

ДИАЛОГ ПОКОЛЕНИЙ: ИЗУЧАЕМ, ОБУЧАЕМ, УЧИМСЯ

**Материалы VI Всероссийской
научно-практической конференции
с международным участием**

Часть II

**DIALOGUE OF GENERATIONS:
LEARN. TEACH. STUDY**

**Proceedings of the VI All-Russian
Research and Practice Conference
with International Participation**

Part II

**Санкт-Петербург
2025**

Министерство науки и высшего образования Российской Федерации
ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ БЮДЖЕТНОЕ ОБРАЗОВАТЕЛЬНОЕ УЧРЕЖДЕНИЕ ВЫСШЕГО ОБРАЗОВАНИЯ
**«Санкт-Петербургский государственный университет
промышленных технологий и дизайна»
Высшая школа технологии и энергетики**

МАТЕРИАЛЫ

VI Всероссийской научно-практической конференции с международным участием

«ДИАЛОГ ПОКОЛЕНИЙ: ИЗУЧАЕМ. ОБУЧАЕМ. УЧИМСЯ»

10–11 апреля 2025 года

Научное издание
2025 • Часть II

*Под общей редакцией заведующего кафедрой иностранных языков,
кандидата филологических наук, доцента В. В. Кирилловой*

Санкт-Петербург
2025

УДК 378.4

ББК 81.2

Д 44

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Д 44 Материалы VI Всероссийской научно-практической конференции с международным участием «Диалог поколений: Изучаем. Обучаем. Учимся» (10-11 апреля 2025 г.). В 2-х частях / Минобрнауки РФ; ФГБОУ ВО «С.-Петерб. гос. ун-т промышленных технологий и дизайна»; под общ. ред. В. В. Кирилловой. — СПб.: ВШТЭ СПбГУПТД, 2025. — Часть II. — 237 с.

ISBN 978-5-91646-443-6

Сборник включает материалы VI Всероссийской научно-практической конференции «Диалог поколений: Изучаем. Обучаем. Учимся» на трех иностранных языках: английском, немецком и французском. Актуальные вопросы педагогики, филологии, экономики, истории, технических и естественных наук представлены преподавателями, аспирантами, магистрантами и студентами различных высших учебных заведений России, Беларуси, Таджикистана и Узбекистана.

Материалы публикуются в авторской редакции. Ответственность за аутентичность и точность цитат, имен, названий и иных сведений, а также за соблюдение законов об интеллектуальной собственности несут авторы публикуемых статей. Организаторы конференции не несут ответственности перед авторами и/или третьими лицами за возможный ущерб, вызванный публикацией статьи.

УДК 378.4

ББК 81.2

ISBN 978-5-91646-443-6

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Ministry of Science and Higher Education of the Russian Federation

FEDERAL STATE BUDGETARY EDUCATIONAL INSTITUTION OF HIGHER EDUCATION

**“Saint Petersburg State University of Industrial Technologies and Design”
Higher School of Technology and Energy**

PROCEEDINGS

**of the VI All-Russian
Research and Practice Conference
with International Participation**

**“DIALOGUE OF GENERATIONS:
LEARN. TEACH. STUDY”**

10–11 April 2025

Scientific publication
2025 • Part II

*Under the general editorship of Head of the Department of Foreign
Languages, PhD in Philology, Associate Professor V. V. Kirillova*

Saint Petersburg
2025

UDC 378.4
BBK 81.2
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D 44 Proceedings of the VI All-Russian Research and Practice Conference with International Participation “Dialogue of Generations: Learn. Teach. Study.” (10-11 April 2025). In 2 parts / Ministry of Education and Science of the Russian Federation; FSBEI HE “Saint Petersburg State University of Industrial Technologies and Design”; under the general editorship of V. V. Kirillova. SPb.: HSTE SPbGUITD, 2025. Part II, 237 p.

ISBN 978-5-91646-443-6

The collection includes the proceedings of the VI All-Russian Research and Practice Conference with International Participation “Dialogue of Generations: Learn. Teach. Study”, published in three foreign languages: English, German and French. Relevant issues of philology, pedagogy, economics, history, technical and natural sciences are discussed in the articles of lecturers, post graduate students, master’s students and students of different universities of Russia, Belarus, Tajikistan and Uzbekistan.

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UDC 378.4
BBK 81.2

ISBN 978-5-91646-443-6

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УДК 330.341.2:334.025

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PROBLEMS OF ENSURING ECONOMIC SECURITY IN THE SPHERE OF PUBLIC PROCUREMENT AND WAYS OF THEIR SOLUTION

Abstract. The article analyzes the role of public procurement in ensuring economic security of the Russian Federation. It considers the impact of the procurement system on economic stability, stimulation of domestic production and the fight against corruption. The problems associated with unfair competition, inefficient use of budgetary funds and violations in the field of procurement are analyzed. Measures to improve transparency and control in procurement are proposed.

Keywords: economic security, public procurement, competition, economic stability, competitiveness, efficiency.

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ПРОБЛЕМЫ ОБЕСПЕЧЕНИЯ ЭКОНОМИЧЕСКОЙ БЕЗОПАСНОСТИ В СФЕРЕ ГОСУДАРСТВЕННЫХ ЗАКУПОК И ПУТИ ИХ РЕШЕНИЯ

Аннотация. Статья посвящена анализу роли государственных закупок в обеспечении экономической безопасности Российской Федерации. Рассматривается влияние системы закупок на экономическую стабильность, стимулирование внутреннего производства и борьбу с коррупцией. Проанализированы проблемы, связанные с недобросовестной конкуренцией, неэффективным использованием бюджетных средств и нарушениями в сфере закупок. Предложены меры по повышению прозрачности и контроля в сфере закупок.

Ключевые слова: экономическая безопасность, государственные закупки, конкуренция, экономическая стабильность, конкурентоспособность, эффективность.

Economic security has a multifactorial and systemic impact on the state of enterprises, being one of the key conditions for their viability, efficiency and development. Preservation and enhancement of the status of the state is directly conditioned by the level of economic security, as well as the ability to resist numerous threats aimed at undermining its financial stability [1, p. 122].

Public procurement is an important mechanism of economic regulation, which has a direct impact on ensuring the economic security of the country. Economic security, understood as the state of protection of the national economy from internal and external threats, largely depends on the efficiency of the use of public resources, including financial, material and human resources. In this context, public procurement performs the function of a tool that contributes to the stabilization of economic processes, maintaining the competitiveness of key industries and ensuring socio-economic sustainability.

Through the public procurement system, budget funds are allocated to meet public needs, such as infrastructure development, healthcare, education and defense industry. As Gladilina I. P., Sergeeva S. A. et al. noted in their works “the procurement system allows solving the problems of effective and timely provision of the state’s needs in goods, works and services” [2, p. 128]. Effective procurement management allows minimizing the risks of corruption, misuse of funds and reducing the quality of goods and services provided, which is directly related to the strengthening of economic security. In addition, public procurement helps to stimulate domestic production, support domestic producers and create conditions for import substitution, which is especially important in the context of global instability and sanctions pressure.

One of the key aspects of the relationship between public procurement and economic security is its role in ensuring financial stability. Inefficient spending of budget funds in procurement activities can lead to destabilization of public finances, increased budget deficit and debt burden. On the contrary, transparency, competitiveness and rationality in procurement contribute to optimizing budget expenditures, increasing confidence in public institutions and strengthening macroeconomic sustainability.

Thus, public procurement acts not only as a tool for implementing public policy, but also as an important factor in ensuring economic security. Their effective organization contributes to minimizing the risks associated with external and internal threats, and also creates prerequisites for sustainable economic development and increasing the competitiveness of the national economy in the international arena.

Public procurement is the most important element of the functioning of the country’s economy, as it not only meets the needs of the state, but also plays a key role in supporting economic stability. However, this sphere faces a number of problems that can threaten economic security. In this article, we will review the main problems, as well as suggest ways to solve them.

The analysis of the problems of ensuring economic security in the context of public procurement reveals a set of systemic threats, among which corruption manifestations occupy a dominant position. Corruption acts in this sphere are characterized by multidimensionality and a high degree of destructive impact on economic processes. Institutional violations in the mechanisms of procurement procedures are often caused by collusion between representatives of government agencies and commercial organizations, which leads to the substitution of the principles of objectivity and competitiveness in the selection of suppliers and contractors.

Classification of corruption offenses in the sphere of public procurement of the Russian Federation includes several key categories of illegal activities [3]. The first category covers the deliberate evasion of competitive procedures for determining the supplier of products or contractor. The second category is represented by actions on the part of the customer aimed at ensuring the victory of an affiliated participant by manipulating the tender documentation, providing insider information to the preferred participant and discrediting competitors through the dissemination of inaccurate data.

