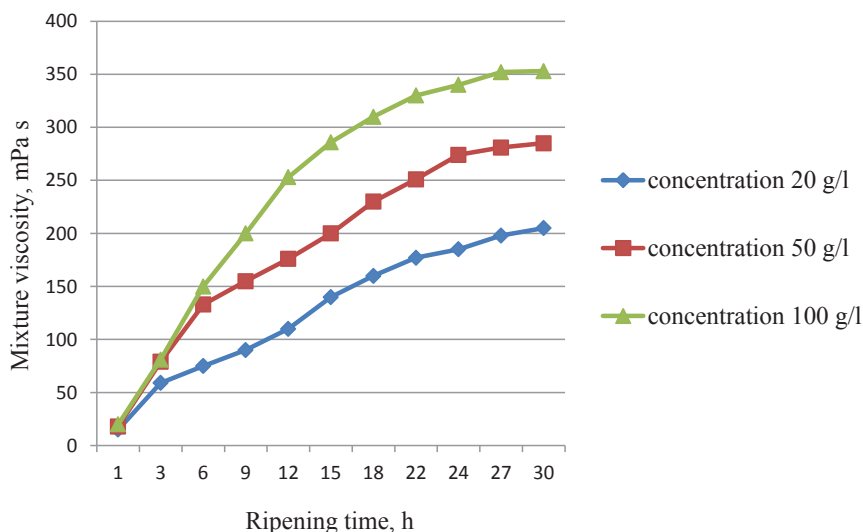
An important indicator in the production of different types of cheese is the formation of a curd. In the production of vegetable cheese from lentils, three types of thickeners were used as a coagulant: collagen (of fish origin), gelatin and agar-agar. Figures 2, 3, 4 show the diagrams of the dynamic viscosity of lentil cheese when using thickener concentrations of 20 g/l, 50 g/l, 100 g/l of the mixture [5].



**Figure 2. Indicators of dynamic viscosity of lentil cheese using collagen (fish origin)**



**Figure 3. Indicators of dynamic viscosity of lentil cheese when using gelatin**



**Figure 4. Indicators of dynamic viscosity of lentil cheese when using agar-agar**

In the course of experimental studies, it was found that collagen and gelatin exhibit weak coagulating properties in the production of lentil cheese. At a concentration of 100 g/l, the dynamic viscosity of the plant product with collagen was 90 mPa·s, and with gelatin, 110 mPa·s. At these rates, the lentil cheese had a poorly bound structure that was unstable upon further storage. There was a slight fishy odor when collagen was added.

The best texture and flavor characteristics were obtained when using agar-agar in the production of lentil cheese. As can be seen in Figure 4, already at 12-15 hours, a dense structure is formed in vegetable cheese, which retains its shape throughout its shelf life. In terms of taste, there is an insignificant lentil taste and smell, which fully satisfies the needs of the consumer.

The resulting product - lentil cheese is characterized by the corresponding indicators. Organoleptically, the product has a fairly dense clot with an acceptable slightly brittle, but not crumbly consistency. Creamy color, evenly distributed over the entire cut area of the finished product, there is a weak taste and smell of lentils.

Using modern research methods, we analyzed the chemical composition of the product being developed, shown in table 1.

**Table 1. Chemical composition of lentil cheese**

Indicator name	Component content in the product, %
Mass fraction of fat	9.5
Mass fraction of protein	6.0
Moisture content	72.0
pH	5.6

From the data in table 1, it can be seen that lentil cheese has the necessary set of appropriate nutritional components to meet the needs of the body.

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**THE PROSPECT OF CREATING NEW ASSORTMENT LINES  
OF FISH PRODUCTS BASED ON THE MULTICULTURAL  
DEVELOPMENT OF POND FISH**

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**Abstract.** In the work, studies of fat, moisture, ash, protein of fish meat and paddlefish liver were carried out. The functional - technological and structural - mechanical properties of fish raw materials have been determined. Organoleptic characteristics, fractional composition of proteins, amino acid composition of fish products, fatty acid composition were studied. Amino acid balance and biological value were calculated using N.N. Lipatov's method .

**Keywords:** paddlefish, fish products, pond fish, biological value, fatty acid composition

The development of the domestic fish market is an object of close attention of the Russian government at the federal and regional levels. At the same time, special attention is paid to the breeding and processing of fish in inland waters through the introduction of new technologies for increasing the volume of raw materials, improving the quality of raw materials, ensuring guaranteed safety and stabilizing consumer demand. Despite a fairly wide variety of fish species in inland water bodies, most of which are occupied by ponds, the problem of developing new fish species based on rationalizing fish farming and introducing new processing technologies remains relevant [1, 2].

Scientists and specialists have developed technologies for breeding inland fish in a mixed culture. There is a positive experience of this method of fish farming in certain regions of Russia, including on the basis of the fishery complex in the Voronezh Oblast of Pavlovsk. On the basis of the

enterprise, silver carp, carp, grass carp and paddlefish are bred. The latter type has not been sufficiently studied, the scientific substantiation of approaches to the formation of assortment lines of products to meet the physiological norms of nutrition and consumer demand at the current level has been poorly developed. It is now known that pond fish serve as a source of not only food and biologically active substances, but also successfully correct and serve as a preventive means of ensuring human health. However, the range of inland fish meat products is extremely limited and consists mainly of fresh and smoked products. Their properties provide a basis for expanding the assortment line, primarily on the basis of minced meat and its raw material combinations, as well as the most food-grade cuttings (liver, milk, caviar, etc.).

Paddlefish — is one of the species of domestic and world ichthyofauna, which is a promising object of aquaculture cultivation in temperate, subtropical and tropical water bodies.

At home, paddlefish is well known as a kind of symbol of the Mississippi - a river that is no less important to the USA than Bora is to Russia. As an object of fishing, paddlefish has been known in the USA since the end of the XIX century, when, after a sharp drop in catches of lake and Atlantic sturgeon, it became the main source of black caviar production. The maximum catch of paddlefish was at the beginning of the XX century, the harvest at that time was more than 1100 tons. Back in the 30s of the XX century, up to 4 tons of paddlefish caviar were sold annually in the USA [3].

The paddlefish range has declined over the past century. The major rivers of the Mississippi Basin are experiencing significant population declines. The increase in fishing has significantly undermined natural reproduction, and the deterioration of the ecological situation and hydraulic construction contributed to the reduction of spawning grounds and the number of paddlefish populations. In the USA, paddlefish is essentially a kind of national symbol, while in Russia it is just one of the interesting acclimatization sites. However, it is possible that due to the peculiarities of its biology, it can become one of the most important objects of the fishery of our inland waters. And first of all, not because it has high gastronomic qualities and has black caviar, but because it is the only representative of sturgeons feeding on zooplankton, which forms the basis of the food base and productivity of many of our inland water bodies [4].

The objects of the study were: live and chilled fish of inland waters - carp (lat. *Cyprinus carpio carpio*), silver carp (lat. *Hypophthalmichthys*) and American paddlefish (lat. *Polyodon spathula*) according to GOST 24896-81 "Live fish. Specifications", GOST 814-96 "Chilled fish. Specifications".

Raw materials were accepted in accordance with the requirements of regulatory documents, the standard for the rules for the reception of fish, as well as instructions № 5 "On the procedure for the reception of live fish, raw fish and chilled fish at processing plants and vessels." The main fish cutting products (fillets, liver), including chilled ones, obtained according to technological instruction № 1 for cutting and washing fish. Raw materials were delivered from JSC "Pavlovskrybkhoz" (Voronezh Oblast, Pavlovsky district, Gavrilsk village). The transportation of live fish was carried out in live fish machines in accordance with the rules for the transportation of perishable goods, subject to the appropriate temperature regimes and oxygen conditions equal to 4 mg O<sub>2</sub> per 1 liter of water.

If necessary, the main and by-products of fish cutting obtained in accordance with the instructions for cutting were stored chilled (at temperatures ranging from -1 to + 5°C for 10 days) or frozen (in specially equipped refrigerating chambers at a temperature of minus 18°C). more than 1 month from the moment of cutting). The choice of these research objects is related to the current situation in the Russian fish products market. The criteria for the selection of raw materials were the data known from the literature on the nutritional and biological value of different fish species and information on the actual volumes of their catch.

When analyzing fish raw materials and products, modern physico-chemical, including instrumental research methods were used, including: the mass fraction of protein - by the Kjeldahl method in the preliminary mineralization of the sample, moisture according to GOST R 52421-2005, fat - refractometric after extraction of fat from a dried sample sample with a low-volatile solvent and in accordance with the recommendations, ash - according to GOST 151138-77. Functional - technological and structural - mechanical properties of fish raw materials: the moisture binding capacity of model food systems (MBC,%) was assessed by the method of Grau and Ham modified by V.P. Volovinskaya and B.I. Kelman according to the ratio of mass fractions of free and bound moisture, water-holding capacity - according to recommendations, stickiness - on a laboratory installation for determining stickiness (according to S. Tyshkevich), fat-holding capacity - according to recommendations, emulsion stability - according to recommendations, emulsifying ability - according to recommendations, Fractional protein composition - by biuret method, amino acid composition of fish products - by ion-exchange chromatography on an AAA-TZZZ analyzer (Czech Republic). Amino acids were separated on an analytical column filled with "Ostion LGFA" cation exchange resin with step elution with three sodium citrate buffers with different pH values (3.50; 4.25; 9.50),

amino acid balance and biological value of the products were evaluated by calculation using N. N. Lipatov using computer modeling methods for the following indicators: amino acid rate, biological value, coefficient of difference between amino acid rate, coefficient of utility. Fatty acid composition - by GLC method according to GOST R 51484-99, organoleptic tests - were carried out according to GOST 28283 - 89, GOST 8756.1-79, GOST 28188 - 89. The digestibility of proteins of the obtained products by digestive enzymes was determined by the Pokrovsky-Ertanov method using the pepsin-trypsin system. The accumulation of hydrolysis products was determined by the color Lowry reaction. [5, 6]

In the experimental studies, the comparative chemical composition of fish from an inland reservoir (a pond with a polyculture) was established. It has been shown that fillets and liver have the highest yield when cutting fish. Interestingly, the song yield is 4 times that of the popular cod among the population. In this regard, along with fish meat, the properties of paddlefish song were studied (table 1). An analysis of the general chemical composition of pond fish meat revealed that the fish are close in terms of the mass fraction of fat - 5.7-8.4% and protein - 17.2 -25.8%.

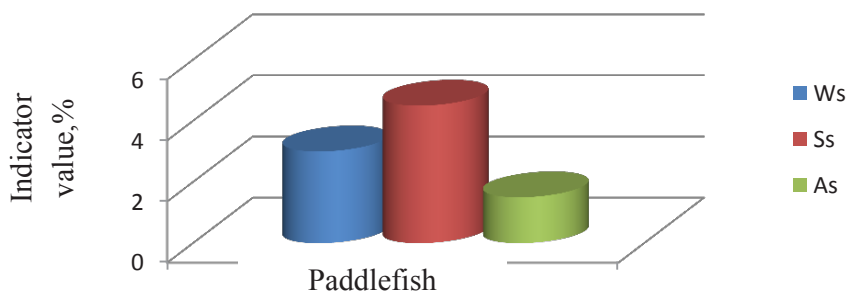
**Table 1 – Comparative chemical composition of fish meat and paddlefish liver**

Sample	Moisture, %	Fat, %	Ash, %	Protein, %	EV, kcal/100g
Paddlefish	63.3±3.33*	8.4±2.48*	2.5±0.50*	25.8±1.02*	178.80
*-P≤0.05 – to the indicator for carp					

Attention is drawn to the high mass fraction of proteins in paddlefish meat (25.8%), the general deficiency and functionality of which in food systems are known worldwide. The fat: protein ratio for the studied fish species differs insignificantly. So, for example, for the muscle tissue of carp this ratio is 0.33:1, for silver carp - 0.37:1, for paddlefish - 0.3:1 (at a rate of 1:1).

The properties of food raw materials and products determine the presence and ratio of various proteins. Proteins are concentrated in muscle, epithelial, connective tissues, as well as in the types of adipose and nervous. In the proteins of the muscle tissue of pond fish, three fractions were isolated: water-soluble (albumin), salt-soluble (globulins) and alkali-soluble (stromal proteins) (figure 1).





**Figure 1 - Comparative fractional composition of fish meat proteins and paddlefish liver**

Thus, the assessment of the fractional composition of paddlefish meat proteins is of interest in connection with the possibility of their further use in industrial production, since the formation of stable systems is impossible without the participation of such protein fractions as salt- and water-soluble. The total content of protein and fat in fish meat does not fully characterize its nutritional value, since along with complete proteins, which include all essential amino acids, without which protein synthesis in the body is impossible, meat contains defective proteins (collagen, elastin). Therefore, the nutritional value of fish meat is determined not only by its high protein content, but also by the composition and ratio of essential amino acids. The content of essential amino acids in meat is possibly about 35% higher than that of silver carp and 11% higher than that of carp. Consequently, meat proteins are more complete, which must be taken into account when designing recipe-component solutions for new fish products. Particular attention should be paid to the methionine content. This amino acid stimulates an intense growth rate. The content of this particular acid is 2.5 times higher in paddlefish meat. Of the nonessential amino acids, the main attention should be paid to the content of glutamic acid, since it acts as a donor of amino groups and actively participates in the biosynthesis of other amino acids. As our research has shown, its content in paddlefish meat is higher by 13.05% in relation to silver carp and carp meat, but lower by 2.3% than in paddlefish liver. Since, in addition, this amino acid is responsible for the taste and aromatic characteristics of fish meat, we note that paddlefish meat contains a large amount (22.13 g/100 g of protein), which explains a somewhat peculiar taste, rather reminiscent of meat [6, 7].

The fatty acid composition of the studied objects is characterized by a high content of saturated and polyunsaturated fatty acids (table 2).

The results of studies of fatty acid composition show that in terms of fat content, fish of inland waters do not belong to products of high biological value, which is compensated by a high protein content. However, this characteristic can be significantly improved by designing recipes for various culinary products based on them. At the same time, as a positive fact, it should be noted the presence in the fillet of carp, silver carp and paddlefish of essential nutritional factors linolenic (0-6), as well as the presence of polyunsaturated fatty acids (PUFA).