A separate group includes financial frauds carried out through the preparation of fictitious acceptance certificates for unfulfilled obligations and the extraction of illegal profits by deliberately understating the quality requirements for the work performed. An additional aspect is the practice of misappropriating payment for work actually performed by the customer's employees within the framework of their official duties, as well as receiving unlawful remuneration for assistance in winning tenders. These corruption manifestations create significant risks for economic security both at the level of individual economic entities and the national economy as a whole, leading to inefficient spending of budget funds and reducing the quality of public services and purchased material goods.

According to economists A. A. Balsevich and E. A. Podkolzina, "the main problem of corruption in the system of public procurement to meet state and municipal needs is the lack of a reliable system of metrics for assessing the effectiveness of the system" [4]. In the context of identifying potential corruption risks in public procurement, a set of metrics and indicators has been developed, including, in particular, the analysis of inconsistency of initial prices with market conditions and the detection of abnormal frequency of victories of individual suppliers, aimed at identifying signs of corruption; however, this toolkit is currently not properly spread in the practice of procurement activities.

One of the significant aspects negatively affecting the efficiency of public procurement is the restriction of competition, which can be determined both by the unfair behavior of individual economic entities and shortcomings in ensuring transparency and information openness of procurement procedures, manifested in a low number of bidders and signs of predetermination of results, which causes suboptimal spending of budget allocations and the emergence of unreasonably high prices.

Another significant factor of inefficiency is the irrational use of budget funds, which is expressed in the acquisition of goods, works and services at inflated prices or in purchases that are not objectively necessary; the insufficient level of subsequent

control over the execution of government contracts potentiates the inconsistency of the results obtained with the planned objectives and, as a consequence, inefficient use of budgetary resources. A widespread problem in the public procurement system is also the inconsistency of the quality of goods supplied, work performed and services rendered with the established requirements and standards, which can be a consequence of both illegal actions of corruption and other abuses, and insufficient qualification or bad faith of participants in procurement activities, as well as defects in the formation of the terms of reference, including incorrect description of the object of purchase. A significant obstacle to participation in public procurement, especially for small and medium-sized businesses, is the excessive complexity and burdensome regulatory and legal regulation of procurement activities, and excessive bureaucratization of procurement processes can determine the violation of the terms of execution of public contracts and the growth of associated administrative costs.

To address the problems associated with corruption and unfair competition in public procurement, a set of measures is proposed, including increased transparency and strengthening of control and oversight functions. In order to increase the transparency of public procurement processes, it is necessary to introduce clearly regulated procedures that minimize opportunities for abuse [5]. A key element of this strategy is to expand the use of electronic trading platforms that provide automated control over the selection of suppliers and reduce the likelihood of manipulation. At the same time, in order to increase the efficiency of the system and reduce the level of offenses, it is advisable to tighten control over compliance with the legislation in the field of public procurement and strengthen liability measures for corrupt practices and unfair practices. At the same time, the Federal Antimonopoly Service (FAS of Russia) plays a leading role in detecting and suppressing corrupt practices by initiating, inter alia, criminal proceedings. However, given the scale of the problem, the activities of the FAS of Russia need to be supplemented by mechanisms of public control. Civil monitoring of public procurement aimed at identifying dubious transactions can become a significant source of information for subsequent actions of law enforcement agencies, providing a synergistic effect in combating corruption.

In 2024, the Federal Antimonopoly Service (FAS) of Russia recorded a 52 % decrease in the number of procurement violations compared to 2023, having identified 17.3 thousand violations as a result of scheduled and unscheduled inspections. In the course of analyzing 33.9 thousand supplier determination procedures, 1.6 thousand orders were issued to eliminate violations of legislation. In addition, the number of complaints from procurement participants considered by the FAS decreased by 31 %, amounting to 31.7 thousand out of the total number of 39.2 thousand complaints received. This decrease is explained by the exclusion from consideration of complaints filed by so-called “professional complainants”. Justified (including partially justified) were recognized 12.6 thousand appeals (39.8 %), which led to the issuance of 11.2 thousand instructions to eliminate the identified violations [6].

As for the Register of Unfair Suppliers (RNP), FAS considered 30.8 thousand appeals for inclusion of information about procurement participants in this register and took 15.2 thousand positive decisions. At the same time, the main reason for inclusion in the RNP in most cases (13.5 thousand) was unilateral termination of the contract [7].

According to the RNP data, in 2024 the register will be replenished with about 17 thousand entries. In accordance with the current procurement legislation, suppliers included in the RNP are deprived of the right to participate in public and corporate procurement for two years.

In order to comprehensively improve the public procurement system, in addition to measures to increase transparency and strengthen control, it is necessary to implement a number of additional areas.

First, systematic professional development of all participants in the procurement process is required. For officials responsible for organizing procurement, it is necessary to continuously update their knowledge of the legislation on the contract system, study law enforcement practices and participate in specialized educational events. Similar training programs focused on the specifics of participation in public procurement should be developed for suppliers. This will minimize the number of errors, unintentional violations and increase the general level of legal literacy of market participants.

Second, stimulating competition is a critical factor for procurement efficiency. In this regard, the elimination of administrative and other barriers to the participation of small and medium-sized enterprises (SMEs) in public procurement, including by simplifying procedures, adapting requirements and possible quotas, contributes to expanding the range of potential suppliers and improving the quality of proposals.

Thirdly, the development of a system of monitoring and auditing of contract performance is an integral element of ensuring the efficiency of budget spending. Establishment of independent bodies controlling the quality of performance of government contracts, as well as the development and implementation of automated systems of verification, makes it possible to timely identify and prevent violations.

And, fourthly, the introduction of anti-corruption technologies is a priority area for improving the public procurement system. Legislative enshrinement of clear and unambiguous rules limiting the discretionary powers of customers is a basic condition for minimizing corruption risks. Along with this, it is necessary to use other mechanisms, such as the strategy of limiting state intervention in the economy, integration of market relations tools into the public procurement management system and introduction of public consumption standards. The use of distributed registry technologies (blockchain), electronic signatures and digital document management helps to increase transparency of procurement procedures, reduce the likelihood of manipulation and strengthen confidence in the system.

Thus, public procurement plays a key role in ensuring economic security, directly affecting the stability of the economy and the development of key industries. However, corruption risks, ineffective control mechanisms, restriction of competition and insufficient transparency of procurement procedures significantly reduce the efficiency of budget funds utilization. Addressing these problems requires a comprehensive approach, including transparent procedures, strengthening control and responsibility, introducing innovative technologies and improving the skills of procurement process participants. The implementation of these measures will contribute to strengthening economic security, increasing the competitiveness of domestic producers and improving the efficiency of spending public resources.

Список литературы:

1. Афанасьева, Н. В. Государственный заказ как инструмент макроэкономического регулирования экономики / Н. В. Афанасьева. – Санкт-Петербург: СЗТУ, 2009. – 160 с. – Текст : непосредственный.
2. Гладилина, И. П. Совершенствование управления закупочной деятельностью в условиях цифровизации на основе мониторинга закупок / И. П. Гладилина, С. А. Сергеева. – Текст : электронный // Финансовые рынки и банки. – М., 2020. – № 3. – С. 128-132. – URL: <https://cyberleninka.ru/article/n/sovershenstvovanie-upravleniya-zakupochnoy-deyatelnostyu-v-usloviyah-tsifrovizatsii-na-osnove-monitoringa-zakupok/viewer> (дата обращения: 05.02.2025).
3. Храмкин, А. А. Противодействие коррупции в госзакупках / А. А. Храмкин – М. : Юриспруденция, 2011. – 152 с. – URL: https://goszakupki.tatarstan.ru/rus/file/pub/pub_102137.pdf (дата обращения: 25.02.2025). – Текст : электронный.
4. Бальсевич, А. А. Влияние структуры розничного рынка на цены государственных контрактов / А. А. Бальсевич, Е. А. Подколзина; Нац. исслед. ун-т «Высшая школа экономики». – М. : Изд. дом Высшей школы экономики, 2013. – 35 с. – URL: https://wp.hse.ru/data/2013/12/19/1338994170/WP10_2013_02.pdf (дата обращения: 25.01.2025). – Текст : электронный.
5. Репина, С. И. Проблемы доступа субъектов малого и среднего предпринимательства к государственным закупкам / С. И. Репина. – Текст: непосредственный // Международный журнал гуманитарных и естественных наук. – 2019. – № 6. – С. 235–237.
6. Федеральной антимонопольной службы: [Официальный сайт]. – URL: <https://fas.gov.ru/> (дата обращения: 21.02.2025). – Текст : электронный.
7. Единая информационная система в сфере закупок: [Официальный сайт]. – URL: <https://zakupki.gov.ru> (дата обращения: 28.02.2025). – Текст : электронный.

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CLASSIFICATION OF SUBTYPES OF HUMAN POTENTIAL AND CAPITAL

Abstract. The paper provides a brief overview of theoretical developments in the problem of studying subtypes of human potential and capital in scientific literature. Subtypes of human potential and capital are considered, their classification is given, and the main and auxiliary subtypes are identified. Current examples of subtypes of human potential and capital are provided.

Keywords: subtypes of human potential and capital, spiritual, intellectual and innovative, organizational, entrepreneurial, social, cultural, vital human potential and capital.

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КЛАССИФИКАЦИЯ ПОДВИДОВ ЧЕЛОВЕЧЕСКОГО ПОТЕНЦИАЛА И КАПИТАЛА

Аннотация. В работе представлен краткий экскурс по теоретическим разработкам проблемы исследования подвидов человеческого потенциала и капитала в научной литературе. Рассматриваются подвиды человеческого потенциала и капитала, дается их классификация, выделяются основные и вспомогательные подвиды. Приводятся актуальные в настоящее время примеры подвидов человеческого потенциала и капитала.

Ключевые слова: подвиды человеческого потенциала и капитала, духовный, интеллектуальный и инновационный, организационный, предпринимательский, социальный, культурный, витальный человеческий потенциал и капитал.

The study of subtypes of human potential and capital remains relevant at the present time. There is a lack of research into the remaining subtypes within human potential and capital within the framework of a narrow approach to understanding their essence, their interrelation, interaction and development at the present stage of development of man, economy and society. Certain issues of comparison of the subtypes of human potential and capital themselves remain poorly studied: their significance for man, similarities and differences, interrelation and interaction with each other. Unique and phenomenal features of spiritual, religious and Orthodox

subtypes of human potential and capital are interesting. In addition, it is necessary to highlight the modern processes of development of the considered subtypes of human potential and capital, their joint and unique development, as well as to conduct a study of the existing institutional system and environment in which these processes occur.

The above issues and problems predict the need to continue the study of the subtypes of human potential and capital, which we conducted in our earlier works. In this paper, we consider it possible to attempt to continue conducting similar studies of various issues related to the subtypes of human potential and capital.

In the scientific literature, extensive studies of all human capital have long been conducted. These are the well-known works of L. Walras, J. Kendrick [1], A. Marshall [2], I. Fisher [3], etc.

The foundations of the modern theory of human capital were laid by foreign scientists G. Becker [4], D. Mintzer, L. Thurow, T. Schultz, and domestic ones – M. A. Bendikov [5], V. S. Goylo [6], A. I. Dobrynin [7], S. A. Dyatlov [8], R. I. Kapelyushnikov, L. S. Shakhovskaya [9], V. V. Klochkov [10], L. G. Simkina [11], etc.

At present, studies of some subtypes of human capital are appearing separately. These are the works of both domestic and foreign economists.

Social, entrepreneurial, organizational, cultural, social and vital human potentials and capitals have been studied less.

Also, recently, interest in the study of spiritual capital has increased (N. M. Tyukavkin [12], O. A. Karpenko [13], L. V. Levchenko [14, 15]).

Human potential and capital consist of their individual subspecies: spiritual, vital, intellectual and innovative, social, entrepreneurial, organizational and cultural ones.

Spiritual potential and capital also partially include all subspecies of human capital, but for the convenience of research they can be distinguished as a separate subspecies of human potential and capital. The remaining subspecies are formed around the spiritual potential of capital, which constitute the core of all human potential and capital. Spiritual potential and capital are the first necessary subspecies. We will consider spiritual potential and capital in a separate chapter.

Graphically, all subtypes of human potential and capital can be placed in the form of circles around the general spiritual potential and capital.

The main subtypes of human capital participating in economic life and income generation are vital potential and capital, intellectual potential and capital, entrepreneurial potential and capital, organizational potential and capital.

We will consider each subtype in more detail in our study.

Vital potential and capital

The vital potential and capital of a person play the primary and most important role in his life; they are vitally important for a person and in most cases determine the quality of his life. Without a healthy and developed vital potential and capital as a reserve of health, vital energy and strength, mood, vital activity, correct direction, as well as the vital capabilities of the physical body, including an expanded vital potential and capital of the family, a person will not be able to fully develop, work and interact in society, realize all his other potential and capital, because he simply will not have

enough strength and energy for this.

In this regard, vital potential and capital are fundamental and basic for a person in one way or another. Along with this, there are professions and activities for which vital potential and capital are the main professional ones, where a person works with his body, and professional success and career development depend on the state of his vital capital and capabilities. These are the professions of dancers, ballet dancers, athletes, models, as well as manual workers – loaders, welders, etc. Here, vital capital becomes the main professional subtype of human capital and directly creates value within the framework of participation in the reproduction process of human capital.

Intellectual potential and capital

A person's intellectual potential and capital as the value of knowledge, skills, abilities and capabilities, especially at the present time, are the main professional subtype of human potential and capital. These are the professions of a doctor, lawyer, economist and accountant, programmer, researcher, managerial positions, etc.

At the same time, intellectual potential and capital actively participate and create value within the framework of participation of human capital not only in professional activity (reproduction process) and human life, but also in social activity, in everyday life, etc.

Intellectual potential and capital are most clearly represented in the intelligentsia. The intelligentsia is a special community of people engaged in mental work, striving to accumulate and organize existing knowledge [16]. Internal intelligence is impossible without a broad outlook and great internal experience, as well as constant openness to the new. A person's desire for analysis and synthesis, conclusions, details and patterns, the desire to learn and curiosity can be characterized as internal intelligence in combination with high internal moral and spiritual qualities. And in the case of a person's religiosity, spiritual qualities are based on the basis of religious qualities and developed religiosity.

Entrepreneurial potential and capital

Entrepreneurial potential and capital are the main resources for entrepreneurs and people engaged in entrepreneurial activity in their free time, since they are the main production resources that create value within the framework of the participation of human capital in this production entrepreneurial activity. They cannot be auxiliary.

Organizational (managerial) potential and capital

Organizational (or managerial) potential and capital are the main ones for managers and executives, individual entrepreneurs, project managers, etc. employees of organizational and managerial activities, whose main task in their activities is management.

In other cases, organizational potential and capital serve as auxiliary potential and capital on the basis that they help to organize their work and other activity processes, streamline all processes and objects, align various systems and processes, etc.

Thus, we see that vital, intellectual, entrepreneurial and, with reservations, organizational potential and capital are the main ones in the system of subtypes of human potential and capital and create value within the framework of the participation of human capital in the professional plan in the reproduction process.

Auxiliary or less significant subtypes of human potential and capital that contribute to the increase or appearance of income are innovative potential and capital, social potential and capital, cultural potential and capital.

In this study, we will consider each subtype in more detail.

Here we do not consider those professions for which social and cultural capital are the main ones – for example, a deputy, a public figure, an actor, a figure in the field of culture and art.

Innovative potential and capital

Innovative potential and capital are mainly auxiliary in any activity. They provide innovative development and creation of novelties and innovations in any type of activity and production.

The exceptions are, for example, innovative companies, design bureaus, etc. organizations and departments whose subject of activity is the creation of innovations. Here, for such activities and such companies, innovative potential and capital are the main resources.

Representatives of any professions and fields of activity can have developed innovative potential and capital.

Social potential and capital

Social potential and capital are also mainly auxiliary for a person. They enable the creation of social contacts and connections, the creation and development of relationships between people, develop a person socially, teach communication and interaction with people, etc. Developed and broad social potential and capital give a person a lot: greater opportunities in life and career, more meetings with people, more events, travel, and in general lead to a more active, productive and interesting life. They are developed in representatives of the public, social activities and work, in politicians, and also in entrepreneurs.

The exceptions here are professional public figures, social workers, managers and workers of social projects, as well as psychologists, for whom social potential and capital are the main ones in their activities and create value within the framework of human capital participation.

Cultural potential and capital

Cultural potential and capital, along with the above-mentioned subtypes, are also often auxiliary. They are developed in representatives of culture and art. They help a person in relationships in a team, in behavior in society, when communicating with colleagues at work and with other social groups. And their importance in general is quite high, since knowledge of etiquette, good manners, the ability to dress, the ability to behave and maintain a small talk, knowledge of literature and art and other cultural skills are highly valued and welcomed in society.

The exceptions here are workers in culture and art, for whom cultural potential and capital are the main ones, creating the value of the product. These are cultural and artistic figures, art historians, tour guides, etc.

Thus, the considered subtypes of human potential and capital – innovative, social and cultural – are mainly auxiliary for a person and additionally help with the creation of value or accompany its creation, with the exception of those specific professions and types of activity for which they are the main creators of value within the framework of

the participation of human capital in the professional plan in the reproduction process.