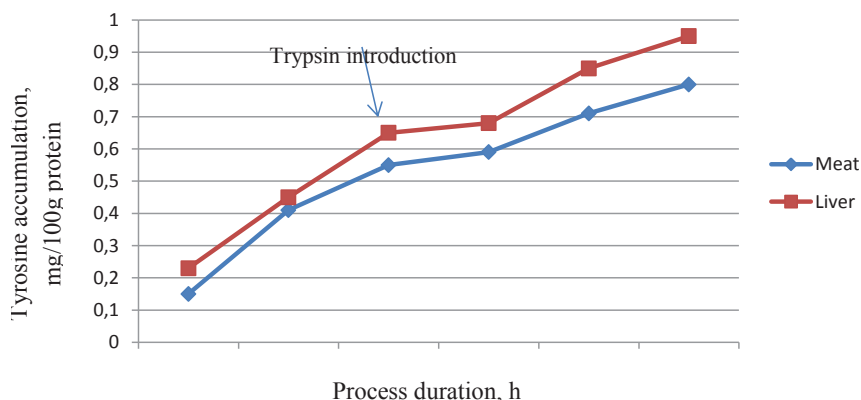
**Table 2 - fatty acid composition of lipids of the test objects (content of fatty acids in%)**

Name of fatty acids	FA Index	Carp fillet	Silver carp fillet	Paddlefish fillet
Myristic	14:0	0.75±0.02	2.41±0.01	0.09±0.01
Palmitic	16:0	16.05±0.04	24.60±0.03	16.6±0.03
Stearic	18:0	7.22±0.02	5.12±0.02	1.37±0.02
Arachinic	20:0	0.13±0.01	0.11±0.01	0.07±0.01
<b>The amount of saturated acids</b>		<b>24.15±0.02</b>	<b>34.24±0.02</b>	<b>18.13±0.02</b>
Palmitoleic	16:1 9- <i>cis</i>	4.76±0.02	8.19±0.02	5.58±0.02
Oleinovaya	18:1 9- <i>cis</i>	46.74±0.05	26.06±0.03	27.67±0.03
Linoleic	18:2	9.68±0.02	11.55±0.02	20.36±0.02
γ - linolenic	18:3 ω-6	0.28±0.01	0.14±0.01	0.77±0.01
<b>The sum of unsaturated acids</b>		<b>61.46±0.02</b>	<b>45.94±0.02</b>	<b>54.38±0.02</b>
<b>The ratio of unsaturated to saturated</b>		<b>2.5</b>	<b>1.4</b>	<b>2.9</b>

The high biological value of pond fish meat is confirmed by calculations (table 3) and the digestibility of proteins in in vitro experiments (figure 2) [8, 9].

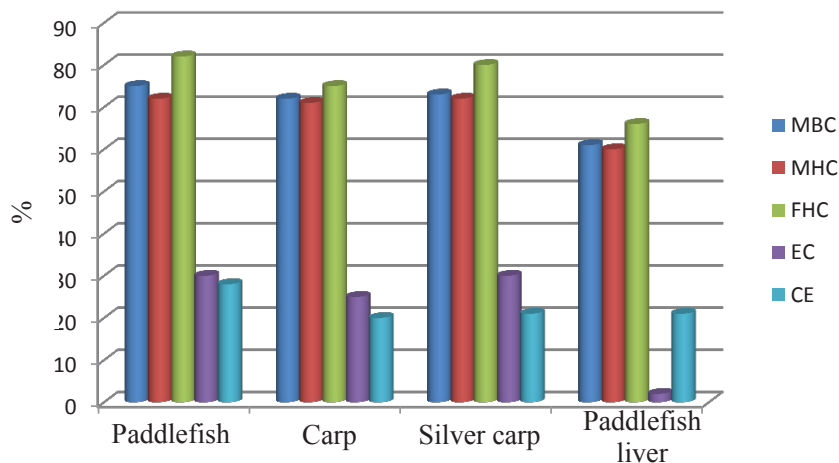
**Table 3 - indicators of the biological value of research objects (in% to dry matter)**

Indicator name	Carp	Silver carp	Paddlefish	Paddlefish liver
SCORmin, %	65.0	52.0	63	54.0
KRAS, %	38.4	36.0	57.1	65.7
BV, %	61.6	64.0	42.9	34.3
U, cu.	0.62	0.61	0.55	0.5
$\sigma_c$ , %	21.1	23.3	29.2	39.6



**Figure 2 - Digestibility of paddlefish meat and liver by the "pepsin-trypsin" digestive enzyme system (invitro)**

The possibility and prospects of using paddlefish as a source of raw materials for the formation of various assortment lines of fish food products are proved by the results of the analysis of the functional and technological properties of raw objects (figure 3), since the levels of moisture-binding, emulsifying and moisture-holding capacity determine the quality indicators and product yield.



**Figure 3 - functional and technological properties of raw materials**

At present, recipes have been developed and technological modes have been substantiated within the framework of the experimental laboratory regulations, and the approbation and tasting of products have been carried out: pate, canned food, semi-finished products, sausages for frying [10].

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## PEROXIDE CELLULOSE FROM HEMP SHIVES

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**Abstract.** Shives of hemp (*Cannabis sativa*) were delignified with the reaction mixture "acetic acid - hydrogen peroxide - sulfuric acid catalyst - water" at a sulfuric acid concentration of 0.45%, a liquid module of 6, and a temperature of 85°C. The influence of the concentration of hydrogen peroxide and the duration of the process on the yield, strength properties and whiteness of technical cellulose was studied. Due to its high strength characteristics, peroxide cellulose from hemp shives can be used in composition with other fibrous semi-finished products in the production of mass types of paper and cardboard products.

**Keywords:** hemp, shives, cellulose, delignification, hydrogen peroxide, peracetic acid, cellulose whiteness, cellulose strength

As a result of breeding work, varieties of industrial hemp (*Cannabis sativa*) were bred, in which the content of tetrahydrocannabinol and other psychoactive substances does not exceed 0.01%, and in 2011 industrial cultivation of this crop was allowed in Russia. It is expected that by 2025 the sown area will reach 20 thousand hectares, and the hemp yield will be 8.5 centners per hectare.

About 65% of the mass of hemp trusts is fibrous shives. One of the promising areas of industrial use of technical hemp is the production of pulp and paper products. From one hectare of cultivated area under hemp, you can get the same amount of cellulose as 4 - 7 hectares of forest. Also noteworthy is the high strength inherent in hemp cellulose paper.

Oxidative delignification of plant raw materials with peroxo compounds is considered as a "green" and resource-saving alternative to existing in-

dustrial methods of cellulose production. To date, the results of a large number of studies in this area have been published, including reviews [1-4]. The essence of the method lies in the processing of plant materials with an aqueous solution of hydrogen peroxide and acetic acid. In this reaction system, acetic acid undergoes catalyzed oxidation to peracetic acid, which, in its middle, oxidizes lignin, converting it into a soluble state. Sulfuric acid is used as catalysts, as well as its combinations with tungstic acid, tungstate and sodium molybdate, titanium dioxide.

We have studied the effect of the conditions of one-stage delignification ("cooking") of hemp shives by the oxidative method on the yield and properties of technical cellulose.

The raw material for the research was shives from hemp brand "Surskaya". The chemical composition is determined by conventional methods [5]: mass fraction of cellulose (Kurschner-Hoffer method) 41.2%; lignin (sulfuric acid method modified by Komarov) 23.4%; extractives (extraction in a Soxhlet apparatus with an azeotropic ethanol-toluene mixture) 4.64%; ash 1.10%.

Shives were delignified with the reaction mixture "acetic acid - hydrogen peroxide - sulfuric acid catalyst - water". Constant delignification conditions: the initial concentration of acetic acid in the cooking solution is 6 g-mol/dm<sup>3</sup> (36%); sulfuric acid concentration 0.046 g-mol/dm<sup>3</sup> (0.45%); liquid module 6.0; isothermal cooking temperature 85°C.

Variable cooking factors:

$X_1$  – initial concentration of hydrogen peroxide in the cooking solution (variation interval 2 ... 4 g-mol/dm<sup>3</sup>);

$X_2$  – cooking duration (interval of variation 135 ... 225 minutes).

The values of these factors varied according to a three-level design of the second-order experiment on the elements of a cube [6] (table 1).

At the end of cooking, a sample of the formed liquor was taken and analyzed for the content of hydrogen peroxide and peracetic acid. The pulp washed after cooking was ground in a CRA apparatus (Yokro mill) to a grinding degree of 34 ... 36°ShR. Paper casts of 75 g/m<sup>2</sup> were made on a Rapid-Keten sheet-molding machine. The experimental results were characterized by the following output parameters:

$Y_1$  – concentration of residual hydrogen peroxide in the liquor, %;

$Y_2$  – concentration of residual peracetic acid in the liquor, %;

$Y_3$  – solid residue yield (technical cellulose), %;

$Y_4$  – grinding time in CRA up to 35°SHR, min;

$Y_5$  – breaking length, m;

$Y_6$  – bursting resistance, kPa;

$Y_7$  – whiteness of castings, %;

$Y_8$  – density of castings, g/cm<sup>3</sup>.

The results of the experiments are shown in table 1.

**Table 1 - Conditions and results of the experiment**

Mode number	Variable factors		Output parameters							
	$X_1$	$X_2$	$Y_1$	$Y_2$	$Y_3$	$Y_4$	$Y_5$	$Y_6$	$Y_7$	$Y_8$
1	3	180	4.01	0.85	53.9	2	8500	198	57	0.651
2	2	135	4.08	0.66	88.2	21	2970	71	45	0.368
3	3	135	5.27	0.76	64.1	6	8120	171	56	0.534
4	4	135	6.51	1.33	54.9	2	9630	251	66	0.705
5	2	180	3.41	0.66	80.6	15	5050	110	48	0.405
6	3	180	4.25	0.89	54.4	2	8550	220	57	0.651
7	4	180	5.78	1.52	48.8	2	10240	272	70	0.783
8	2	225	2.81	0.57	67.7	6	6160	123	51	0.498
9	3	225	3.65	0.76	52.1	2	12000	238	60	0.594
10	4	225	4.42	1.33	47.8	2	12500	362	74	0.717
11	3	180	3.75	0.81	53.4	2	8450	180	53	0.651

Mathematical processing of the results was performed using the Statgraphics Centurion software package. The dependence of each of the output parameters on variable factors was approximated by polynomial second-order regression equations [8]:

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{22}X_2^2 + b_{12}X_1X_2.$$

The terms with an estimate of the confidence probability of the regression coefficients of less than 95% were excluded from the equation with the recalculation of the remaining coefficients. Statistically significant coefficients (threshold significance level 0.05) are shown in table 2.

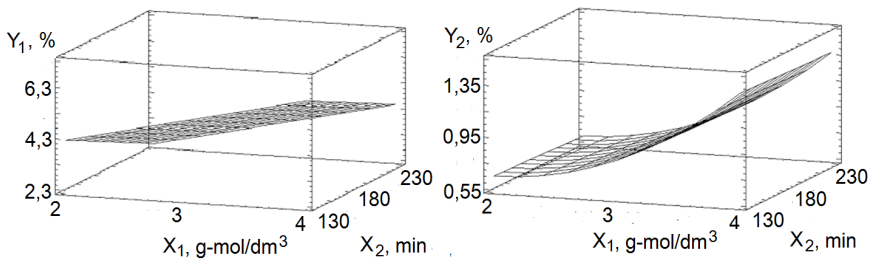
Regression equations were used to graphically represent the results in the form of three-dimensional response surfaces [7].

The dependences of the concentration of residual values of hydrogen peroxide  $Y_1$  and peracetic acid  $Y_2$  in the liquor on variable factors (figure 1) are almost identical and predictable, they are due to the nature of the above-mentioned sequentially occurring oxidative reactions.

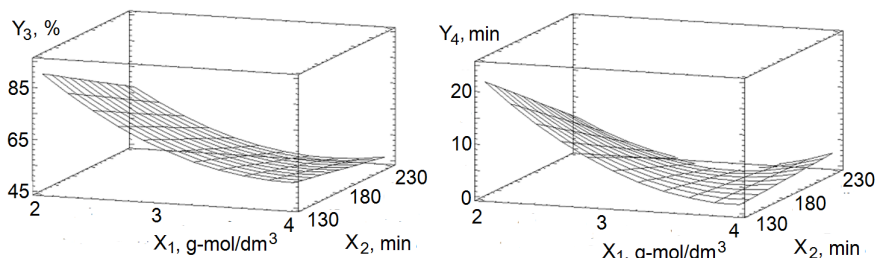


**Table 2 – Coefficients and statistical characteristics of regression equations**

$b_{ij}$ coefficients and statistical characteristics	Output parameters							
	$Y_1$	$Y_2$	$Y_3$	$Y_4$	$Y_5$	$Y_6$	$Y_7$	$Y_8$
$b_0$	4.47	1.51	246.5	125.3	-7953	-244	12.91	0.129
$b_1$	1.07	-0.80	-82.1	-52.2	12551	96.8	11.0	0.156
$b_2$	-0.02	—	-0.37	-0.32	-110	0.852	0.067	—
$b_{11}$	—	—	9.08	5.20	-1586	—	—	—
$b_{22}$	—	0.198	0.074	—	0.409	—	—	—
$b_{12}$	—	—	—	0.083	—	—	—	—
Determination coefficient, %	92.5	95.9	98.2	97.5	97.4	96.0	95.5	84.3
Forecast standard error for $\hat{Y}$	0.332	0.076	2.30	1.32	586.4	18.4	2.14	0.0055

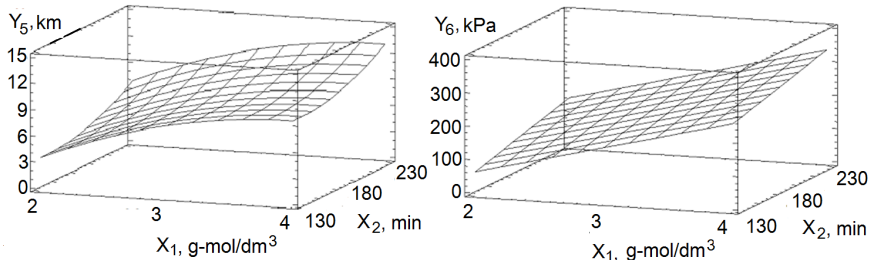

**Figure 1 – Dependence of the concentration of hydrogen peroxide  $Y_1$  and peracetic acid  $Y_2$  in the liquor on the variable cooking factors**

The yield of cellulose naturally decreases with an increase in the initial concentrations of active reagents in the cooking liquor and the duration of cooking ( $Y_3$ , figure 2). At the same time, the grinding time is significantly and almost symbatically reduced with the yield ( $Y_4$ , figure 2) - a consequence of the removal of cellulose incrustations as the shives are delignified.



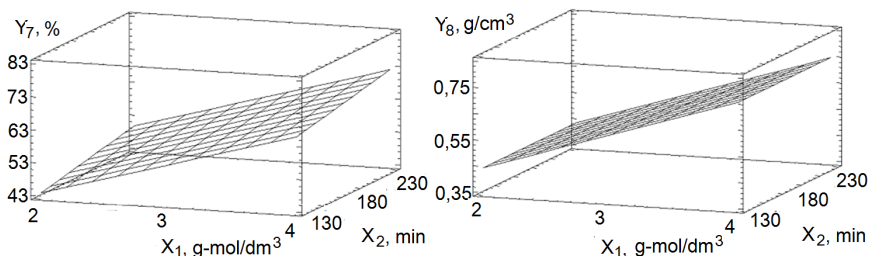
**Figure 2 – Dependence of the yield of cellulose  $Y_3$  and the duration of grinding  $Y_4$  on the variable cooking factors**

As a result of the deepening delignification, the strength characteristics of cellulose naturally increase - resistance to tearing and punching ( $Y_5$  and  $Y_6$ , Figure 3), as well as its whiteness ( $Y_7$ , figure 4).