Список литературы:

1. Кендрик, Дж. Совокупный капитал США и его функционирование / Дж. Кендрик. – М. : Прогресс, 1976. – 275 с. – Текст : непосредственный.
2. Маршалл, А. Принципы экономической науки / А. Маршалл. – М. : Прогресс, 1993. – 594 с. – Текст : непосредственный.
3. Фишер, И. Построение индексов: учение об их разновидностях, тестах и достоверности / И. Фишер; перев. с 3-го американск. изд. А. С. Яновского. – Москва : Центр. стат. упр-ние СССР, «Мосполиграф» Центр. полиграф. школа ФЗУ им. т. Борщевского, 1928. – 464 с. – Текст : непосредственный.
4. Беккер, Г. С. Экономический анализ и человеческое поведение / Г. С. Беккер. – Текст : непосредственный // THESIS. – 1993. – Т. 1, вып. 1. – С. 24-40.
5. Бендилов, М. А. О гармонизации развития инновационной инфраструктуры и национальной инновационной системы / М. А. Бендилов. – Текст : непосредственный // Прикладная информатика. – 2009. – № 5 (23). – С. 121-128.
6. Гойло, В. С. Современные буржуазные теории воспроизводства рабочей силы: крит. очерк / В. С. Гойло; АН СССР, Ин-т междунар. рабочего движения. – Москва : Наука, 1975. – 231 с. – Текст : непосредственный.
7. Добрынин, А. И. Региональные пропорции воспроизводства / А. И. Добрынин; М-во высш. и сред. спец. образования РСФСР. – Ленинград : Изд-во Ленингр. ун-та, 1977. – 127 с. – Текст : непосредственный.
8. Дятлов, С. А. Теория человеческого капитала: учеб. пособие / С. А. Дятлов; С.-Петербург. ун-т экономики и финансов, каф. общ. экон. теории. – СПб. : Изд-во С.-Петербург. ун-та экономики и финансов, 1996. – 141 с. – Текст : непосредственный.
9. Шаховская, Л. С. Регионалистика : учебное пособие / Л. С. Шаховская, М. В. Плешакова, Л. П. Курбатова, А. Г. Кравец. – Москва : КНОРУС, 2017. – 234 с. – Текст : непосредственный.
10. Ключков, В. В. Человеческий капитал и его развитие. Экономическая теория. Трансформирующаяся экономика / В. В. Ключков. – М. : ЮНИТИ, 2004. – 406 с. – Текст : непосредственный.
11. Симкина, Л. Г. Человеческий капитал в инновационной экономике / Л. Г. Симкина. – Санкт-Петербург: ИНЖЕКОН, 2000. – 152 с. – Текст : непосредственный.
12. Тюкавкин, Н. М. Духовность экономики / Н. М. Тюкавкин. – Текст : непосредственный // Вестник СамГУ. – 2013. – № 7 (108). – С. 95-100.
13. Карпенко, О. А. Современное интеллектуально-духовное развитие России в начале второго десятилетия XXI века / О. А. Карпенко. – Текст : непосредственный // XII Южно-российский политологический конвент «Современные риски и кризисы: политический анализ и прогноз»: материалы

Всероссийской онлайн-конференции с международным участием. – Ростов-на-Дону, Таганрог, 2022. – С. 63-67.

14. Карпенко, О. А. Взаимосвязь и взаимодействие отдельных подвидов в составе человеческого капитала / О. А. Карпенко, Л. В. Левченко. – Москва, 2024. – 109 с. – Текст : непосредственный.

15. Карпенко, О. А. Развитие основных подвидов человеческого капитала в условиях современной экономики / О. А. Карпенко, Л. В. Левченко. – Текст : непосредственный // Технологические инновации и научные открытия: сборник трудов по материалам XII Международного конкурса научно-исследовательских работ. – Уфа, 2023. – С. 165-174.

16. Интеллигентность. Психология и психиатрия : [сайт]. – 2025. – URL: <https://psihomed.com/intelligentnost/> (дата обращения: 10.02.2025). – Текст : электронный.

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FUNCTIONING OF SPIRITUAL REPRODUCTION IN THE MODERN ECONOMY

Abstract. The article provides a brief overview of the development of the theory of spiritual production, and examines the process of spiritual reproduction in the modern economy. The economic foundations of spiritual production and its features are indicated. The reproduction process and the creation of value, the connection between spiritual capital and subspecies of human capital are considered.

Keywords: spiritual potential and capital, spiritual production and reproduction, spiritual activity and labor, spiritual resources, spiritual products and services, intellectual and spiritual activity, intellectual and spiritual capital, spiritual resources, resources of spiritual production.

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ФУНКЦИОНИРОВАНИЕ ДУХОВНОГО ВОСПРОИЗВОДСТВА В СОВРЕМЕННОЙ ЭКОНОМИКЕ

Аннотация. В статье представлен краткий обзор развития теории духовного производства, а также рассматривается сам процесс духовного воспроизводства в современной экономике. Описываются экономические основы духовного производства и его особенности. Рассматриваются процессы воспроизводства и создания ценности, связь духовного капитала с подвидами человеческого капитала.

Ключевые слова: духовный потенциал и капитал, духовное производство

и воспроизводство, духовная деятельность и труд, духовные ресурсы, духовные продукты и услуги, интеллектуально-духовная деятельность, интеллектуально-духовный капитал, духовные ресурсы, ресурсы духовного производства.

Recently, and especially in connection with the events of the Special Military Operation (SMO), the need to introduce the population to spiritual and religious culture has increased. And, accordingly, the role of spiritual capital and production in all areas and spheres of activity also increases. Its role is especially increasing in the social, cultural and intellectual spheres due to the existence of a close connection between the spiritual, cultural, intellectual and social directions in a person depending on his spiritual level and development. And, accordingly, the role of spiritual capital and production in all areas and spheres of life also increases, including a growing emphasis on the spiritual in economic activity and processes.

In modern scientific works, research is conducted on the place of spiritual capital in the human capital system, the essence and components of spiritual capital, its role in economic and social life are considered.

The problem of spiritual production has been poorly studied in economic science. Some of its postulates are contained in the works of K. Marx, [1] F. Engels [2] and others. This issue has also been studied in our works [3, 4, 5, 6].

In the 60–70s of the 20th century, the activity-based approach to the study of production and its division into material and spiritual was reflected in the works of V. Zh. Kelle [7], M. Ya. Kovalzon [8], K. Kh. Momdzhyan [9] and others.

In the works of modern scientists, there are comparatively few studies on spiritual production (for example, in the works of N. P. Ragozin [10], A. K. Pavlov [11], Yu. V. Batalov [12] and others).

At first, the spiritual needs of man did not exist separately from the material ones. And only later, as the production of material goods created the necessary conditions for this (stable reproduction of surplus production), spiritual production turned into an independent industry.

However, at the same time, the very existence of spiritual production in the economy raises questions and the processes of its functioning remain unstudied.

Today, the very concept of spiritual production is used in several meanings.

Spiritual production as the creation of ideas, opinions, models, samples, projects, etc. precedes any material production. This is human activity associated with the creation, distribution, exchange and consumption of spiritual values (scientific works, literary works, works of architecture and sculpture, music, painting, films and television programs, etc.), which carry the ideas, views, images, feelings, assessments, representations, etc. created by their authors. It is as necessary as material production. In the sphere of distribution and development of spiritual values, spiritual production covers education, moral and aesthetic education and other forms of introduction to spiritual culture.

It is also stated in literature that spiritual production is an activity that ensures the formation of consciousness of people and an individual, which becomes the most important condition for human communication, interaction and joint activities of individuals. Here we are talking, for example, about how the possibility of

communication through chats in instant messengers on phones and social networks, etc. appeared in people's consciousness. In our opinion, this is certainly an important moment of modern spiritual production, but its definition should not be limited to this and is much broader than the elements that form a new consciousness, it also includes elements of creativity, art, intellectual, creative, spiritual activity, etc.

Spiritual production is also production aimed at creating goods and services that represent spiritual values, for example, writing songs, poems, literary and other works, etc. It also has a material expression – publishing collections of poems and literature, replicating songs, launching films for distribution, etc.

There are two subgroups of industries in spiritual production:

- Spiritual creativity – science, art, literature.
- Dissemination of knowledge – education, culture, information.

Spiritual production is also production in the spiritual and religious sphere, for example, creating icons, building churches, writing church books, etc. Here it also has a large material production. Let us consider the distinctive features of spiritual production. The main feature of spiritual production is that it exists not only to meet the needs of society for spiritual goods, but also contributes to the self-realization of the creator of these goods.

At the same time, the revelation of the meaning of a spiritual product can occur much later than its creation (remember all the writers who were unrecognized during their lifetime, for example).

Distinctive features of spiritual production are as follows:

1. A person will be both an object (formed as a spiritual personality consuming spiritual values) and a subject of spiritual production.

2. The results of production are individual, they have the attributes and characteristics of those personalities who created them.

3. Products of spiritual production can be consumed by all of humanity. The means of production (ideas, images) are inseparable from the producer. Modern production activity, especially high-tech, is inseparable from scientific ideas and principles. It is based on those developments that are the result of the functioning of the intellect.

4. The final product represents ideal formations that cannot be alienated from their direct producer.

5. The results of spiritual activity cannot be measured by traditional production methods (kilograms, liters, etc.), they often cannot be evaluated quantitatively. A qualitative approach is mainly used to evaluate them.

6. Material goods are limited, whereas spiritual goods are inexhaustible and have no limitations.

7. Spiritual production is valuable in itself (the process itself is valuable). Works of art cannot be separated from the process of creation and their creator.

8. Spiritual production is both the result and the prerequisite for the work of public consciousness. And at the same time, it is a way of self-realization of the creator of intangible goods.

9. It is almost impossible to draw a clear distinction between the two main spheres of human activity – material and spiritual. The created spiritual product

requires its recording on material media, which can be books, works of art, electronic computers, etc.

10. There is often a gap between the moment of creation of a spiritual product and the time of disclosure of its meaning to other people.

11. Spiritual activity is valuable in itself, it has significance often regardless of the result. This is almost never the case in material production.

12. In the area of material goods, it is not their creator who is valued more, but their owner. In spiritual production, everything is different, the creator and author are valued much more, and there are a large number of owners of goods.

13. In the material sphere, the overwhelming majority of members of society are offered the labor itself, while the product is withdrawn. In the sphere of spiritual activity, on the contrary, the majority are offered the products of spiritual labor (ideas, images, principles, etc.), while the process of their creation remains inaccessible. That is, the division of production and consumption is also evident in spiritual production, but it occurs in the opposite way.

14. The results of spiritual production – the ideas of people or groups of people specifically engaged in spiritual production, that is, what can be achieved only through consciousness, creativity, thoughts, recognized as the best through their evaluation by society, become the property of the spiritual culture of society.

The main difference between spiritual and material production is the universal nature of its consumption.

Despite the presence of a number of common points with material production, spiritual production has its own specifics. The subject of labor in it is not only nature and natural substances, but also social progress in all the wealth of its social connections, human thinking and human activity.

The totality of the processes of spiritual production, distribution, exchange and consumption represents a single process of spiritual reproduction.

Before proceeding to the study of the processes of functioning of spiritual reproduction in the economy, we will define the basic concepts that will be useful to us in this section.

In modern spiritual production, in connection with the increasing role of knowledge and information, the main type of activity and the corresponding capital is intellectual and spiritual activity and capital.

Intellectual and spiritual activity is simultaneously the activity of the spirit and mind, associated with the transformation of reality with the help of the abilities of rational knowledge with the simultaneous transformation of the spirit, spiritual space and environment.

Intellectual and spiritual capital is the combined relationship of intellectual and spiritual capital, the value of human knowledge, skills, abilities, as well as spiritual values, goals, guidelines, qualities and knowledge of intellectual and spiritual talents capable of generating or increasing income.

The intellectual and spiritual component is present in almost every type of creative activity, and especially in socially useful and socially significant types of activity, where the spiritual component is more clearly expressed.

Intellectual and spiritual activity, as well as intellectual and spiritual work, are

closely intertwined and interconnected. Often, the spiritual cannot exist without the intellectual, and the intellectual has even less meaning without the spiritual. All three types of work and activity are closely intertwined, interconnected and interdependent.

In the economy, physical labor and activity cannot occur without intellectual and even less so without spiritual.

Intellectual and spiritual work is a process of consuming intellectual and spiritual strength and applied human energy.

Spiritual resources are the means that produce social forms of consciousness, these include information, knowledge, intelligence, abilities for spiritual and intellectual activity and creativity.

Resources of spiritual production are resources necessary and applicable in spiritual production: people and their consciousness, abilities, motives for spiritual and intellectual activity and creativity, abilities and opportunities for prayer and blessing, etc.

Basically, intellectual and spiritual labor and capital of a person participate in spiritual production, but his social, cultural, organizational and even entrepreneurial subtypes of human capital also participate.

Let us identify the main economic foundations of spiritual production. They are:

- production of spiritual products in the form of economic goods and services;
- commodity form of a spiritual product;
- the presence of economic conditions of production in the form of human spiritual needs and rare, limited spiritual resources;
- economic choice of the method and order of satisfying spiritual needs based on a comparison of results and costs;
- spiritual consumption is also an act of spiritual production.

Let us define the economic features of the modern development of spiritual production:

- The spiritual needs include their highest forms – self-realization, fulfillment of the purpose and mission of a person.
- Spiritual resources are replenished with new types of resources – knowledge and information.
- There is a transformation of the commodity form of the spiritual product, which takes the form of information, files, etc.

The functioning of spiritual capital occurs in the reproduction process.

In the process of reproduction, spiritual capital can be individual and, less often, collective (when creating groups of people close in spirit and spiritual qualities), which contributes to better and more coordinated work of the entire team.

Spiritual capital participates in the reproduction process, for example, the provision of consulting services (legal, psychological, etc.), making its circulation in the system of production, distribution, exchange and consumption.

The primary difference between intellectual capital and spiritual capital, from which all further differences follow, is the very nature of the two subtypes of human capital – material and spiritual.

Along with this, the main difference between intellectual capital and spiritual

capital is the fact that intellectual capital participates in the production process only as intellectual capital and a factor of production of “knowledge”, while spiritual capital in the reproduction process can participate not only in conjunction with intellectual capital, but also with other subtypes of human capital:

- with vital or biophysical and the “labor” factor (when performing various jobs),
- with entrepreneurial and the “entrepreneurship” factor (when creating entrepreneurial projects),
- with social and the “information” factor (when creating social projects, social and public events),
- with intellectual and the “knowledge” factor (when writing books, scientific articles and other intellectual activities),
- with cultural capital and the “labor” factor (when creating works of art, holding cultural events).

And the corresponding types of income are also obtained:

- wages for the “labor” factor,
- entrepreneurial income for the “entrepreneurship” factor,
- a portion of the profit, interest on capital, rent or wages for the “information” factor,
- a portion of the profit, rent or wages for the “knowledge” factor.

It is especially significant that spiritual capital can participate in the reproduction process as various subtypes of human capital and various factors of production, and also receive corresponding various types of factor income. At the same time, it can participate both as one of the subtypes of human capital (for example, intellectual or entrepreneurial), and as several subtypes of human capital simultaneously (for example, intellectual and social, vital and social, intellectual and entrepreneurial, social and cultural), which is undoubtedly its unique feature.

And the third most important feature of spiritual capital in the reproduction process is that a person with high spirituality and developed spiritual capital transforms all relationships and processes around him in a positive direction, ultimately, contradictions and conflicts are resolved, problems are solved, tasks are accomplished, new and competent specialists arrive, production processes develop, etc. And such a person, possessing high spiritual qualities, even despite his possible incomplete literacy in something, or lack of experience, becomes very necessary in production, he is noticed and promoted, trusted with work and management of teams. And, conversely, if such a person is unfairly offended or has to quit, then everything can go wrong at this enterprise and many problems will appear, because spiritual energy is the most scarce energy and it manifests itself in the world only through such people.

Spiritual capital, as well as intellectual capital, participates in the reproduction process, for example, the provision of consulting services (legal, psychological, etc.), making its circulation in the system of production, distribution, exchange and consumption.

The process of creating value occurs through human labor and activity – physical, intellectual and spiritual.

And if activity and labor can be not only physical and intellectual, but also purely

intellectual, then the spiritual component is present in all types of labor and activity.

Physical labor can create value only together with some share of intellectual labor, as well as spiritual labor, since such labor must be socially necessary and useful.

And only spiritual labor and spiritual activity are socially necessary and useful, i.e. any activity that is socially necessary and has a spiritual component.

Abstract labor, which creates value, also contains both physical and intellectual and spiritual labor. It exists in the form of physiological expenditure of human labor power and his vital energy. This is homogeneous impersonal productive labor, comparable to the labor of another person. It creates the real value of the goods.

Thus, three types of labor and activity take part in a single complex process and a single mechanism for creating the value of goods and services.

We also see many positive differences between religious and spiritual production and ordinary production, which speaks in favor of its constant further development.