**Figure 3 – Dependence of the resistance of cellulose to tearing  $Y_5$  and bursting shear  $Y_6$  on variable cooking factors**

A characteristic feature of peroxide cellulose that has not yet received an explanation is the increased density of the paper sheet made from it [3]. In the experiment under discussion, this feature manifested itself most clearly ( $Y_8$ , Table 1 and figure 4): a decrease in the cellulose yield from 88 to 48% was accompanied by an increase in density from 0.37 to 0.72 g/cm<sup>3</sup>.



**Figure 4 – Dependence of Y7 whiteness and Y8 dressing density on variable cooking factors**

Due to its high strength characteristics, hemp shives peroxide cellulose can be used in combination with other fibrous semi-finished products in the production of many mass types of paper and cardboard products.

The work was carried out within the framework of the state assignment of the Ministry of Education and Science of Russia for the implementation of the project "Technology and equipment for the chemical processing of plant raw materials biomass" by the team of the research laboratory "Deep processing of plant raw materials" (topic number FEFE-2020-0016).

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## THE USE OF PROPYLENE OXIDE IN THE COMPOSITION OF ALCOHOL FUELS AS A WAY TO REDUCE ITS COST

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**Abstract.** The main advantages and disadvantages of alcohol fuels in comparison with traditional gasolines are considered. The main problem of alcohol fuel associated with low phase stability between the hydrocarbon and alcohol parts, which requires the use of highly dehydrated alcohol, has been identified. It is proposed to use low-boiling propylene oxide ether instead of the hydrocarbon part, which significantly reduces the requirements for alcohol strength, and hence the cost of all alcohol fuel.

**Keywords:** ethyl alcohol, bioethanol, propylene oxide, starting fraction of alcohol fuel, phase stability.

Today, the use of alcohol fuels, mainly bioethanol, is an excellent alternative to traditional motor gasoline. The main competitive advantages of alcohol bioethanol fuels are that they significantly increase the environmental safety of road transport and, at the same time, are renewable energy resources. In addition, ethyl alcohol has a higher detonation resistance compared to even the most premium gasolines. So the octane number of alcohol is 129.5 units according to the research method, which makes it possible to increase the compression ratio of the engine to 19 units versus 10 for traditional gasoline. Under these conditions, the efficiency of an engine running on alcohol fuel becomes higher than on traditional gasoline.

The environmental friendliness of alcohol fuel is manifested in the reduction of harmful emissions with exhaust gases in terms of CO, CH and NO<sub>x</sub>. In addition, bioethanol can significantly reduce carbon dioxide emissions into the atmosphere. The fact is that in the process of burning ethanol from plant raw materials, exactly the same amount of CO<sub>2</sub> is released into the atmosphere as was previously absorbed by the same plants as a

result of the photosynthesis reaction [1, 2]. Of course, carbon dioxide is non-toxic to humans, but, nevertheless, it belongs to greenhouse gases and contributes to global warming on the planet. Each country that has entered the Kyoto Protocol has certain quotas for greenhouse gas emissions.

The renewability of bioethanol lies in the fact that it can be produced from almost any plant material, in contrast to oil, whose quantity on the planet is limited.

Alcohol fuel also has its drawbacks, the main of which is poor volatility compared to gasoline. This makes it difficult to start a cold engine. So with 100% alcohol, starting a cold engine becomes problematic even at temperatures below +10°C. This problem is solved by adding gasoline or low-boiling hydrocarbon fractions to alcohol, as a result, such a "starting fraction" ensures engine start at low temperatures. The most famous alcoholic composition is E85 alcohol fuel (in Russia it is labeled as Ed75-Ed85 according to GOST R 54290-2010) [3]. This alcohol fuel is subdivided into summer and winter. Summer contains 74% ethanol and 17 - 26% hydrocarbons and aliphatic ethers as a "starting fraction". Winter contains 70% ethanol and 17 - 30% hydrocarbons and simple aliphatic ethers as a "starting fraction".

The "starting fraction" solves the problem of cold starting the engine, but other problems associated with it arise. Traditionally, commercial gasoline was used for the "starting fraction", then they tried to use narrow hydrocarbon fractions, including pentane, isopentane, butane, isobutane and propane [4], to reduce the cost of the composition it was proposed to use low-quality gasolines and gasoline fractions, including by-products of oil refining and even waste. For example, low-octane fraction of direct distillation of oil or gas condensate [5], gasoline fraction of the hydrocracking process [6], coking gasoline [7] and the like. These and other hydrocarbon fractions have one common drawback - it is low phase stability, that is, under operating and storage conditions, there is a possibility of separation of the hydrocarbon part and alcohol. The presence of water in the fuel and a drop in temperature dramatically increase the likelihood of delamination. To avoid it, increased requirements are imposed on the strength of alcohol, as a rule, the moisture content in alcohol should not exceed 2%, that is, the ethanol content must be at least 98%. This degree of dehydration of alcohol requires additional costs in its production. Certain difficulties arise when refueling cars, since moisture is often present in refueling containers.

Even if we use AI-92 commercial gasoline as a "starting fraction", provided that this fraction is 30%, and 70% ethanol with an octane number of 129.5, the octane number of the finished fuel will be about 118 units

according to the research method. Thus, even in the ideal case, there is an underutilization of the antiknock potential of bioethanol, which is to say about the use of non-crankcase gasolines and gasoline fractions as "starting fractions", whose octane number according to the research method rarely exceeds 70 units.

The use of cheap non-candable gasolines and gasoline fractions as "starting fractions" in some cases may be fraught with excessive sulfur and tar content.

The most important of these problems is the problem of the phase stability of bioethanol fuels. According to the authors, if it is not possible to fully stabilize the alcohol-gasoline mixture, then not only the gasoline part, but also the hydrocarbon part in general should be abandoned. Low boiling ethers can be used instead. The author proposes to use propylene oxide as such an ether [8]. Propylene oxide is a simple cyclic ether with a boiling point of 34.2°C and a density of 859 kg/m<sup>3</sup> at 20°C.

Since ethanol is unrestrictedly soluble in water, and propylene oxide (PO) also has good solubility with water, it was assumed that phase stability in the ethanol-PO-water system would be retained even with an extremely high amount of water. The maximum amount of water in known water-fuel emulsions does not exceed, as a rule, 20% [9], therefore, for the study, we used two samples of bioethanol (ethyl alcohol № 1 with a water content of 5% by volume and ethyl alcohol № 2 with a water content 20% vol.). The characteristics of bioethanol alcohols are presented in table 1.

**Table 1. – Bioethanol characteristics**

№	Indicator name	Component name	
		Ethyl alcohol № 1	Ethyl alcohol № 2
1	Ethyl alcohol content,% vol.	95	80
2	Water content,% vol.	5	20
3	Density at 15 °C, kg/m <sup>3</sup>	812.3	856.1

The main physicochemical indicator on which the phase stability of fuels depends is the cloud point; therefore, in order to assess the phase stability, the cloud points of various samples of bioethanol fuels were determined. The results are shown in table 2.

**Table 2. – Bioethanol fuels research results**

№	Component name		Component content% vol.				Test method
			1	2	3	4	
1.	Ethyl alcohol № 1		90	95	-	-	
2.	Ethyl alcohol № 2		-	-	90	95	
3.	Propylene oxide		10	5	10	5	
Total components			100	100	100	100	
№	Indicator name	ASTM D5798/ EN15293	Test results				
1.	Motor octane number	No lower than 85,0 <sup>1)</sup>	100,8	101,0	101,0	102,0	Determined by calculation method
2.	Volume fraction of ethyl alcohol	No lower than 70 <sup>2)</sup>	90	95	90	95	ASTM D 5501
3.	Volume fraction of methyl alcohol,%	No more than 0,5	absence				
4.	Mass fraction of sulfur, mg/kg, no more	No more than 10 <sup>3)</sup>	0	0	0	0	ASTM D 5453
5.	Saturated vapor pressure, kPa	35 – 100 <sup>3)</sup>	41.8	36.8	34	28	ASTM D 4953
6.	Boiling end, °C	No more than 215	85	82	100	100	ASTM D 86
7.	Mass concentration of resins, mg/100 cm <sup>3</sup>						ASTM D 381
	-not washed with solvent	No more than 20	0	2	2	0	
	-washed with solvent	No more than 5	0	0	0	0	
8.	Volume fraction of water in alcohol,% vol.	No more than 2	5	5	20	20	



9.	Volume fraction of water in the composition,% vol.	No more than 1,2	4.50	4.75	18.00	19.00	
10.	Cloud point, °C	Not higher than minus 30°C	Below minus 65°C				GOST 5066
11.	Corrosion effect on a copper strip, units on a scale (3 hours at 50°C)	Class 1	Class 1				ASTM D 130
1) Requirement of GOST 32513 for motor gasoline AI-95 2) Requirement of GOST R 54290-2010 "Fuel ethanol (Ed75-Ed85) for automobile engines with positive ignition. Technical conditions". 3) The requirement of the "Technical Regulations" for motor gasoline of ecological class K5.							

As can be seen from the table, turbidity of all four bioethanol fuel samples did not occur even at a temperature of minus 65°C. According to the requirements of regulatory documents, in particular GOST R 52201 for benzanol, the cloud point should be no higher than minus 30°C. The obtained cloud point results are not only very good, they completely solve the issue of phase stability even for heavily watered ethanol.

An important point is the starting properties of the fuel. For bioethanol fuels, starting properties are determined by the efficiency of the "starting fraction", the lower its boiling point, the easier and faster the engine will start. If commercial gasoline is used as a "starting fraction", then it has a boiling point of 33 to 210°C, while PO has about 34°C. Thus, it is clear that PO has better volatility characteristics than gasoline, which means that less PO is required to achieve the same effect. To prove this, various fuels were distilled. The classic bioethanol fuel E85 (85% ethanol and 15% commercial gasoline) was used as a reference. Since the distillation temperature of 10% is responsible for starting the engine, in order to evaluate the efficiency of PO as a "starting fraction", it is necessary to compare these values for different compositions of bioethanol fuels (see table 3.).

**Table 3. – Results of distillation of fuel samples**

distilled fuel, %	AI-98 gasoline	85% alcohol, 15% gasoline	90% alcohol at 95% vol., 10% propylene oxide	95% alcohol, strength 95% vol., 5% propylene oxide	90% alcohol with a strength of 80% and 10% propylene oxide	95% alcohol at 80% vol., 5% propylene oxide
	distillation temperature, °C					
NR	45	62	61	70	60	70
10	53	75	72	74	72	75
20	67	78	74	76	76	77
30	79	80	76	77	77	78
40	92	86	77	77	78	79
50	106	91	77	77	79	79
60	119	93	77	77	79	80
70	130	97	77	77	80	81
80	146	101	77	77	81	84
90	176	106	77	77	85	85
	195(92%)	128(97%)	85(98%)	82(99%)	100(98%)	100(99%)
losses	6.5%	2.5%	2%	1%	2%	1%
residue	1.5%	0.5%	0%	0%	0%	0%

As can be seen from the table, the distillation temperature of 10% for the classic bioethanol fuel was 75°C, and the same temperature values for the samples containing PO instead of gasoline did not exceed 75°C. This means that 5% PO in bioethanol fuel can easily replace 15% of commercial gasoline in terms of starting characteristics. To obtain a more complete picture of the starting properties of the fuel, along with the fractional composition, it is also necessary to take into account the saturated vapor pressure (see table 2). As can be seen from the table, those samples of bioethanol fuel, where the moisture content of 5% in terms of saturated vapor pressure, fits well into the GOST indicators, which means that PO really has good starting properties and is three times more efficient than commercial gasolines. Those samples of bioethanol fuel, where the amount of moisture of 20% does not quite reach the standard values in terms of satu-

rated vapor pressure, but one must understand that 20% is an outrageous amount of water and not every water-fuel emulsion contains it in such an amount. If the goal of using such a watered fuel is set, it can be easily achieved by slightly increasing the PO concentration in the bioethanol fuel.

The fact that PO in the "starting fraction" requires three times less gasoline or gasoline fractions is a very important competitive advantage. First, the smaller the "starting fraction", the larger the ethanol portion, which means that alcohol will be able to more fully realize its antiknock qualities. Secondly, the octane number of PO should be approximately at the level of isopropanol, according to the research method it is 119.1, which is much higher than AI-92 gasoline, not to mention straight-run fractions, whose octane number is not higher than 70 units. Even if the octane number of PO was 92 units, it would still be more profitable to use it than AI-92, since PO is needed three times less, which means that when mixed with ethanol, the octane number drawdown is less. Thirdly, these are economic indicators, if the volume of the "starting fraction" is less, then its final price will be lower. Yes, the PO price today is 150 thousand rubles per ton, which significantly exceeds not only cheap straight-run fractions, but also commercial gasoline, but since its volume is three times lower, the total cost will be comparable to AI-92 gasoline, the price of which is about 50 thousand rubles per ton. In addition, the use of PO as a "starting fraction" completely solves the problem associated with the sulfur content in the fuel and significantly reduces tar.

However, the main advantage of using PO as a "start-up fraction" is the ability to use water-cut alcohol. Thus, the first stage in obtaining commercial alcohols is to obtain "raw alcohol", in which the moisture content is about 12%, and then for classic fuel ethanol the moisture content is brought to 2 - 3%, which significantly increases the cost of alcohol. PO allows you to use not only alcohol with a strength of 95%, but even raw alcohol, the strength of which is 88%, which has a very significant effect on the cost of alcohol.

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## THE MAIN TYPES OF VEHICLE ENGINE DIAGNOSTICS

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**Abstract.** The authors reviewed the types of diagnostics of internal combustion engines of vehicles, which showed that there are mainly three types of diagnostics of engines, which differ in the accuracy of the results, the time of its implementation and the cost of the service. The authors believe that diagnostics based on the parameters of the crankcase oil of an internal combustion engine, which is widespread in foreign countries, is beginning to be in demand in the Russian Federation. It allows, with minimal costs and with high accuracy, to analyze the state of the engine without taking the machine out of operation, because it is enough to send an oil sample to the laboratory or perform some simple express analyzes at the place of machine operation.

**Keywords:** engine diagnostics, engine oil, performance indicators, equipment, oil analysis, car malfunctions.

The main unit of the car, which is responsible for the dynamic characteristics of the car, its power and throttle response is the internal combustion engine (hereinafter referred to as the engine or ICE). ICE is a complex technical unit containing a number of systems and mechanisms. In order for its operation to be uninterrupted and reliable, it is necessary to regularly carry out maintenance of the car engine in accordance with the recommendations of the manufacturer.

One of the most important conditions for maintaining a high level of efficiency and reliability of engines is the timely detection and prevention of

failures that occur during operation. It is carried out using technical diagnostic tools. Diagnostics allows you to detect hidden failures of the mechanism and determine the repair necessary to eliminate them, and in the absence of failures, identify the service life of the mechanism and the need for prevention.

Today there are three types of engine diagnostics:

1) **Mechanical diagnostics** – examination of the engine for mechanical damage. The main task of mechanical diagnostics — is to determine the need for repair of the main components of the ICE. It is carried out both outside the engine and inside. Internal diagnostics is carried out by disassembling the engine, which is one of the most time-consuming jobs. This diagnostics allows with 100% probability to determine all malfunctions (wear of parts, carbon deposits, crankshaft condition, gasket defect, and so on). To carry out such a diagnosis, a disassembly is required: a universal and special tool (keys, socket heads, special pullers, and so on) and a measuring one (internal gauge, vernier caliper, micrometer). An area for a working post and an area for an aggregate section are required. Features of mechanical diagnostics are that the engine is diagnosed in accordance with the repair and maintenance manual for an engine of a particular brand and model.