Список литературы:

1. Маркс, К. Немецкая идеология: соч. Т. 3 / К. Маркс, Ф. Энгельс. – 2-ое изд. – Москва : Политиздат, 1955. – С. 7-544. – Текст : непосредственный.
2. Момджян, К. Х. Социальная философия. Деятельностный подход к анализу человека, общества, истории : учебник для студентов высших учебных заведений, обучающихся по направлению подготовки ВПО 03100 «Философия» / К. Х. Момджян; Московский гос. ун-т им. М. В. Ломоносова. – Москва : Изд-во Московского ун-та, 2013. – 22 с. – Текст : непосредственный.
3. Карпенко, О. А. Духовный капитал в экономической науке / О. А. Карпенко. – Москва, 2023. – 96 с. – Текст : непосредственный.
4. Карпенко, О. А. Духовный потенциал и капитал в современной экономической теории и прикладной экономике / О. А. Карпенко. – Москва, 2022. – 100 с. – Текст: непосредственный.
5. Карпенко, О. А. Духовный капитал в современной микро- и макроэкономике / О. А. Карпенко. – Москва, 2018. – 67с. – Текст : непосредственный.
6. Карпенко, О. А. Духовное, интеллектуальное и социальное развитие в современной экономике и обществе в начале 20-х годов XXI века / О. А. Карпенко, Л. В. Левченко. – Текст : непосредственный // Социальная безопасность в евразийском пространстве: материалы III международной научной конференции. – Москва-Тюмень, 2024. – С. 86-92.
7. Келле, В. Ж. Курс исторического материализма: / В. Ж. Келле, М. Я. Ковальзон. – 2-е изд., перераб. и доп. – Москва : Высш. школа, 1969. – 431 с. – Текст : непосредственный.
8. Ковальзон, М. Я. Общественное сознание и общественные науки / М. Я. Ковальзон, д-р филос. наук, Н. И. Макешин, канд. техн. наук. – Москва : Знание, 1973. – 64 с. – Текст : непосредственный.
9. Момджян, К. Х. Социальная философия. Деятельностный подход к анализу человека, общества, истории: учебник для студентов высших учебных

заведений, обучающихся по направлению подготовки ВПО 03100 «Философия» / К. Х. Момджян; Московский гос. ун-т им. М. В. Ломоносова. – Москва : Изд-во Московского ун-та, 2013. – 22 с. – Текст : непосредственный.

10. Рагозин, Н. П. Понятие «духа» в ранних работах К. Маркса : становление концепции духовного производства / Н. П. Рагозин. – Текст : непосредственный // Культура и цивилизация. – 2018. – № 2(8). – С. 8 -19.

11. Павлов, А. К. Духовное производство и духовное потребление / А. К. Павлов. – URL: <https://infourok.ru/pavlov-a-k-duhovnoe-proizvodstvo-i-duhovnoe-potreblenie-nauchnaya-statya-5518728.html> (дата обращения 12.01.2025). – Текст : электронный.

12. Пилипенко, Е. В. Духовное производство как основа экономической теории / Е. В. Пилипенко, Ю. В. Баталов. – Текст : непосредственный // Известия ИГЭА. – 2013. – № 1 (87). – С. 8 -12.

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THE PROCESS OF IMPLEMENTING IP TELEPHONY IN THE ACTIVITIES OF THE ORGANIZATION

Abstract. The advantages and risks of implementing IP telephony in the activities of the organization are considered, a brief overview of domestic sources on this topic is given. It is concluded that the topic is scarcely studied from the economics point of view. The results of the implementation of IP telephony “Mango Office” in the activities of the organization are recorded. After implementation, calls were reduced by 19 minutes per day, and communication costs were reduced by 37 %.

Keywords: process, implementation, VoIP, IP telephony, activities of the organization, Mango Office.

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ПРОЦЕСС ВНЕДРЕНИЯ IP-ТЕЛЕФОНИИ В ДЕЯТЕЛЬНОСТЬ ОРГАНИЗАЦИИ

Аннотация. В статье представлен анализ достоинств и потенциальных угроз внедрения технологий VoIP в организациях, а также обзор основных российских исследований, посвященных этой теме. Сделан вывод о том, что данная тема в отечественной науке с экономической точки зрения практически не изучена. Описаны результаты внедрения IP-телефонии «Манго Офис» в деятельность организации. После внедрения звонки сократились на 19 минут за день, а расходы на коммуникацию снизились на 37 %.

Ключевые слова: процесс, внедрение, VoIP, IP-телефония, деятельность организации, Манго Офис.

The IP protocol is a universal platform that provides voice, video and other data transmission. Global telecom operators are actively investing in the development of their own IP-based infrastructures, which makes this system increasingly attractive in the context of rising tariffs for traditional telephone services. Thanks to digital transmission and data compression, IP telephony significantly reduces the cost of calls, especially international ones, and opens up opportunities for communication via Internet services with advanced functionality [1]. However, the capabilities of IP

telephony go beyond simple economic gain. The corporate sector requires high mobility, reliable interaction between employees, integration with IT infrastructure and access to a variety of voice solutions and additional services. In modern conditions, small and medium businesses are actively implementing IP telephony, primarily to reduce the cost of long-distance communication. Improving the quality of Internet connections contributes to this process. However, when implementing VoIP, it is necessary to take into account the risks associated with security threats: wiretapping, service failures and cyber-attacks on devices [2].

However, along with many advantages, IP telephony also carries certain risks. The main ones include:

1. The possibility of intercepting conversations by simply obtaining data.
2. Denial of service, which can be implemented both physically and through IP DoS attacks.
3. Theft of services, for example, by replacing the IP address of the device.
4. Hacking IP telephony equipment, including computers with the appropriate software, which is not so difficult. IP telephony software is available and inexpensive. Popular products are Mango, Novofon, Freefon, Microsoft NetMeeting, IDT Net2Phone and DotDialer.

These applications implement various IP communication schemes: NetMeeting is used for PC-to-PC communication, while Net2Phone and DotDialer implement the PC-to-phone scheme and are designed to call regular phones of subscribers anywhere in the world. Compaq and Cisco offer enterprise-class IP telephony solutions [3]. The topic of IP telephony has been poorly studied in domestic science due to its novelty. Basically, the study of this issue is carried out mainly from the point of view of networks within the framework of information security of communication systems and networks.

However, along with a number of advantages, IP telephony is associated with unique dangers:

1. Vulnerability to interception of secret conversations – easily implemented due to the availability of data.
2. The possibility of complete termination of communication, including attacks in the form of IP DoS attacks, which can be implemented both at the hardware level and through software.
3. Unauthorized appropriation of services – often by manipulating the IP addresses of devices.
4. Ease of hacking the IP telephony infrastructure, including computers equipped with the appropriate software.

The offers on the market are extensive: Mango, Novofon, Freefon and other popular solutions (including Microsoft NetMeeting for communication between personal computers) offer a variety of IP communications models. Especially notable are the products from Compaq and Cisco – corporate class.

In the Russian scientific community, the topic of IP telephony remains little studied due to its youth, mainly focusing on aspects of information security and communications. Key works include the research of T. A. Onufrieva and A. A. Zaitseva on modeling IP telephony networks [4]. Also, in the article

“IP Telephony for Business. Economic Aspect” by I. A. Serebryanik and A. V. Druzhinina, the low cost of such networks is considered in detail, as well as not only the advantages, but also the risks and threats of implementing IP telephony

The goal of our project was to implement Mango IP telephony in the work of Arlight LLC. The project participants were the head of the project department, 2 call center operators, 3 sales managers.

The concept was that the end result would be configured Mango IP telephony on five work computers in the office of the project department, as well as operators and managers who know how to use it. This is done in order to reduce the company's costs for calls, maintain a customer base and connect the client with a personal manager. The implementation took place in several stages. The implementation period was 3 months.

At the first stage, information is collected in the department, questions are clarified. At the second stage, the type of Mango IP telephony is selected. At the third stage, the program is downloaded and configured on computers by one of the call center operators, who already has experience in installing such telephony. At the fourth stage, sales managers, operators and the head of the department are trained to use Mango. Finally, at the last stage, access rights to listen to calls are set up, testing and debugging of telephony takes place. The result will be a working Mango telephony and employees of the project department using it.

Financial resources: the program itself and its configuration are free, the monthly tariff is 2500 rubles or 30,000 rubles per year.

Project risks: the project may drag on for 1 or even 2 months, due to the complexity of the setup and slow training of employees.

IP telephony was launched in November 2024. For clarity, let us compare the call statistics for November 2024 and February 2025 (Table).

Table – The number of calls before and after implementation of Mango Office

Parameters	Before Mango Office	After Mango Office
Incoming, outgoing calls	1109	1521
Missed client calls	254	351
Incoming client calls	159	371
Total client calls	413	722

Based on the implementation of Mango Office IP telephony, we can draw the following conclusions. Both the number of incoming calls and the number of missed calls has increased. This fact may indicate the need to expand the call center staff. The duration of conversations between managers and clients has also increased.

The call recording function has allowed the company to resolve conflict situations with clients more quickly and easily, as well as identify weak points in employee communication with clients. The management can determine which employees need to undergo training to improve their communication skills with clients and sales.

The system interface allows for automatic distribution of incoming calls to managers in turn. This feature helps to make the workload of employees more even. Also, thanks to the call distribution function, call center operators spend less time

finding out the client's needs. A study conducted by Cisco showed that, on average, companies using IP telephony reduce the time spent on conversations with clients by 32 minutes per day. When using traditional telephone communication, this time is spent on the call center employee finding out which department the client needs and connecting the client with this department. Arlight LLC was able to reduce 19 minutes a day in this way.