2) **Computer diagnostics** – carried out using special computers equipped with software. It began to evolve with the advent of the electronic engine management system (EEMS). An electronic control unit (ECU) controls the operating parameters of such a system. This diagnostics evaluates the condition of the systems and mechanisms associated with the EEMS, such as the power supply system, the valve timing mechanism, the ignition system, the cooling system, the EGR, and so on. To carry it out, you need an autoscanner, software for it and a diagnostic cable. Diagnosing a car with a scanner or using a computer allows you to identify malfunctions in ICE, and also fairly accurately determine existing problems. Computer diagnostics of the machine makes it possible to comprehensively assess the technical condition of the engine, obtain information that displays the general condition of parts, mechanisms, components and assemblies of ICE, as well as identify weak points that can further lead to deterioration in performance or even to engine shutdown.

Computer diagnostics of a car engine is performed in several stages. Each stage ends with an error report that is displayed on the screen. The detected errors are decoded, and on the basis of the information received, a recommendation is made on the need to replace or repair certain assemblies, sensors or individual parts.

3) **Diagnostics by parameters of crankcase oil** – carried out by examining the engine oil. Years of experience accumulated in different countries (USA, Germany, France, etc.) shows that machine diagnostics based on the analysis of operating oil is a reliable way to identify malfunctions [1,2,3,4]. In the Russian Federation, such work is carried out by the diagnostic center of LLC "Himnotolog" [5]. When disassembling and repairing machines, predicted defects are confirmed in 95% of cases [6].

During the operation of engine oils, physical and chemical processes occur, accompanied by the actuation of additives, the accumulation of wear products, which leads to the premature depletion of the potential of the physicochemical properties of the oil and a decrease in the resource of the power unit [7]. Oil is the most efficient, variable and controllable element that determines the efficiency and reliability of the engine.

To analyze engine oil, the following equipment is required, as shown in table 1.

**Table 1**  
**Required equipment for analysis**

Equipment	Functions
Viscometer	Designed to determine the dynamic and kinematic viscosity of oil
Infrared analyzer	Shows the degree of oil degradation (oxidation, nitration and base number) and oil contamination (soot, water, antifreeze and fuel)
Particle counter with magnetometer	Shows the content of metal particles in engine oil, wear products of engine parts
Multichannel photoelectric spectrograph	Determines the concentration of metals in used oils by the spectral method
Oil tester	Allows you to determine the presence of malfunctions in the car engine by changing the viscosity, density and other characteristics of the oil

Diagnostics of the oil operating in the engine has the following advantages [7,8]:

- performed without disassembly and visual inspection;
- the vehicle does not stop operating during the analysis;
- detecting faults at an early stage;
- minimal laboriousness of diagnostics;
- the ability to change the oil not by mileage, but by its actual performance.

To carry out the analysis, you will need about 130-150 cm<sup>3</sup> or 0.15 liters of motor. Groups of indicators are presented in table 2 [9,10].

**Table 2**  
**Indicators obtained in the analysis of engine oil**

Analysis group	Indicators	Norm
Wear – indicators that correspond to the metal content of engine parts	Iron (Fe)	< 30 mg/kg
	Lead (Pb)	< 10 mg/kg
	Copper (Cu)	< 50 mg/kg
	Chromium (Cr)	< 5 mg/kg
	Aluminum (Al)	< 10 mg/kg
	Nickel (Ni)	< 15 mg/kg
	Silicon (Si)	< 20 mg/kg
Contamination – indicators indicating the presence of other fluids in the engine oil	Water (H <sub>2</sub> O)	< 0 %
	Coolant	< 0 %
	Fuel	< 0 %
Chemical properties of oil	Alkaline number	< 8-9 mgKOH/g
	Acid number	< 6-7 mgKOH/g
	Kinematic viscosity	9,5-12,5 mm <sup>2</sup> /s
Various additives	Zinc (Zn)	Standard indicators depend on the type of test oil and are indicated in the technical passport
	Phosphorus (P)	
	Magnesium (Mg)	
	Molybdenum (Mo)	
	Boron (B)	
	Barium (Ba)	

Thus, the analysis of engine oil provides a fairly large number of indicators by which it is possible to make a verdict on the engine's performance and its further maintenance.

Examples of various malfunctions that can be detected when diagnosing a working engine oil.

**Mechanical wear of parts** — these defects can be detected at the earliest stages when obtaining oil analysis results [11]:

- presence of lead and tin – bearing wear;
- presence of iron – wear of the camshaft;
- presence of iron, lead, tin and copper/aluminum – wear of the crankshaft;



- the presence of iron, chromium and aluminum – wear of the cylinder-piston group;

- chrome and fuel – piston ring wear.

Examples of diagnostics based on crankcase oil parameters.

**Example 1.** In the analysis of the oil sample, an increased amount of metals was found that make up the parts of the cylinder-piston group and the crankshaft bearings.

Conclusion - an abrasive got into the oil, road dust gets into the engine.

Possible malfunctions:

- defective air filter;  
- damage to the gaskets between the engine intake manifold and the cylinder head.

**Example 2.** Decreased kinematic viscosity and sharply increased the flash point of the oil.

Conclusion – fuel gets into the oil.

Possible malfunctions:

- a leak in the fuel supply system;  
- non-combustion of fuel in one of the cylinders;  
- violation of fuel atomization by nozzles.

**Example 3.** The oil sample has an increased mass fraction of water, and intense bands of ethylene glycol are seen in the IR spectrum of the oil.

Conclusion – liquid enters the oil from the cooling system.

Possible malfunctions:

- damage to the cylinder head gasket [12].

In addition to malfunctions with the engine, you can determine the very quality of the used engine oil by comparing it with the technical data sheet.

Table 3 shows the comparative characteristics of the considered engine diagnostics for individual parameters.

**Table 3**  
**Comparison of types of engine diagnostics**

Parameters	Crankcase oil diagnostics	Mechanical diagnostics	Computer diagnostics
Service cost	15\$ - 30\$	Over 135\$	8\$ - 15\$
Time spent	1 to 24 hours (depending on the equipment used)	Full diagnostics takes from one day	20-30 minutes
Accuracy of the result	90%	100%	50%

As can be seen from the table, according to the price-time criterion, the most effective diagnostics is for used engine oil.

The combination of express analyzes with detailed analysis of engine oil samples makes it possible both to carry out an oil change on time and to identify many engine malfunctions at the earliest stage of their occurrence.

This type of diagnostics is widely used in the European Union and the USA when diagnosing engines, primarily trucks and road construction equipment. In Russia, car engine diagnostics based on the analysis of operating engine oil have not yet gained sufficient popularity compared to others.

It should be noted the effectiveness of this diagnostic method in relation to vehicles with diesel engines and off-road vehicles.

When carrying out diagnostics for engine oil, a number of conditions should be observed, failure to fulfill which leads to inaccurate results [8]:

- the engine must run on one brand of oil, only a change in viscosity classes is permissible when operating on seasonal oils;
- sampling frequency should be equal to a quarter of the recommended mileage according to the instruction manual.

Changing the oil according to the assigned resource without preliminary monitoring of its condition leads to the fact that in new engines the engine oil is drained while it is still fully functional, and in worn out engines it is too late, with a real loss of its performance [8].

### **Conclusion.**

The review of the types of diagnostics of internal combustion engines of vehicles showed that the diagnostics of the engine by the parameters of crankcase oil has sufficient accuracy and is increasingly used among other types of diagnostics, especially in motor transport enterprises and enterprises operating road construction equipment.

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## INFORMATION MODELING TECHNOLOGIES IN BRIDGE TESTING

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**Abstract.** During the operation of bridges, it becomes necessary to check the operability of the structure. BIM technologies make it possible not only to design engineering structures, but also to perform verification calculations of the structure during operation. In this case, the calculations should agree with the results of instrumental tests of the bridge. The article presents a comparative analysis of the results of modeling the stress-strain state of a metal bridge and test data using the Tensor MS system.

**Keywords:** information modeling, model, BIM, metal bridge, calculation, stress-strain state, testing, sensors.

### Introduction

Information modeling technologies are actively implemented in the design of buildings through the development of an architectural model with subsequent calculations in design programs. In the process of modeling, an intelligent copy of a building or structure is developed. Decree of the Government of Russia № 331 obliges to use information modeling technologies in the design of objects of state orders for any purpose and regardless of their cost. In the design of engineering structures, including bridges, the implementation of BIM technologies is only gaining momentum. For the design of bridges, a bundle of Inventor-Revit programs is used, which provides high accuracy of dimensions and shapes. Civil 3D is also used in the design of bridges and infrastructure. Among the many BIM design programs for bridges, Midas Civil is the best.

There are enough examples of bridge projects using BIM technologies.

One of them is the famous "Russian Bridge" with a length of more than 3 km, with the longest cable-stayed span in Russia - 1104 m. The height of the bridge is 334 m. The project was developed in 6 months. This highly complex project was carried out using the Midas software, in which the structural analysis and the general model of the bridge were performed. Modeling technologies made it possible to calculate cables, which consist of strands of ropes from 13 to 85 pieces [1].

The information model of the structure is also necessary during the operation of the facility. When conducting constant monitoring and periodic inspections of the technical condition of bridges, the implementation of structural calculations using the model allows in a short time to obtain information about the stress-strain state of structures and to develop solutions for strengthening or reconstruction.

When examining and testing a metal railway bridge in the Krasnodar Territory, the service life of which is more than 30 years, it was decided to determine the stresses in the bridge structures using the Tensor MS system. Also, computational models were developed in finite element analysis programs for performing verification calculations. To draw conclusions about the stress-strain state of the bridge, a comparison of calculations and tests is performed.

### **Materials and methods**

Railway bridge 42.25 m long, single-span metal, span length 28.05 m, width of the bridge between the railing - 5.0 m. Abutments and cones are made of monolithic reinforced concrete, concrete stairs with platforms are arranged on the abutments. The adjoining approaches on both sides are crushed stone. The superstructure is metal, it consists of the main beams, operational facilities in the form of metal railings and a service sidewalk, which is a wooden flooring on metal structures.

When examining and testing the bridge, the tasks of determining the technical state of structures, their wear, detecting defects and deformations, checking the strength and bearing capacity were solved [2]. In the process of measuring work, the main geometric and stiffness characteristics of the structure, the height of the under-bridge dimensions, the gaps between the spans and abutments, and the correct location of the supporting parts were established. A general view of the bridge is shown in fig. 1.

The main beams (lower and upper) are of I-section 550x10 № 55a according to OST 10016-39. The beams are combined into a common spatial structure of the superstructure with uprights and braces, consisting of 5 panels, each 5.4 m in size. The connection of all metal elements is riveted.

To establish the load-carrying capacity of the bridge and the speed of

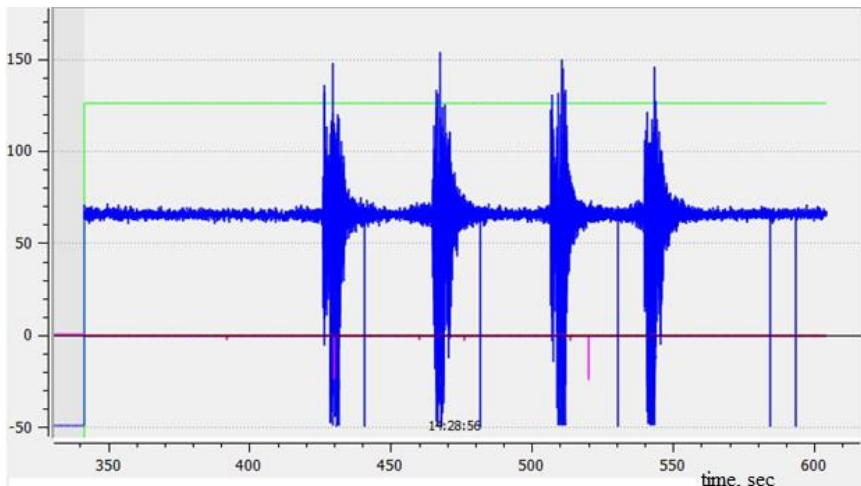
movement, the bridge was run-in under a test load. Dynamic tests were carried out by repeated passage of a single locomotive without hindrance at speeds of 5, 10, 15, 18 km/h. In this case, the leveling of the main beams was carried out in order to determine the deflections of the superstructure from the load. At the maximum speed of the locomotive, the vertical displacements of the central point of the superstructure were 7-8 mm.



**Fig. 1. General look of the bridge**

To determine the stress-strain state of structural elements of the bridge, spatial finite element models of a metal bridge have been developed in the StructureCad and Midas Civil programs. The calculations were performed for the main combination of loads, taking into account the load from a moving locomotive.

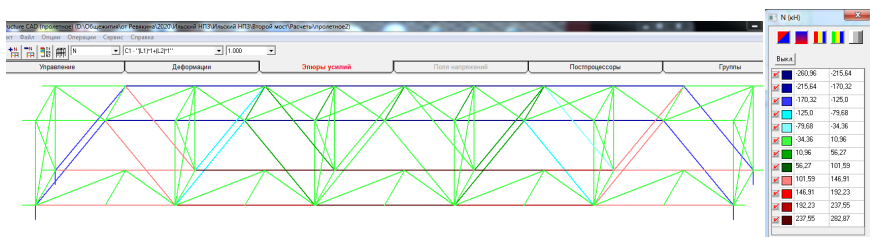
To analyze the stress-strain state of structures, a mobile automated measuring system for vibration diagnostics Tensor-MS was used. With the help of strain gauges of the Tensor MS strain gauge control system, the vibrations of the spans from the passage of the test load (frequencies and decrements of vibrations, amplitudes and modes of vibrations of elements and structures) were recorded. The sensors were installed in the weakest places. Based on the results obtained, the stresses in the elements on which the sensors were installed were calculated. Fig. 2 shows a graph of stresses in the lower main girder of the superstructure in the process of running in with a test load (when the locomotive is passing). According to the technical characteristics, the measurement error is up to 10% [3].



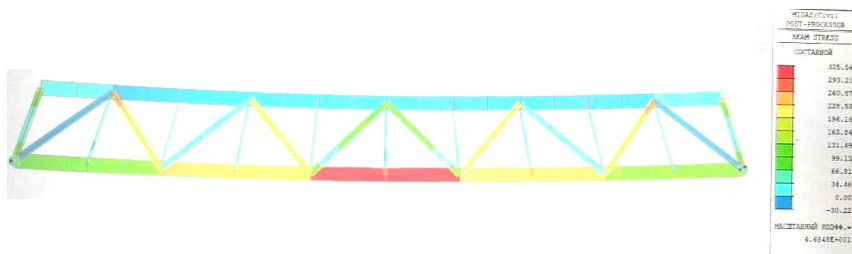
**Fig. 2. Graph of stresses in structures during the passage of a locomotive**

### Results and discussion

As a result of modeling the bridge superstructure in the StructureCad program (fig. 3) and Midas Civil (fig. 4), the values of displacements, forces and stresses in the elements were obtained.