Companies using CRM report an increase in sales by 29 %, productivity by 39 %, and the accuracy of sales forecasts by 32 % [5]. In the case of Arlight LLC, the calling costs decreased by 37 %. This is due to the fact that internal corporate communications in Mango Office telephony are free. As noted in [6] “the integration of CRM and IP telephony will be able to help attract new customers, increase retention and increase sales among the existing customer”. Thus, the implementation of a cloud PBX and IP telephony helped Arlight LLC reduce costs on communication with clients, identify sales managers who need training, and also use employees' time more efficiently and increase the flow of requests. In the future, it is planned to expand the staff of call center operators, as well as integrate IP telephony with the CRM system for a more detailed analysis of the sales funnel.

Список литературы:

1. Аверченков, В. И. Служба защиты информации: организация и управление: учебное пособие для вузов / В. И. Аверченков, М. Ю. Рытов. – 4-е изд., стер. – Москва : Издательство «Флинта», 2021. – 186 с. – URL: <http://biblioclub.ru/index.php?page=book&id=93356>. (дата обращения: 10.02.2025). – Текст : электронный.
2. Волков, А. С. Основы технологии IP-телефонии на базе ПО Asterisk: учеб. пособие / А. С. Волков, А. Е. Баскаков, Г. А. Кожин. – Москва : МИЭТ, 2022. – 108 с. – URL: <https://e.lanbook.com/book/324845>. (дата обращения: 11.02.2025). – Текст : электронный.
3. Серебряник, И. А. IP-телефония для бизнеса: экономический аспект / И. А. Серебряник, А. В. Дружинина. – Текст : непосредственный // Актуальные проблемы гуманитарных и естественных наук. – 2014. – № 2. – С. 92-93.
4. Онуфриева, Т. А. Моделирование и анализ сети IP-телефонии / Т. А. Онуфриева, А. А. Зайцева. – Текст: непосредственный // Инновационная наука. – 2015. – № 11. – С. 92-93.
5. Rasulov, K. (2025) The Essence of Customer Relationship Management Systems, Development Theories // International Conference on Economics, Finance, Banking and Management, 102-111. URL: <http://hdl.handle.net/1765/21274> (date accessed: 19.03.2025).
6. Kuzmak, O., Voitovych, S. Business Development towards the Application of Innovative Customer Relationship Management (CRM) Technologies in the Context of Global Transformational Changes. Data-Centric Business and Applications: Modern Trends in Financial and Innovation Data Processes 2023. Springer Nature Switzerland, 2024. 2, 47-69. URL: https://link.springer.com/chapter/10.1007/978-3-031-53984-8_3 (date accessed: 20.03.2025).

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FEATURES OF THE ORGANIZATION'S STRATEGIC MANAGEMENT SCHOOLS

Abstract. In a rapidly changing external environment, increasing global competition, technological breakthroughs and growing uncertainty, strategic management is becoming a key tool for ensuring the sustainability and adaptability of organizations. This topic is particularly relevant in the context of digitalization, the growing importance of sustainable development, changing consumer behavior and the transformation of traditional business models. A comprehensive study of strategic management schools contributes to the formation of hybrid strategic models combining elements of rational analysis, innovative thinking, organizational learning and adaptation to the institutional environment. Thus, the study of strategic management schools not only enriches the theoretical and methodological base of strategic management, but also has important practical significance for the formation of effective strategies in modern conditions of high turbulence and dynamics of the market environment.

Keywords: schools of strategic management, classification, enterprise strategy, strategic management, methods of strategic management, strategic management of the organization.

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ОСОБЕННОСТИ ШКОЛ СТРАТЕГИЧЕСКОГО УПРАВЛЕНИЯ ОРГАНИЗАЦИЕЙ

Аннотация. В условиях стремительно меняющейся внешней среды, усиления глобальной конкуренции, технологических прорывов и возрастания неопределенности стратегическое управление становится ключевым инструментом обеспечения устойчивости и адаптивности организаций. Особую актуальность данная тема приобретает в контексте цифровизации, роста значимости устойчивого развития, изменения потребительского поведения и трансформации традиционных бизнес-моделей. Комплексное изучение школ

стратегического управления способствует формированию гибридных стратегических моделей, сочетающих элементы рационального анализа, инновационного мышления, организационного обучения и адаптации к институциональной среде. Таким образом, исследование школ стратегического управления не только обогащает теоретико-методологическую базу стратегического менеджмента, но и имеет важное прикладное значение для формирования эффективных стратегий в современных условиях высокой турбулентности и динамики рыночной среды.

Ключевые слова: школы стратегического управления, классификация, стратегия предприятия, стратегическое управление, методы стратегического управления, стратегическое управление организацией.

Schools of strategic management represent a set of theoretical and methodological directions, each of which reveals the strategic process from a unique point of view, focusing on various aspects of strategy formation, implementation and control. These concepts have emerged over several decades, reflecting the evolution of managerial thought and changes in the business environment. There are various areas in strategic management that identify certain methodological priorities. These areas are called schools of strategic management. Strategic management as a scientific discipline includes many approaches combined into the so-called schools of strategic management. Each school reflects certain views on the strategy development process, its implementation mechanisms, and key success factors. The most famous classification of strategic management schools is the model proposed by Henry Mintzberg, which identifies ten main schools (Table, compiled by the author based on [1, 2, 3, 4, 5]).

Table – Scientific School of Strategic Management

№	Name	Strategy as	Responsible person
1	Design	Process of comprehension	Manager
2	Planning	Formal process	Strategic planning department
3	Positioning	Analytical process	Board of directors
4	Entrepreneurship	Process of foresight	Leader
5	Cognitive	Mental process	Director
6	Education	Developing process	Anybody in organization
7	Power	Negotiation process	Power structures
8	Organizational culture	Collective process	Social interaction between organization's members
9	Environment	Reactive process	Anybody in organization
10	Configuration	Transformation process	Board of directors

Let us look at them in more detail.

1. School of Design (Design School)

The main postulate of this school is that the strategy should be formed on the basis of a clear comparison of the internal capabilities of the organization and external threats and chances. The approach of the school of design assumes a rational, logically verified process of strategic choice based on the uniqueness of the organization. The central tool here is SWOT analysis, which allows you to systematize information and work out the best course of action. An example is the IKEA model which embodies the approach of the design school. The company analyzed its own strengths (efficient logistics, standardized design, self-service) and the capabilities of the external environment (growing demand for affordable furniture), which allowed them to create a sustainable strategy.

2. The Planning School

The School of Planning focuses on systematization and detailed elaboration of all stages of the strategy within the framework of a formalized process. The main focus is on methodical forecasting, goal setting and consistent implementation of strategic steps. Planning is carried out in a top-down hierarchical model, where top management develops a strategy and the middle management implements it. For example, in the 1970s and 1980s, General Electric Corporation actively applied the strategic planning approach to manage a diversified portfolio of business units using a system of long-term planning and balanced indicators.

3. The Positioning School

This direction considers strategy as the choice of the optimal position of the company in the market. The emphasis is on the use of analytical tools and quantitative models, in particular, Michael Porter's Five Competitive Forces model and typical competitive advantage strategies (cost leadership, differentiation, focus). An example is Ryanair which has focused on a cost-minimization strategy by offering basic services to customers at the lowest prices, allowing it to occupy a niche in low-cost air travel in Europe.

4. Entrepreneurial School

This school focuses on the key role of an entrepreneur with strategic vision, intuition, and leadership skills. Strategy is considered here as a personal vision of the leader, often formed in conditions of high uncertainty. This approach is particularly effective in the early stages of an organization's development or in innovative breakthroughs. An example is Apple's strategy under the leadership of Steve Jobs based on an intuitive vision of the future of consumer electronics, which allowed the company not only to predict trends, but also to shape them.

5. Cognitive School

The Cognitive School focuses on the study of mental models of strategists, arguing that the perception and interpretation of information have a key influence on strategy formation. Here, strategy is the result of subjective thinking limited by cognitive distortions, knowledge, experience, and beliefs. For example, the management of companies that do not perceive technological threats (for example, digitalization) may not take timely action, which leads to missed opportunities – an example of cognitive inertia.

6. Learning School

Within the framework of this school, strategy is considered as a product of the evolutionary process of learning and adaptation. An organization forms a strategy as it accumulates knowledge, analyzes experience, and responds to changes in the external environment. The approach is particularly applicable in conditions of high uncertainty. An example is Toyota's production system, based on the philosophy of kaizen (continuous improvement), which involves constant adjustment of strategies based on feedback and learning at all levels.

7. The School of Power

The school of government considers strategy as the result of a political process in which various participants – both internal (managers, shareholders, trade unions) and external (government, suppliers, media) – compete for influence. This approach emphasizes conflict and the need for a balance of interests. For example, when developing strategies for a state-owned holding company such as Gazprom, the interests of the government, international partners and internal influence groups are taken into account, which demonstrates a complex system of strategic coordination.