**Fig. 3. N forces in elements obtained in StructureCad PC**



**Fig. 3. N forces in elements obtained in the Midas Civil PC**

The results obtained were compared with the data of tensometric observations and are shown in table 1.

**Table 1 – Comparison of calculation results**

Index	StructureCad PC	Midas Civil PC	Tensor MS
Deflection of the lower beam in the center of the span, mm	7.5	8.0	9.0
Maximum longitudinal forces, kN	282.87	293.28	155.0
Maximum transverse forces, kN	14.23	12.15	14.3

As a result of the analysis of the obtained values of the stress-strain state of the bearing structures of the bridge structure under the action of test loads, it can be seen that the calculation complexes have results that are close in convergence to each other (the discrepancy is no more than 5%). Strain gauge data have overlap. The most significant indicator of the superstructure performance is that the tensile forces in the calculations and test data have a significant discrepancy.

## Conclusions

Testing of engineering structures is a responsible activity that requires an individual approach. In the process of testing, it is necessary to carry out a set of works. Information modeling technologies make it possible to get an idea of the stress-strain state of the structures of an operating structure [4, 5]. The performed calculations showed the possibility of using finite element modeling programs when checking the state of operated bridges and high convergence results in direct instrumental tests.



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**MATHEMATICAL MODELS OF THE PROPAGATION OF A PLASTIC WAVE IN A HALF-SPACE WITH THE PROPERTY OF LINEAR COMPRESSIBILITY AND LINEAR IRREVERSIBLE UNLOADING<sup>1</sup>**

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**Abstract.** The problem of the effect of a moving load of an arbitrarily decreasing profile on a soil layer of finite thickness lying on a horizontal foundation is considered.

The soil is modeled by an ideal compressible medium in which the relationship between pressure and volumetric deformation under loading and during unloading of the medium is linear and irreversible.

The load is applied to the upper surface of the layer and moves at a superseismic speed.

If the moving load acting on the boundary of the half-space has a monotonically decreasing profile, then in the perturbation region, the medium is unloaded and the oblique compression wave is obtained by the load-unloading wave. The pressure of the medium against the background of this wave, depending on the depth of the half-space, decreases slowly than on the free surface. In the case when the relationship between pressure and deformation during loading of the medium is assumed to be nonlinear and shock, which corresponds to the propagation of a shock wave in the medium, the pressure in the perturbed region is somewhat overestimated in comparison with the linear one.

**Keywords.** Mathematical models, moving load, propagation, plastic wave, soil, half-space, wave front, ideal fluid, linear compressibility, irreversible unloading equation of motion, continuity, states of the environment.

<sup>1</sup>The work was carried out under the program APO9562377 of the Grant financing of SC MES RK

**Formulation of the problem.** The problem of the effect of a moving load of an arbitrarily decreasing profile on a soil layer of finite thickness  $h$ , lying on a rigid horizontal foundation is considered.

The soil is modeled by an ideal compressible medium, in which the relationship between pressure  $P$  and volumetric deformation  $\varepsilon$  under loading and during unloading of the medium is linear and irreversible.

The load is applied to the upper surface of the layer and moves at a superseismic speed  $D$ . Since in this case the modulus of volumetric compression  $\alpha_1 > E_1$  – of the modulus of unloading of the medium, in the physical plane  $(\xi, \eta)$  the characteristic  $AB$  has a greater in comparison with the speed of the reflected wave  $AD$ , and as a result, regions 2, 3, 4 appear, which are separated by the characteristic of the positive direction  $BC$  and the front reflected wave  $AD$ . The parameters of the environment in region 1 are known from the solution of the problem about  $AB$ . Note that this problem is stationary, and therefore all the parameters of the medium depend on two moving coordinates  $\xi = x + Dt$ ,  $\eta = y$ , and the motion of the medium in regions 2 and 3 of loading and unloading is described by the wave equation of the potential of the velocity  $\varphi$  we have the wave equation [1-4]

$$\mu^2 \frac{\partial^2 \varphi}{\partial \xi^2} - \frac{\partial^2 \varphi}{\partial \eta^2} = 0, \quad \left( \mu^2 = \frac{D^2}{C_p^2} - 1 \right) \text{ in plane deformation.}$$

We represent solutions in research areas in the form

$$\begin{aligned} \varphi_2(\xi, \eta) &= f_1(\xi - \mu\eta) + f_2(\xi + \mu\eta), \\ \varphi_3(\xi, \eta) &= f_3(\xi - \mu\eta) + f_4(\xi + \mu\eta), \end{aligned} \quad (1)$$

where  $\varphi_2, \varphi_3$  – velocity potentials.

To find the unknown functions  $f_1$  and  $f_2$  i.e. to solve the problem in region 2, we have the conditions for the continuity of the velocities on the characteristic  $AB$  and the condition that at different horizontal levels ( $\eta = \text{const}$ ) the pressure of the medium in front of the reflected wave is equal to the pressure at the front of the incident wave. This means that the state of the medium in region 1 is on the unloading branches of the  $P \sim \varepsilon$  diagram, and after the arrival of perturbations from the rigid boundary using the characteristic  $AB$ , in region 2 the pressure increases continuously to values determined by the points of intersection of the unloading and loading branches of the  $P \sim \varepsilon$  diagram. Subsequently, under the action of the reflected plastic wave  $AD$  an abrupt increase in pressure occurs. This means that the reduced media in regions 2 and 3, according to the

hydrostatic compressed, obeys Prandtal's scheme. A similar picture takes place in the rod theory with the difference that, in this case, the loading of the medium starts from the perturbed unloading region 1.

Thus, to solve the problem in domain 2 in the case of an exponential load  $f(\xi) = P_0 e^{-\gamma \xi}$ ,  $\gamma > 0$ ,  $\xi \geq 0$  we have the conditions

on characteristic  $AB$ , i.e. when  $\xi + \mu\eta = \frac{(1 + \mu tg\alpha)}{tg\alpha}$

$$u_2 = \frac{\partial \varphi_2}{\partial \xi} = -\frac{P_0}{\rho_0 D} \Psi_9(\xi, \eta), \quad (2)$$

$$\vartheta_2 = \frac{\partial \varphi_2}{\partial \eta} = -\frac{P_0}{\rho_0 D} \Psi_{10}(\xi, \eta), \quad (3)$$

where

$$\Psi_9(\xi, \eta) = \left\{ \sum_{n=0}^{\infty} \lambda^{n+1} e^{-\lambda^{n+1} \gamma \xi} \left[ e^{\lambda^{n+1} \gamma \left( \frac{(1 + \mu tg\alpha)}{tg\alpha} h - \xi \right)} - e^{-\lambda^{n+1} \gamma \left( \frac{(1 + \mu tg\alpha)}{tg\alpha} h - \xi \right)} \right] - e^{-\gamma \left( 2\xi - \frac{(1 + \mu tg\alpha)}{tg\alpha} h \right)} \right\}$$

$$\Psi_{10}(\xi, \eta) = \left\{ \sum_{n=0}^{\infty} \lambda^{n+1} e^{-\lambda^{n+1} \gamma \left( \frac{2h}{tg\alpha} - \xi \right)} \left[ e^{\lambda^{n+1} \gamma \mu tg\alpha \left( \frac{2h}{tg\alpha} - \xi \right)} - e^{\lambda^{n+1} \gamma \mu tg\alpha \left( \frac{2h}{tg\alpha} - \xi \right)} \right] + e^{\gamma \left( 1 - \mu tg\alpha \right) \left( \frac{2h}{tg\alpha} - \xi \right)} \right\}$$

in the section  $AE$  of the reflected wave front, i.e. when  $\eta + \xi tg\alpha = 2h$  [5-10]

$$P_2 = -\rho_0 D u_2 = P_0 \Psi_{11}(\xi, \eta). \quad (4)$$

where

$$\Psi_{11}(\xi, \eta) = \left\{ \sum_{n=0}^{\infty} \lambda^{n+1} e^{-\lambda^{n+1} \gamma \xi} \left[ e^{\lambda^{n+1} \gamma \left( \frac{(1 + \mu tg\alpha)}{tg\alpha} h - \xi \right)} + e^{-\lambda^{n+1} \gamma \left( \frac{(1 + \mu tg\alpha)}{tg\alpha} h - \xi \right)} \right] + e^{-\gamma \left( 2\xi - \frac{(1 + \mu tg\alpha)}{tg\alpha} h \right)} \right\} \text{cm.}$$

Then, substituting (1) into (2), (4) taking into account (3), we obtain the expressions

$$f_1'(z) = -f_2' \left( \frac{(1 + \mu tg\alpha)}{tg\alpha} h \right) - \frac{P_0}{\rho_0 D} \Psi_{12}(\xi, \eta) - \frac{P_0}{\rho_0 D} e^{-\gamma z}, \quad (5)$$

$$f_2'(z) = -f_2' \left( \frac{(1 + \mu tg\alpha)}{tg\alpha} h \right) + \frac{P_0}{\rho_0 D} \Psi_{13}(\xi, \eta) - \frac{P_0}{\rho_0 D} e^{-\gamma \left( \frac{(z-2\mu h)}{\lambda} - 2\mu h \right)} \frac{P_0}{\rho_0 D} \Psi_{14}(\xi, \eta), \quad (6)$$

$$f_2' \left( \frac{(1 + \mu tg\alpha)}{tg\alpha} h \right) = \frac{P_0}{\rho_0 D} \sum_{n=1}^{\infty} \lambda^{-\lambda^{n+1} \frac{(1 + \mu tg\alpha)}{tg\alpha}}. \quad (7)$$

$$\text{where } \Psi_{12}(\xi, \eta) = \sum_{n=0}^{\infty} \lambda^{n+1} e^{-\lambda^{n+1} \frac{\gamma}{2} \left( \frac{1+\mu g \alpha}{t g \alpha} h + z \right)} \left[ e^{\lambda^{n+1} \frac{\gamma}{2} \left( \frac{1+\mu g \alpha}{t g \alpha} h - z \right)} - e^{-\lambda^{n+1} \frac{\gamma}{2} \left( \frac{1+\mu g \alpha}{t g \alpha} h - z \right)} \right],$$

$$\Psi_{13}(\xi, \eta) = \sum_{n=0}^{\infty} \lambda^{n+1} e^{-\lambda^{n+1} \frac{\gamma}{2} \left( \frac{z-2\mu h}{\lambda} + \frac{(1+\mu g \alpha)}{t g \alpha} h \right)} \times \left[ e^{\lambda^{n+1} \frac{\gamma}{2} \left( \frac{(1+\mu g \alpha)}{t g \alpha} h + 1\mu h - \frac{(z-2\mu h)}{\lambda} \right)} - e^{-\lambda^{n+1} \frac{\gamma}{2} \left( \frac{(1+\mu g \alpha)}{t g \alpha} h + 2\mu h - \frac{(z-2\mu h)}{\lambda} \right)} \right],$$

$$\Psi_{14}(\xi, \eta) = \left\{ \sum_{n=0}^{\infty} \lambda^{n+1} e^{-\lambda^{n+1} \frac{\gamma}{2} \left( \frac{2h}{t g \alpha} + \frac{(z-2\mu h)}{(1-\mu g \alpha)} \right)} \left[ e^{\lambda^{n+1} \mu g \alpha \left( \frac{2h}{t g \alpha} + \frac{(z-2\mu h)}{(1-\mu g \alpha)} \right)} e^{-\lambda^{n+1} \mu g \alpha \left( \frac{2h}{t g \alpha} + \frac{(z-2\mu h)}{(1-\mu g \alpha)} \right)} \right] + e^{\gamma(1-\mu g \alpha) \left( \frac{2h}{t g \alpha} + \frac{(z-2\mu h)}{(1-\mu g \alpha)} \right)} \right\},$$

So, the solution to the problem when using (5) and (6) will finally be written in the form

$$u_2(\xi, \eta) = \frac{\partial \varphi_2}{\partial \xi} = -\frac{P_0}{\rho_0 D} \Psi_{15}(\xi, \eta), \quad (8)$$

$$\vartheta_2(\xi, \eta) = \frac{\partial \varphi_2}{\partial \eta} = -\frac{P_0}{\rho_0 D} \Psi_{16}(\xi, \eta), \quad (9)$$

$$\text{where } \lambda = \frac{1-\mu t g \alpha}{1+\mu t g \alpha},$$

$$\begin{aligned} \Psi_{15}(\xi, \eta) = & \left\{ \sum_{n=0}^{\infty} 2\lambda^{n+1} \left[ sh \left( \lambda^{n+1} \frac{\gamma}{2} \left( \frac{1+\mu t g \alpha}{t g \alpha} h - \xi + \mu \eta \right) \right) \cdot e^{\left( -\lambda^{n+1} \frac{\gamma}{2} \left( \frac{1+\mu t g \alpha}{t g \alpha} h - \xi + \mu \eta \right) \right)} - \right. \right. \\ & - sh \left( \lambda^{n+1} \frac{\gamma}{2} \left( \frac{1+3\mu t g \alpha}{t g \alpha} + 2\frac{\mu}{\lambda} \right) h - \frac{(\xi + \mu \eta)}{\lambda} \right) \cdot e^{\left( \lambda^{n+1} \frac{\gamma}{2} \left( \frac{1+3\mu t g \alpha}{t g \alpha} + 2\frac{\mu}{\lambda} \right) h - \frac{(\xi + \mu \eta)}{\lambda} \right)} + \\ & + \left( \lambda^{n+1} \gamma t g \alpha \left( \frac{2h}{t g \alpha} - \frac{\xi + \mu \eta - 2\mu h}{1-\mu t g \alpha} \right) \right) \cdot e^{\left( \lambda^{n+1} \gamma t g \alpha \left( \frac{2h}{t g \alpha} - \frac{\xi + \mu \eta - 2\mu h}{1-\mu t g \alpha} \right) \right)} \Big] + \\ & \left. + \left[ e^{\gamma(\xi - \mu \eta)} + e^{-\gamma(1-\mu g \alpha) \left( \frac{2h}{t g \alpha} - \frac{\xi + \mu \eta}{1-\mu g \alpha} \right)} - e^{-\gamma \left( \frac{\xi + \mu \eta}{\lambda} - 2\mu \right) \left( 1 + \frac{1}{\lambda} \right)} \right] \right\} \\ \Psi_{16}(\xi, \eta) = & \left\{ \sum_{n=0}^{\infty} 2\lambda^{n+1} \left[ sh \left( \lambda^{n+1} \frac{\gamma}{2} \left( \frac{1+3\mu t g \alpha}{t g \alpha} + 2\frac{\mu}{\eta} \right) p + \frac{\xi + \mu \eta}{\lambda} \right) \cdot e^{\left( -\lambda^{n+1} \frac{\gamma}{2} \left( \frac{1+3\mu t g \alpha}{t g \alpha} + 2\frac{\mu}{\eta} \right) h \right)} \right. \right. \\ & + sh \left( \lambda^{n+1} \frac{\gamma}{2} \left( \frac{\xi + \mu \eta}{\lambda} - 2\mu \right) \left( 1 + \frac{1}{\lambda} \right) \right) \cdot e^{\left( \lambda^{n+1} \frac{\gamma}{2} \left( \frac{\xi + \mu \eta}{\lambda} + \frac{1+\mu t g \alpha}{1-\mu t g \alpha} h \right) \right)} + e^{\lambda^{n+1} \frac{\gamma}{2} \left( \frac{1+\mu t g \alpha}{t g \alpha} \right)} \Big] + \\ & \left. + \left[ e^{\gamma(\xi - \mu \eta)} + e^{-\gamma \left( \frac{\xi + \mu \eta}{\lambda} - 2\mu \right) \left( 1 + \frac{1}{\lambda} \right) h} - e^{-\gamma \left( \frac{2h}{t g \alpha} - \frac{\xi + \mu \eta - 2\mu}{1-\mu t g \alpha} \right)} \right] \right\} \end{aligned}$$

Now let's start solving the problem in region 3. For this, we have the following conditions: at the front of the reflected wave  $AE$ , i.e. at  $\eta + \xi tg\alpha = 2h$  [5,6-10], [5,6-10],

$$\rho_0 a (\mathcal{G}_{n3} - \mathcal{G}_{n2}) = P_3 - P_2, \quad \mathcal{G}_{r3} = \mathcal{G}_{r2}, \quad (10)$$

on a rigid boundary at  $\eta = h$ ,  $\xi_a \leq \xi \leq \xi_c$

$$\frac{\partial \varphi_3}{\partial \eta} = 0. \quad (11)$$

$$\text{Given that } \mathcal{G}_n = -u \sin \alpha - \mathcal{G} \cos \alpha, \quad \mathcal{G}_r = u \cos \alpha - \mathcal{G} \sin \alpha, \quad a = D \sin \alpha, \quad (12)$$

from (10) we obtain

$$(\mathcal{G}_3 - \mathcal{G}_2) tg\alpha = u_3 - u_2. \quad (13)$$

From the second equation in (1), taking into account (10) and (11) with respect to the function  $f_3$  and  $f_4$  we obtain a system of equations in the form

$$f_3'(z) = f_4'(z + 2\mu h), \quad (14)$$

$$f_4'(z) + \lambda f_4'(z + 2\mu h) = G(z), \quad (15)$$

where

$$\begin{aligned} G(z) = & -\frac{P_0}{\rho_0 D} \left\{ \sum_{n=0}^{\infty} 2\lambda^{n+1} \left[ sh \left( \lambda^{n+1} \frac{\gamma}{2} \left( \frac{1 + \mu tg\alpha}{tg\alpha} + 2\mu \right) h - z \right) e^{-\lambda^{n+1} \frac{\gamma}{2} \left( z + \frac{1 + \mu tg\alpha}{tg\alpha} h \right)} (1 - \lambda) + \right. \right. \\ & + \lambda sh \left( \lambda^{n+1} \gamma \mu tg\alpha \left( \frac{2h}{tg\alpha} - \frac{z}{1 + \mu tg\alpha} \right) \right) e^{\lambda^{n+1} \gamma \left( \frac{2h}{tg\alpha} - \frac{z}{1 + \mu tg\alpha} \right)} \left. \right] + e^{-\gamma(z - 2\mu h)} (1 - \lambda) + \\ & + \lambda e^{-\gamma(1 - \mu tg\alpha) \frac{2h}{tg\alpha}} e^{\gamma \lambda z} + (1 - \lambda) \sum_{n=0}^{\infty} \lambda^{n+1} e^{-\lambda^{n+1} \gamma \frac{(1 + \mu tg\alpha)}{tg\alpha} h} \left. \right\} \end{aligned}$$

Solving equation (15), by the method of successive approximations, it is easy to obtain the formula

$$f_4'(z) = G(z) + \sum_{n=0}^{\infty} (-\lambda)^n G \left[ \lambda^n z + 2\mu h \frac{(\lambda^n - 1)}{(\lambda - 1)} \right]. \quad (16)$$

Thus, for region 3 we have a solution to the problem in the form

$$u_3(\xi, \eta) = G(\xi - \mu\eta + 2\mu h) + G(\xi + \mu\eta) \Psi_{17}(\xi, \eta), \quad (17)$$

$$\mathcal{G}_3(\xi, \eta) = \mu [G(\xi + \mu\eta) - G(\xi - \mu\eta + 2\mu h) + \Psi_{18}(\xi, \eta)], \quad (18)$$

where

$$\Phi_{17}(x, t) = \left\{ \begin{aligned} & U_2(x-l) \left[ 1 - \exp\left(-\frac{bE_0 t}{a\rho}\right) \right] \left[ 1 - S\left(\sqrt{\frac{\rho}{IE}} \frac{(x+l)^2}{4t}\right) - C\left(\sqrt{\frac{\rho}{IE}} \frac{(x+l)^2}{4t}\right) \right] \times \\ & \times \left[ \frac{1}{2} - \frac{1}{2} \exp\left(-\frac{bE_0 t}{2a\rho}\right) \right] + \sqrt[4]{\frac{\rho}{IE}} \frac{bE_0}{a\rho} \frac{x+l}{8\sqrt{2\pi}} \sum_{n=0}^{\infty} [F_1(n, t, x+l) + F_2(n, t, x+l)] \times \\ & \times \frac{1}{n+1} \left[ 1 + (-1)^n \exp\left(-\frac{bE_0 t}{a\rho}\right) \right] - \frac{a^3 \rho}{4bE_0} \sqrt{\frac{\rho}{IE}} \left[ S\left(\sqrt{\frac{\rho}{IE}} \frac{(x+l)^2}{4t}\right) - C\left(\sqrt{\frac{\rho}{IE}} \frac{(x+l)^2}{4t}\right) \right] \times \\ & \times \left[ \exp\left(-\frac{bE_0 t}{a\rho}\right) - 4 \exp\left(-\frac{bE_0 t}{2a\rho}\right) - \frac{bE_0 t}{2a\rho} + 3 \right] + \sqrt[4]{\frac{\rho}{IE}} \frac{bE_0}{a\rho} \frac{x+l}{4\sqrt{2\pi}} \times \\ & \times \sum_{n=0}^{\infty} [F_2(n, t, x+l) - F_1(n, t, x+l)] \left[ 2 + \left( (-1)^n \exp\left(-\frac{bE_0 t}{a\rho}\right) + \frac{bE_0 t}{a\rho} - 3 \right) \frac{1}{n+1} \right] - \\ & - U_1(l-x) \left[ 1 - S\left(\sqrt{\frac{\rho}{IE}} \frac{(x-l)^2}{4t}\right) - C\left(\sqrt{\frac{\rho}{IE}} \frac{(x-l)^2}{4t}\right) \right] \times \\ & \times \left[ \frac{1}{2} - \frac{1}{2} \exp\left(-\frac{bE_0 t}{2a\rho}\right) \right] - \sqrt[4]{\frac{\rho}{IE}} \frac{bE_0}{a\rho} \frac{|x-l|}{8\sqrt{2\pi}} \sum_{n=0}^{\infty} [F_1(n, t, |x-l|) + F_2(n, t, |x-l|)] \times \\ & \times \frac{1}{n+1} \left[ 1 + (-1)^n \exp\left(-\frac{bE_0 t}{a\rho}\right) \right] + \frac{a^3 \rho}{4bE_0} \sqrt{\frac{\rho}{IE}} \left[ S\left(\sqrt{\frac{\rho}{IE}} \frac{(x-l)^2}{4t}\right) - C\left(\sqrt{\frac{\rho}{IE}} \frac{(x-l)^2}{4t}\right) \right] \times \\ & \times \left[ \exp\left(-\frac{bE_0 t}{a\rho}\right) - 4 \exp\left(-\frac{bE_0 t}{2a\rho}\right) - \frac{bE_0 t}{a\rho} + 3 \right] + \sqrt[4]{\frac{\rho}{IE}} \frac{bE_0}{a\rho} \frac{|x-l|}{4\sqrt{2\pi}} \times \\ & \times \sum_{n=0}^{\infty} [F_2(n, t, |x-l|) - F_1(n, t, |x-l|)] \left[ 2 + \left( (-1)^n \exp\left(-\frac{bE_0 t}{a\rho}\right) + \frac{bE_0 t}{a\rho} - 3 \right) \frac{1}{n+1} \right] + \\ & + \frac{a^3 \rho}{bE_0} \sqrt{\frac{\rho}{IE}} \left[ C\left(\sqrt{\frac{\rho}{IE}} \frac{(x+l)^2}{4t}\right) - S\left(\sqrt{\frac{\rho}{IE}} \frac{(x+l)^2}{4t}\right) \right] \left[ \exp\left(-\frac{bE_0 t}{a\rho}\right) - 1 + \frac{bE_0 t}{2a\rho} \right] + \\ & + \sqrt[4]{\frac{\rho}{IE}} \frac{bE_0}{a\rho} \frac{x+l}{4\sqrt{2\pi}} \sum_{n=0}^{\infty} [F_2(n, t, x+l) - F_1(n, t, x+l)] \\ & + \left[ 1 + \left( \frac{bE_0 t}{2a\rho} - 1 \right) \right] \frac{1}{n+1} + U_1(l-x) \times \\ & \times \left[ C\left(\sqrt{\frac{\rho}{IE}} \frac{(x-l)^2}{4t}\right) - S\left(\sqrt{\frac{\rho}{IE}} \frac{(x-l)^2}{4t}\right) \right] \left[ \exp\left(-\frac{bE_0 t}{2a\rho}\right) - 1 + \frac{bE_0 t}{2a\rho} \right] + \\ & + \sqrt[4]{\frac{\rho}{IE}} \frac{bE_0}{a\rho} \frac{|x-l|}{4\sqrt{2\pi}} \sum_{n=0}^{\infty} [F_2(n, t, |x-l|) - F_1(n, t, |x-l|)] \left[ 1 + \left( \frac{bE_0 t}{2a\rho} - 1 \right) \right] \frac{1}{n+1} \end{aligned} \right\},$$

$$\Phi_{18}(x, t) = \left\{ \begin{aligned} & U_2(x-l) \frac{a\rho}{bE_0} \left[ \exp\left(-\frac{bE_0 t}{a\rho}\right) - 1 + \frac{bE_0 t}{a\rho} \right] - \cos\left(\sqrt{\frac{\rho}{IE}} \frac{az}{2}\right) \times \\ & \left[ \frac{a\rho}{bE_0} \left[ 1 - C\left(\sqrt{\frac{\rho}{IE}} \frac{(x+l)^2}{4t}\right) - S\left(\sqrt{\frac{\rho}{IE}} \frac{(x+l)^2}{4t}\right) \right] \times \right. \\ & \times \left[ \exp\left(-\frac{bE_0 t}{a\rho}\right) - 1 + \frac{bE_0 t}{a\rho} \right] + \sqrt[4]{\frac{\rho}{IE}} \frac{x+l}{8\sqrt{2\pi}} \times \\ & \times \sum_{n=0}^{\infty} [F_1(n, t, x+l) + F_2(n, t, x+l)] \times \\ & \times \left[ \frac{1}{n+1} \left( 1 - (-1)^n \exp\left(-\frac{bE_0 t}{a\rho}\right) - \frac{bE_0 t}{a\rho} \right) - 2 \right] \\ & \left. \times \left[ \frac{a\rho}{2bE_0} \left[ C\left(\sqrt{\frac{\rho}{IE}} \frac{(x+l)^2}{4t}\right) - S\left(\sqrt{\frac{\rho}{IE}} \frac{(x+l)^2}{4t}\right) \right] \right] \right. \\ & \times \left[ \exp\left(-\frac{bE_0 t}{a\rho}\right) - 1 + \frac{bE_0 t}{a\rho} \right] + \sqrt{\frac{\rho}{IE}} \frac{x+l}{8\sqrt{2\pi}} \\ & \left. + \sum_{n=0}^{\infty} [F_2(n, t, x+l) - F_1(n, t, x+l)] \right. \\ & \left. \times \left[ 2 + \frac{1}{n+1} \left( (-1)^{n+1} \exp\left(-\frac{bE_0 t}{a\rho}\right) + \frac{bE_0 t}{a\rho} - 1 \right) \right] \right\} \times \sin\left(\sqrt{\frac{\rho}{IE}} \frac{az}{2}\right) \times \end{aligned} \right\}$$

The pressure in the region is determined by the formula

$$P = -\rho_0 Du_i, \quad (i=2,3). \quad (19)$$

**Conclusion.** An analytical solution to the problem of the propagation of a plastic wave in a half-space is constructed in the case when the relationship between pressure and volumetric deformation during loading and unloading is linear, but different. Based on the analysis of the calculation results, it is shown that if the moving load acting on the boundary of the half-space has a monotonically decreasing profile, then in the disturbance region, the medium is unloaded and an oblique compression wave is obtained by the load-unloading wave. The pressure of the medium against the background of this wave, depending on the depth of the half-space, decreases slowly than on the free surface. In the case when the dependence between  $P$  and during loading of the medium is assumed to be nonlinear and shock, which corresponds to the propagation of a shock wave in the medium, the pressure in the perturbed region, in comparison with the linear case, is somewhat overestimated.



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**MATHEMATICAL MODELS OF WAVE PROPAGATION ON  
A SOIL LAYER WITH THE PROPERTY OF NON-LINEARLY  
COMPRESSIBLE AND IRREVERSIBLE UNLOADING WITH THE  
BASE UNDER THE INFLUENCE OF A MOVING LOAD<sup>1</sup>**

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**Abstract.** The problem of the effect of a mobile load on a soil layer of finite thickness lying on a horizontal elastic foundation is considered.

The soil is modeled by an ideal nonlinearly compressible and irreversible unloading medium, in which the relationship between pressure and volumetric deformation under loading and during unloading of the medium is linear and irreversible.

The load is applied to the upper surface of the layer and moves at a superseismic speed. The problem of the effect of a moving load on a two-layer medium consisting of a soft soil layer and an elastic-yielding pad with different thicknesses and densities is considered. The solution to the problem is constructed analytically in both reverse and direct ways.

A two-layer medium consists of a soft soil layer of thickness  $h$  with an elastic deformable base. The soil is modeled by an inelastic ideal medium with linear compressibility and linear irreversible unloading. Consequently, the shear resistance of the medium is neglected. According to this statement, the influence of the deformability of the base and the load profile on the distribution of the dynamic parameters of the layer and the contact surface was investigated.

**Keywords.** Mathematical models, propagation, plastic wave, half-spaces, analytical solution, wave front, ideal fluid, linear compressibility, ir-

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reversible unloading, equation of motion, continuity, states of the medium.

**Formulation of the problem.** Let us consider the problem of the effect of a moving load on a two-layer medium consisting of a soft soil layer and an elastic-yielding pad with thicknesses  $h, h_1$  and densities  $\rho, \rho_1$ . The soil is modeled by a nonlinearly compressible medium, and the pad, which has a weaker, than a soil with a stiffness  $K$  and a density  $\rho_2 \leq \rho_1$  with a Winkler base. The lower boundary of the two-layer medium is solid and non-deformable. According to the accepted assumptions, the wave process in the spacer is neglected, and the compressed wave  $OA$  at  $\xi \geq \xi_a$  from the contact surface of the two media is reflected in the form of the unloading wave  $AB$  of a strong rupture, and the behavior of the soil in regions 1, 2, 3, etc. is determined by the unloading branches of the  $P \sim \varepsilon$  diagram.

The problem is of practical importance in assessing the levels of reduction of dynamic loads on various underground structures using a bulk screen with a resilient pad.

The solution to the problem is constructed analytically in both reverse and direct ways. Let's proceed with the presentation of these decisions. In the course of this task, the load profile  $f(\xi)$ , was determined, which in the future, when constructing solutions to the problem for areas 2 and 3, is considered given [1,2-5].

Taking into account that the medium in region 2 is in a state of unloading, then to solve the problem with respect to the velocity potential  $\varphi_2(\xi, \eta)$  we have the equation

$$\mu^2 \frac{\partial^2 \varphi_2}{\partial \xi^2} - \frac{\partial^2 \varphi_2}{\partial \eta^2} = 0, \quad \left( \mu^2 = \frac{D^2}{C_p^2} - 1, \quad C_p = \sqrt{\frac{E}{\rho_1}} \right), \quad (1)$$

with the following boundary conditions

$$tg\beta(V_1 - V_2) = (U_1 - U_2) \quad \text{at } \eta + \xi tg\beta = 2h_1, \quad (2)$$

$$D \frac{\partial P_2}{\partial \xi} = K_x V_2, \quad \text{at } \eta = h, \quad \xi_a \leq \xi \leq \xi_c, \quad (3)$$

Where  $C_h = D \sin \beta$ ,  $tg\beta = 1/M$ ,  $K_x = K/h_2$ ,  $U_2, V_2$  – horizontal and vertical components of speed;  $P_2$  – medium pressure in area 2;  $\beta$  – the angle of inclination of the reflected wave with the line  $AC$ ;  $K$  – Young's modulus spacers.

It is known that equation (1) for  $D > C_p$  admits a solution of the form

$$\varphi_2(\xi, \eta) = f_1(\xi - \mu\eta) + f_2(\xi + \mu\eta). \quad (4)$$

Hence

$$\begin{aligned} U_2(\xi, \eta) &= \frac{\partial \varphi_2}{\partial \xi} = f_1'(\xi - \mu\eta) + f_2'(\xi + \mu\eta), \\ V_2(\xi, \eta) &= \frac{\partial \varphi_2}{\partial \eta} = -\mu f_1'(\xi - \mu\eta) + \mu f_2'(\xi + \mu\eta). \end{aligned} \quad (5)$$

Substituting (5) into (2), after some transformations, we obtain

$$\begin{aligned} f_1'(z) &= \frac{1}{2} \left[ u_1 \left( \frac{z + \mu(h + \xi_a \operatorname{tg} \beta)}{2} - \frac{z - \mu(h + \xi_a \operatorname{tg} \beta)}{2} \right) - \right. \\ &\quad \left. - \mathcal{Q} \operatorname{tg} \beta \left( \frac{z + \mu(h + \xi_a \operatorname{tg} \beta)}{2} - \frac{z - \mu(h + \xi_a \operatorname{tg} \beta)}{2} \right) \right]. \end{aligned}$$

Substitute (5) into (3). Then we have

$$f_2'(z) + \frac{K_x \mu}{\rho_1 D^2} f_2'(z) = -f_1'(z - 2\mu h) + \frac{K_x \mu}{\rho_1 D^2} f_1'(z - 2\mu h), \quad (7)$$

where the dash above means the derivative with respect to the argument.

Equation (7) has a solution of the form

$$\begin{aligned} f_2'(z) &= C_2 e^{-lz} - f_1'(z - 2\mu h) + f_1'(z - 2\mu h) e^{-l(z-z_0)} + \\ &\quad + 2l e^{-lz} \int_{z_0}^z e^{lz} f_1'(z - 2\mu h) dz. \end{aligned} \quad (5.6.8),$$

where  $z_{02} = \xi_a \mu h$ ,  $l = (K_x \mu) / (\rho_1 d^2)$ .

Obtain

$$C_2 = -e^{l(\xi_a + \mu h)} \left[ U_1(\xi_a, h) - \frac{1}{\mu} V_1(\xi_a, h)_1 \right]. \quad (9)$$

Thus, the solution to the problem in region 2 is expressed by the formulas

$$U_2(\xi, \eta) = \frac{1}{2} \Psi_{35}(\xi, \eta) - \frac{1}{2} \Psi_{36}(\xi, \eta) + l e^{-l(\xi + \mu\eta)} \Psi_{37}(\xi, \eta), \quad (10)$$

$$V_2(\xi, \eta) = -\frac{\mu}{2}\Psi_{38}(\xi, \eta) - \frac{\mu}{2}\Psi_{39}(\xi, \eta) + \mu l e^{-l(\xi + \mu\eta)}\Psi_{40}(\xi, \eta), \quad (11)$$

$$P_2(\xi, \eta) = -\rho_1 dU_2(\xi, \eta). \quad (12)$$

where

$$\begin{aligned} \Psi_{35}(\xi, \eta) &= \left[ U_1 \left( \frac{(\xi - \mu\eta) + (\xi_a + \mu h)}{2} - \frac{(\xi - \mu\eta) + (\xi_a + \mu h)}{2\mu} \right) - \right. \\ &\quad \left. - \frac{1}{\mu} V_1 \left( \frac{(\xi - \mu\eta) + (\xi_a + \mu h)}{2} - \frac{(\xi - \mu\eta) + (\xi_a + \mu h)}{2\mu} \right) \right], \\ \Psi_{36}(\xi, \eta) &= \left[ U_1 \left( \frac{(\xi + \mu\eta) + (\xi_a - \mu h)}{2} - \frac{(\xi + \mu\eta) + (\xi_a + 3\mu h)}{2\mu} \right) - \right. \\ &\quad \left. - \frac{1}{\mu} V_1 \left( \frac{(\xi + \mu\eta) + (\xi_a - \mu h)}{2} - \frac{(\xi + \mu\eta) + (\xi_a + 3\mu h)}{2\mu} \right) \right], \\ \Psi_{37}(\xi, \eta) &= \int_{z_{02}}^{\xi + \mu\eta} e^{lz} \left[ U_1 \left( \frac{z + (\xi_a - \mu h)}{2} - \frac{z + (\xi_a + 3\mu h)}{2\mu} \right) - \frac{1}{\mu} V_1 \left( \frac{z + (\xi_a - \mu h)}{2} - \right. \right. \\ &\quad \left. \left. - \frac{z + (\xi_a + 3\mu h)}{2\mu} \right) \right] dz, \\ \Psi_{38}(\xi, \eta) &= \left[ U_1 \left( \frac{(\xi - \mu\eta) + (\xi_a + \mu h)}{2} - \frac{(\xi - \mu\eta) + (\xi_a + \mu h)}{2\mu} \right) - \right. \\ &\quad \left. - \frac{1}{\mu} V_1 \left( \frac{(\xi - \mu\eta) + (\xi_a + \mu h)}{2} - \frac{(\xi - \mu\eta) + (\xi_a + \mu h)}{2\mu} \right) \right], \\ \Psi_{39}(\xi, \eta) &= \left[ U_1 \left( \frac{(\xi + \mu\eta) + (\xi_a - \mu h)}{2} - \frac{(\xi + \mu\eta) + (\xi_a + 3\mu h)}{2\mu} \right) - \right. \\ &\quad \left. - \frac{1}{\mu} V_1 \left( \frac{(\xi + \mu\eta) + (\xi_a - \mu h)}{2} - \frac{(\xi + \mu\eta) + (\xi_a + 3\mu h)}{2\mu} \right) \right], \\ \Psi_{40}(\xi, \eta) &= \int_{z_{02}}^{\xi + \mu\eta} e^{lz} \left[ U_1 \left( \frac{z + (\xi_a - \mu h)}{2} - \frac{z + (\xi_a + 3\mu h)}{2\mu} \right) - \frac{1}{\mu} V_1 \left( \frac{z + (\xi_a - \mu h)}{2} - \right. \right. \\ &\quad \left. \left. - \frac{z + (\xi_a + 3\mu h)}{2\mu} \right) \right] dz, \end{aligned}$$

Now let's start solving the problem in region 3. For this we have the equation [6,7-10]

$$\mu^2 \frac{\partial^2 \varphi_3}{\partial \xi^2} - \frac{\partial^2 \varphi_3}{\partial \eta^2} = 0, \quad (13)$$

and boundary conditions

$$V_3 - V_2 = -\mu(U_3 - U_2) \quad \text{at} \quad \xi - \mu\eta = 2\mu h, \quad (14)$$

$$P_3(\xi, 0) = f(\xi) \quad \text{at} \quad \eta = 0, \quad \xi_b \leq \xi \leq \xi_d. \quad (15)$$

We represent the solution of equation (6.6.6) in the form

$$\varphi_3(\xi, \eta) = f_3(\xi - \mu\eta) + f_4(\xi + \mu\eta). \quad (16)$$

Then, substituting (16) into (14) and (15) to find the required functions  $f_3(z)$  and  $f_4(z)$  we get the formulas

$$f_3'(z) = -\frac{1}{2\mu} \left[ V_2 \left( \frac{z}{2} + \mu h, \frac{z - 2\mu h}{2\mu} \right) + \mu U_2 \left( \frac{z}{2} + \mu h, \frac{z - 2\mu h}{2\mu} \right) \right] - \frac{f(z)}{\rho_1 d}, \quad (17)$$

$$f_4'(z) = -\frac{1}{2\mu} \left[ V_2 \left( \frac{z}{2} + \mu h, \frac{z - 2\mu h}{2\mu} \right) + \mu U_2 \left( \frac{z}{2} + \mu h, \frac{z - 2\mu h}{2\mu} \right) \right] - \frac{f(z)}{\rho_1 d}, \quad (18)$$

So, to determine the components of the velocity and pressure of the medium in region 3, we have the formulas

$$U_3(\xi, \eta) = -\frac{1}{2\mu} \Psi_{41}(\xi, \eta) - \frac{f(\xi - \mu\eta)}{\rho_1 d} + \frac{1}{2\mu} \Psi_{42}(\xi, \eta), \quad (19)$$

$$V_3(\xi, \eta) = \frac{1}{2} \Psi_{43}(\xi, \eta) + \frac{f(\xi - \mu\eta)}{\rho_1 d} + \frac{1}{2} \Psi_{44}(\xi, \eta), \quad (20)$$

$$P_3(\xi, \eta) = -\rho_1 d U_3(\xi, \eta). \quad (21)$$

where

$$\begin{aligned} \Psi_{41}(\xi, \eta) &= \left[ V_2 \left( \frac{(\xi - \mu\eta)}{2} + \mu h, \frac{(\xi - \mu\eta) - 2\mu h}{2\mu} \right) + \right. \\ &\quad \left. + \mu U_2 \left( \frac{(\xi - \mu\eta)}{2} + \mu h, \frac{(\xi - \mu\eta) - 2\mu h}{2\mu} \right) \right], \\ \Psi_{42}(\xi, \eta) &= \left[ V_2 \left( \frac{(\xi + \mu\eta)}{2}, \frac{(\xi - \mu\eta) - 2\mu h}{2\mu} \right) + \mu U_2 \left( \frac{(\xi + \mu\eta)}{2} + \mu h, \frac{(\xi + \mu\eta) - 2\mu h}{2\mu} \right) \right], \\ \Psi_{43}(\xi, \eta) &= \left[ V_2 \left( \frac{(\xi - \mu\eta)}{2} + \mu h, \frac{(\xi - \mu\eta) - 2\mu h}{2\mu} \right) + \mu U_2 \left( \frac{(\xi - \mu\eta)}{2} + \mu h, \frac{(\xi - \mu\eta) - 2\mu h}{2\mu} \right) \right], \\ \Psi_{44}(\xi, \eta) &= \left[ V_2 \left( \frac{(\xi + \mu\eta)}{2} + \mu h, \frac{(\xi - \mu\eta) - 2\mu h}{2\mu} \right) + \mu U_2 \left( \frac{(\xi + \mu\eta)}{2} + \mu h, \frac{(\xi + \mu\eta) - 2\mu h}{2\mu} \right) \right], \end{aligned}$$

The solution to the problem for the subsequent areas is not given, since it is constructed in a similar way. If the gasket material has a rigid plastic property, i.e.  $\sigma = \sigma_s = \text{const}$ , then for the solution of the problem in the region of 2 substitutions (3) we have the condition [1-4,10]

$$U_2(\xi, \eta) = -\frac{\sigma_s}{\rho_1 d} \quad \text{at } \eta = h, \quad \xi_a \leq \xi \leq \xi_c \quad (22)$$

In this case, the unknown function  $f_2(z)$ , in contrast to (8), is found using the formula

$$f_2'(z) = -f_1'(z - 2\mu h) - \frac{\sigma_s}{\rho_1 d}. \quad (23)$$

Then the velocity components  $U_2(\xi, \eta)$  and  $V_2(\xi, \eta)$  and in region 2 are represented as

$$U_2(\xi, \eta) = \frac{1}{2}\Psi_{45}(\xi, \eta) - \frac{1}{2}\Psi_{46}(\xi, \eta) - \frac{\sigma_s}{\rho_1 d}, \quad (24)$$

$$V_2(\xi, \eta) = -\frac{\mu}{2}\Psi_{47}(\xi, \eta) - \frac{\mu}{2}\Psi_{48}(\xi, \eta) - \frac{\sigma_s \mu}{\rho_1 d}. \quad (25)$$

where

$$\begin{aligned} \Psi_{45}(\xi, \eta) &= \frac{1}{2} \left[ \left[ U_1 \left( \frac{(\xi - \mu\eta)}{2} + \mu h, h - \frac{\text{tg}\beta}{2}(\xi - \mu\eta) \right) \right] - \text{tg}\beta \cdot V_1 \left( \frac{(\xi - \mu\eta)}{2} + \mu h, h - \frac{\text{tg}\beta}{2}(\xi - \mu\eta) \right) \right], \\ \Psi_{46}(\xi, \eta) &= \left[ U_1 \left( \frac{(\xi + \mu\eta)}{2}, -\frac{\text{tg}\beta}{2}((\xi + \mu\eta) - 2\mu h) \right) - \text{tg}\beta \cdot V_1 \left( \frac{(\xi + \mu\eta)}{2}, -\frac{\text{tg}\beta}{2}((\xi + \mu\eta) - 2\mu h) \right) \right], \\ \Psi_{47}(\xi, \eta) &= \left[ \left[ U_1 \left( \frac{(\xi - \mu\eta)}{2} + \mu h, h - \frac{\text{tg}\beta}{2}(\xi - \mu\eta) \right) \right] - V_1 \text{tg}\beta \cdot V_1 \left( \frac{(\xi - \mu\eta)}{2} + \mu h, h - \frac{\text{tg}\beta}{2}(\xi - \mu\eta) \right) \right], \\ \Psi_{48}(\xi, \eta) &= \left[ U_1 \left( \frac{(\xi + \mu\eta)}{2}, -\frac{\text{tg}\beta}{2}((\xi + \mu\eta) - 2\mu h) \right) - \text{tg}\beta \cdot V_1 \left( \frac{(\xi + \mu\eta)}{2}, -\frac{\text{tg}\beta}{2}((\xi + \mu\eta) - 2\mu h) \right) \right], \end{aligned}$$

In order to study the effect of laying on soil parameters, it is necessary to carry out a series of calculations on a PC for areas 2 and 3.

**Conclusion.** Mathematical models of wave propagation under the influence of a moving load on a nonlinearly compressible and irreversible unloading soil layer with a base have been built. An analytical solution is obtained for the problem of the propagation of a plastic wave in the case when the relationship between pressure and volumetric deformation during loading and unloading is linear, but different. Based on the analysis of the calculation results, it is shown that if the moving load acting on the boundary has a monotonically decreasing profile, then in the perturbation region, the medium is unloaded and an oblique compression wave is ob-

tained by the load-unloading wave. The pressure of the medium against the background of this wave, depending on the depth, decreases slowly than on the free surface. In the case when the dependence between  $P$  and under loading of the medium is assumed to be nonlinear and shock, which corresponds to the propagation of a shock wave in the medium, the pressure in the perturbed region, in comparison with the linear case, is somewhat overestimated.

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**MATHEMATICAL MODELS OF PROPAGATION AND  
REFLECTION OF A PLASTIC WAVE IN A BAND LYING ON AN  
ELASTIC HALF-SPACE, WHICH HAS THE PROPERTY OF LINEAR  
COMPRESSIBILITY AND LINEAR IRREVERSIBLE UNLOADING <sup>1</sup>**

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**Abstract.** The problem of the effect of a mobile load on a soil layer of finite thickness lying on a horizontal elastic foundation is considered.

The soil is modeled by an ideal nonlinearly compressible and irreversible unloading medium, in which the relationship between pressure and volumetric deformation under loading and during unloading of the medium is linear and irreversible.

The load is applied to the upper surface of the layer and moves at a superseismic speed. The problem of the effect of a moving load on a two-layer medium consisting of a soft soil layer and an elastic-yielding pad with different thicknesses and densities is considered. The solution to the problem is constructed analytically in both reverse and direct ways.

A two-layer medium consists of a soft soil layer of thickness  $h$  with an elastic deformable base. The soil is modeled by an inelastic ideal medium with linear compressibility and linear irreversible unloading. Consequently, the shear resistance of the medium is neglected. According to this statement, the influence of the deformability of the base and the load profile on the distribution of the dynamic parameters of the layer and the contact surface was investigated.

**Keywords.** Mathematical models, propagation of a plastic wave, half-space, analytical solution, wave front, ideal fluid, linear compressibility,

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irreversible unloading. equation of motion, continuity, states of the environment

**Formulation of the problem.** Let us consider the problem of the propagation of a plastic wave in a two-layer medium with a plane-parallel interface under the action of an intense load of a falling profile moving along its upper boundary with a constant super seismic velocity  $D$ .

A two-layer medium consists of a soft soil layer of thickness  $h$  with an elastic deformable base. The soil is modeled by an inelastic ideal medium with linear compressibility and linear irreversible unloading. Consequently, the shear resistance of the medium is neglected.

According to this statement, the influence of the deformability of the base and the load profile on the distribution of the dynamic parameters of the layer and the contact surface was investigated. The results of the numerical calculation are compared with the results of the acoustic layer and the layer with a rigid base. The solution of the problem is constructed in series, and their convergence is proved.

Let a monotonically decreasing normal load move along the upper boundary of the layer with an elastic base with a speed  $D$  exceeding the speed of wave propagation. The layer material has such a property that, under loading and unloading, the relationship between pressure  $P$  and volumetric deformation  $\varepsilon$  is linear and irreversible, the slope  $E_2$  of the unloading branch of the  $P \sim \varepsilon$  diagram exceeds the slope  $E_1$  of the loading branch, i.e.  $E_1 < E_2$ .

Under the action of the above load, a compression wave  $\Sigma_1$ , first propagates in the layer, which is reached by the contact line of the media, induces a reflected plastic wave  $\Sigma_2$ , in the layer, and in the second medium a system of elastic (longitudinal and transverse) waves  $\Sigma_a$  and  $\Sigma_b$ . At  $E_1 < E_2$  the speed of propagation of the  $AD$  characteristic is greater than the speed of the front  $\Sigma_2$ , therefore, as in the previous section, regions 2, 3, 4, etc. appear. On the  $\Sigma_a$  and  $\Sigma_b$  system, the layer material is instantly loaded, and then in areas 1, 2, 3, the medium is unloaded. Taking into account that the solution of the problem in domains 1 and 2 was obtained in the previous section, below we propose a solution to the problem only in domains 3 of layers and  $\alpha, b$  of the elastic half-plane. For the joint problem of the domain 3,  $\alpha, b$  (5.1.7) holds and the equations for the displacement potentials  $\Phi, \Psi$  the elastic half-plane

$$\mu_1^2 \frac{\partial^2 \Phi}{\partial \xi^2} = \frac{\partial^2 \Phi}{\partial \eta^2}, \quad \mu_2^2 \frac{\partial^2 \Psi}{\partial \xi^2} = \frac{\partial^2 \Psi}{\partial \eta^2}, \quad (1)$$

$$\mu_1^2 = \left( \frac{D}{a_0} \right) - 1, \quad \mu_2^2 = \left( \frac{D}{b_0} \right) - 1, \quad a_0^2 = \frac{\lambda + 2G}{\rho_0}, \quad b_0^2 = \frac{G}{\rho_0}.$$

and according to the d'Alembert formula, their solutions are represented in the form

$$\begin{aligned} \varphi(\xi, \eta) &= f_3(\xi - \mu_1 \eta) + f_4(\xi + \mu_1 \eta), \quad \Phi(\xi, \eta) = F_3(\xi - \mu_1 \eta), \\ \Psi(\xi, \eta) &= F_2(\xi - \mu_2 \eta) \end{aligned} \quad (2)$$

where  $\rho_{02}$ ,  $\lambda$ ,  $G$  – initial density and Lamé coefficients of an elastic medium.

The boundary conditions for this problem are as follows:

at the front of the reflected wave at  $\eta + \xi \operatorname{tg} \alpha = 2h$

$$\operatorname{tg} \alpha (\mathcal{G}_3^* - \mathcal{G}_2^*) = u_3^* - u_2^*, \quad (3)$$

on contact  $AE$  of two media at  $\eta = h$ ,  $\xi \geq \frac{h}{\operatorname{tg} \alpha}$

$$\sigma_{\xi\eta} = 0, \quad D \left( \frac{\partial^2 \Phi}{\partial \xi \partial \eta} + \frac{\partial^2 \Psi}{\partial \xi^2} \right) = \frac{\partial \varphi}{\partial \xi}, \quad P = -\sigma_{\eta\eta}. \quad (4)$$

Here,  $\sigma_{\xi\eta}$ ,  $\sigma_{\eta\eta}$  stress components in an elastic medium. To find the function  $f_4'(t)$  from (3) and (4), taking into account (2), we obtain the functional equation

$$f_4'(\xi) - \lambda_1 f_4'(\lambda_0 \xi + 2\mu h) = -\frac{\lambda_1}{\lambda_0} G_1(\xi), \quad (5)$$

where

$$G_1(\xi) = f_1'(\xi - 2\mu h) + \lambda_0 f_2'(\lambda_0 \xi + 2\mu h),$$

$$A(\lambda, G) = - \left[ \lambda \frac{(\mu_1^2 + 1)(\mu_2^2 - 1)}{2\mu_1} + 2G \left( \frac{\mu_1(\mu_2^2 - 1)}{2} + \mu_2 \right) \right],$$

$$\frac{\lambda_1}{\lambda_2} = - \frac{A(\lambda, G) + \frac{\rho_0 D^2}{\mu} \left( 1 + \frac{\mu_2^2 - 1}{2} \right)}{A(\lambda, G) - \frac{\rho_0 D^2}{\mu} \left( 1 + \frac{\mu_2^2 - 1}{2} \right)}.$$

The solution to equation (5) is constructed by the method of successive approximations. Indeed, taking as the zero approximation

$$f'_{40}(\xi) = -\frac{\lambda_1}{\lambda_0} G_1(\xi).$$

for the first approximation we have

$$f'_{40}(\xi) = -\frac{\lambda_1}{\lambda_0} \left[ G_1(\xi) + \lambda_1 G_1(\lambda_0 \xi + 2\mu h) \right].$$

Then, continuing the iteration process, we obtain a recurrent formula of the form

$$f'_4(\xi) = -\frac{\lambda_1}{\lambda_0} \left[ G_1(\xi) + \sum_{n=1}^{\infty} \lambda_1^n G \left( \lambda_0^n \xi + 2\mu h \frac{(\lambda_0^n - 1)}{(\lambda_0 - 1)} \right) \right]. \quad (6)$$

Research has shown that  $\lambda_1 < 1$ ,  $\lambda_0 < 1$  and  $G_1(\xi)$  are monotonically decreasing functions.

Consequently, according to the d'Alembert criterion, series (6) converges absolutely, and one can set the radius of its convergence. Then the solution of the problem taking into account (6) takes the form

$$P(\xi, \eta) = -\rho_0 D \Psi_{28}(\xi, \eta), \quad (7)$$

$$\mathcal{Q}(\xi, \eta) = -\mu \Psi_{29}(\xi, \eta). \quad (8)$$

where

$$\Psi_{28}(\xi, \eta) = \left\{ G_1(\xi - \mu\eta + 2\mu h) - \frac{\lambda_1}{\lambda_0} G_1(\xi + \mu\eta) + \sum_{n=1}^{\infty} \lambda_1^n G_1 \left[ \lambda_0^n (\xi - \mu\eta + 2\mu h) + 2\mu h \frac{(\lambda_0^n - 1)}{(\lambda_0 - 1)} \right] - \frac{\lambda_1}{\lambda_0} \sum_{n=1}^{\infty} \lambda_1^n G_1 \left[ \lambda_0^n (\xi + \mu\eta) + 2\mu h \frac{(\lambda_0^n - 1)}{(\lambda_0 - 1)} \right] \right\},$$

$$\Psi_{29}(\xi, \eta) = \left\{ G_1(\xi - \mu\eta + 2\mu h) - \frac{\lambda_1}{\lambda_0} G_1(\xi + \mu\eta) + \sum_{n=1}^{\infty} \lambda_1^n G_1 \left[ \lambda_0^n (\xi - \mu\eta + 2\mu h) + 2\mu h \frac{(\lambda_0^n - 1)}{(\lambda_0 - 1)} \right] + \frac{\lambda_1}{\lambda_0} \sum_{n=1}^{\infty} \lambda_1^n G_1 \left[ \lambda_0^n (\xi + \mu\eta) + 2\mu h \frac{(\lambda_0^n - 1)}{(\lambda_0 - 1)} \right] \right\}$$

In this case, the normal stress  $\sigma_{\eta\eta}$  of the elastic half-plane in the regions  $a$  and  $b$  is determined by the formulas

$$\sigma_{\eta\eta} = \frac{\mu(\mu_2^2 - 1) \left( 1 + \frac{\lambda_1}{\lambda_0} \right)}{2D\mu_1 \left( 1 + \frac{\mu_2^2 - 1}{2} \right)} \Psi_{30}(\xi, \eta) + \frac{2G\mu_2\mu \left( 1 + \frac{\lambda_1}{\lambda_0} \right)}{D \left( 1 + \frac{\mu_2^2 - 1}{2} \right)} \Psi_{31}(\xi, \eta), \quad (5.5.9)$$

at  $\xi - \mu_2\eta \geq 0, \quad \eta \geq h$ .

$$\sigma_{\eta\eta} = \frac{\mu(\mu_2^2 - 1) \left( 1 + \frac{\lambda_1}{\lambda_0} \right)}{2D\mu_1 \left( 1 + \frac{\mu_2^2 - 1}{2} \right)} \Psi_{32}(\xi, \eta), \quad (10)$$

At  $\xi - \mu_2\eta \geq 0, \quad \mu = h,$

If  $\lambda \rightarrow \infty$ ,  $G \rightarrow \infty$ , then  $\lambda_1 = -\lambda_0$ , and from (7), (8) for the case of a layer with an absolutely rigid base we have

$$P(\xi, \eta) = -\rho_0 D \Psi_{33}(\xi, \eta), \quad (11)$$

$$\mathcal{Q}(\xi, \eta) = -\mu \Psi_{34}(\xi, \eta). \quad (12)$$

where

$$\Psi_{34}(\xi, \eta) = \left\{ \begin{aligned} & G_1[(\xi - \mu\eta + 2\mu h) - G_1(\xi + \mu\eta)] + \\ & + \sum_{n=1}^{\infty} (-\lambda_0)^n G_1 \left[ \lambda_0^n (\xi - \mu\eta + 2\mu h) + 2\mu h \frac{(\lambda_0^n - 1)}{(\lambda_0 - 1)} \right] - \\ & - \sum_{n=1}^{\infty} (-\lambda_0)^n G_1 \left[ \lambda_0^n (\xi + \mu\eta) + 2\mu h \frac{(\lambda_0^n - 1)}{(\lambda_0 - 1)} \right] \end{aligned} \right\},$$

$$\Psi_{33}(\xi, \eta) = \left\{ \begin{aligned} & G_1(\xi - \mu\eta + 2\mu h) - G_1(\xi - \mu_1\eta) + \\ & + \sum_{n=1}^{\infty} (-\lambda_0)^n G_1 \left[ \lambda_0^n (\xi - \mu\eta + 2\mu h) + 2\mu h \frac{(\lambda_0^n - 1)}{(\lambda_0 - 1)} \right] + \\ & + \sum_{n=1}^{\infty} (-\lambda_0)^n G_1 \left[ \lambda_0^n (\xi + \mu\eta) + 2\mu h \frac{(\lambda_0^n - 1)}{(\lambda_0 - 1)} \right] + \end{aligned} \right\},$$

In the future, based on formula (7)-(12), it is necessary to carry out some calculations on a PC and analyze them.

Note that the above technique allows us to solve the problem of the effect of a moving load on a nonlinearly compressible strip lying on an elastic half-space.

**Conclusion.** The problem of propagation, reflection and a two-dimensional stationary plastic wave in a two-layer medium with densities  $\rho_1$ ,  $\rho_2$  is investigated for the case when the state diagram  $P = P(\varepsilon)$  of the first medium (soil) is shock and under loading has the form  $P(\varepsilon) = \alpha_1 \varepsilon + \alpha_2 \varepsilon^2$ , and the second medium (black rock of a rock or pad) - elastic or rigid plastic. The problem is solved analytically by both direct and inverse methods, taking into account wave processes in the second medium and without taking them into account. Analysis of the results obtained on the PC shows that at  $\rho_1 > \rho_2$  taking into account the elastic - plastic properties of the second medium (spacer), modeled by a half-space, leads mainly to a decrease in the maximum values of stresses (pressure) at the contact of two media. At  $\rho_1 < \rho_2$  a stress concentration appears on the contact surface, and the pressure acquires the highest value in the case of an acoustic layer lying

on a rigid foundation. The qualitative and quantitative picture of changes in the values of pressure and kinematic parameters depends not only on the stiffness characteristics of the media, but also on the ratio of their densities.

Thus, the above studies on the study of the two-dimensional stress-strain state of a homogeneous, inhomogeneous and layered medium under intense action of a mobile load on the boundary of a multilayer half-space confirm the need and importance of taking into account nonlinear, irreversible, wave processes.

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## NOTES

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