8. Cultural School

Supporters of this school believe that strategy is formed as an expression of organizational culture – a system of values, norms, traditions, and beliefs shared by employees. Cultural aspects play a key role in choosing strategic guidelines. For example, the customer service-oriented corporate culture of Zappos forms a strategy based on maximum customer satisfaction, which has become its competitive advantage.

9. Environmental School

The ecological school proceeds from the idea that strategy is a way of survival imposed by the external environment. The organization is perceived as a structure dependent on external conditions, forced to adapt to them. An example is the transition of energy companies to a sustainable development strategy and the introduction of "green" technologies dictated by the requirements of legislation and public pressure, rather than an internal initiative.

10. Configuration School

The school of configuration combines elements of all previous schools, considering strategy as a process taking place within the framework of stable configurations, alternating with phases of transformation. The approach is applicable to the analysis of the organization's life cycle and major organizational changes. Netflix's transformation from a DVD rental service to a global streaming platform is an example of a change in the strategic configuration necessary to remain competitive.

Conclusion

Schools of strategic management reflect a wide range of scientific approaches to understanding strategy as a management category. They highlight the diversity of factors that influence strategic thinking and practice, from rational analysis and leadership vision to political, cultural, and environmental conditions. Practice shows that effective strategic management requires the integration of various approaches adapted to the specifics of the company, industry and historical context. Awareness of the multilevel nature of the strategic process allows organizations to achieve

sustainable development, flexibly respond to environmental challenges and strengthen their competitive position in the market.

Список литературы:

1. Гапоненко, А. Л. Стратегическое управление : учеб. для студентов вузов, обучающихся по специальности 061100 «Менеджмент орг.» / А. Л. Гапоненко, А. П. Панкрухин. – 2-е изд., стер. – М. : Изд-во ОМЕГА-Л, 2006. – 464 с. – Текст: непосредственный.
2. Анцупов, А. Я. Стратегическое управление / А. Я. Анцупов. – 4-е изд., испр. и перераб. – Москва : Проспект, 2020. – 343 с. : схем., табл., ил. – URL: <https://biblioclub.ru/index.php?page=book&id=607508> (дата обращения: 07.04.2025). – DOI 10.31085/9785392314713-2020-344. – Текст : электронный.
3. Кузнецов, Б. Т. Стратегический менеджмент: учеб. пособие для студентов вузов, обучающихся по специальностям экономики и управления 080100 / Б. Т. Кузнецов. – М. : ЮНИТИ-ДАНА, 2007. – 623 с. – Текст : непосредственный.
4. Отварухина, Н. С. Стратегический менеджмент : учебное пособие / Н. С. Отварухина, Ю. Ю. Отварухина, А. Н. Мыльникова. – Москва : Проспект, 2018. – 84 с. : схем., табл., ил. – URL: <https://biblioclub.ru/index.php?page=book&id=569906> (дата обращения: 07.04.2025). – Текст : электронный.
5. Теория и практика менеджмента : инструментальное обеспечение управленческой деятельности : учебник / М. В. Хайруллина, Н. Л. Микиденко, С. П. Сторожева [и др.] ; под ред. М. Хайруллиной, А. А. Борисовой. – Москва : Проспект, 2021. – 646 с. : ил., табл. – URL: <https://biblioclub.ru/index.php?page=book&id=696761> (дата обращения: 07.04.2025). – Текст : электронный.

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CREATIVE INDUSTRIES AS A MARKETING ELEMENT OF SOCIO-ECONOMIC DEVELOPMENT OF SOCIETY

Abstract. The role of creative industries as a key marketing element of socio-economic development of society is considered in the article. The importance of these industries as a driver of innovation, formation of new consumer values and tools of economic growth is emphasized. Modern trends in this sphere are analyzed, the mechanisms of the influence of creative industries on the economy, innovative development and marketing strategies are revealed. Special attention is paid to the importance of digital technologies and branding in the formation of competitive advantages of creative industries.

Keywords: creative industries, marketing, socio-economic development, digital technologies, innovation.

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КРЕАТИВНЫЕ ИНДУСТРИИ КАК МАРКЕТИНГОВЫЙ ЭЛЕМЕНТ СОЦИАЛЬНО-ЭКОНОМИЧЕСКОГО РАЗВИТИЯ ОБЩЕСТВА

Аннотация. В статье рассматривается роль креативных индустрий как ключевого маркетингового элемента социально-экономического развития общества. Подчеркивается их значение как драйвера инноваций, формирования новых потребительских ценностей и инструментов экономического роста. Проанализированы современные тенденции в данной сфере, раскрыты механизмы влияния креативных отраслей на экономику, инновационное развитие и маркетинговые стратегии. Особое внимание уделено значению цифровых технологий и брендинга в формировании конкурентных преимуществ креативных индустрий.

Ключевые слова: креативные индустрии, маркетинг, социально-экономическое развитие, цифровые технологии, инновации.

Creative industries occupy a special place in the system of socio-economic development, as they combine culture, technology and entrepreneurship, creating unique conditions for the formation of innovative economy. They act as a driver of growth, ensuring the integration of new ideas and solutions in various spheres of social life, contributing to the modernization of traditional industries and stimulating the development of society's creative potential.

Their influence on society is expressed not only in the creation of innovative products, but also in the transformation of consumer behavior, the development of creative clusters and the formation of competitive strategies. The process of digitalization and globalization strengthens the role of creative industries, facilitating the spread of new consumption patterns, the development of digital platforms and the formation of sustainable business ecosystems focused on flexibility and adaptation to transforming market conditions.

The modern economy is increasingly oriented towards innovative and creative approaches, which causes the growing importance of creative industries. They become not only a tool for cultural development, but also an important element of marketing strategies that contribute to economic growth. In the conditions of digital transformation, the marketing mechanisms of creative industries are undergoing significant changes, forming new models of consumption and interaction with the target audience.

The analysis of recent publications has shown that the raised problematics is widely spread among domestic scientists. Authors D. D. Apreleva [1], N. V. Burova [2], G. I. Gumerova [3], K. N. Eliseeva [4], M. V. Ivanov [5], E. B. Kurganova [6], N. N. Lavrukhina [7], K. M. Levashev [8], A. I. Matveeva [9], F. A. Mukhametshina [10], S. V. Panasenko [11], N. R. Safonova [12], V. A. Yakovlev-Chernyshev [13] and others are engaged in research on the economic impact of creative industries on regional development, and the formation of the gross domestic product of the country, creative industries in the data economy, problems and prospects of development of creative industries, ecosystems of educational activities and professional training for creative industries, neurogamification as a method of training specialists in the field of

creative industries, modern challenges of public administration in the field of creative industries, creative industries as a driver of innovative development in conditions of digital transformation, economic aspects of development in the field of creative entrepreneurship.

Creative industries are a set of industries based on intellectual labor and creativity, playing a key role in the formation of innovative economy and sustainable socio-cultural development. They contribute to the generation of new ideas, the development of entrepreneurship and the formation of the cultural capital of society. According to the classification of UNESCO and the European Commission, creative industries include: advertising and marketing activities; architecture and design; film and animation industry; publishing; fashion industry; software and video games development; music and theatre industries; craft and art production.

In Russia, the development of creative industries has been legislated. According to the Law of the Russian Federation 'On the Development of Creative Industries' (adopted by the State Duma on 30.07.2024, approved by the Federation Council on 02.08.2024), the list of these industries was supplemented by gastronomy, which emphasizes the importance of culinary art not only as an element of national culture, but also as an important economic sector in which innovation and creativity contribute to the creation of new business formats and attract investment.

The main feature of creative industries is their ability to create intangible assets with high added value, including intellectual property, unique author's products and innovative business models, which contribute to the formation of a competitive image of territories, companies and brands.

Creative industries have an important impact on socio-economic development, ensuring the creation of new jobs and the development of human resources, increasing the share of intangible assets in the economy, diversifying sources of income, attracting investment and the development of urban areas, creating an innovative environment and stimulating entrepreneurship.

According to the researches, the creative sector provides a significant share of employment in the economy, attracting professionals ranging from designers and programmers to artists and researchers. Innovative ideas and intellectual labor become the basis for economic growth, helping to diversify income sources. Creative clusters form a sustainable ecosystem of small and medium-sized businesses, cultural spaces, educational institutions and innovation centers. Flexible business models and digital technologies offer opportunities for rapid growth and adaptation of companies operating in creative fields. For example, the development of creative clusters contributes to the competitiveness of cities and regions by forming a sustainable ecosystem including small and medium-sized businesses, scientific and educational institutions, and cultural spaces.

Marketing plays a key role in the development of creative industries, helping to effectively promote products and services, build engagement with target audiences and form emotional attachment to brands. Key strategies include:

- branding to create a unique image of a product or region, focused on the target audience;

- content marketing as the formation of a value proposition through quality and original content;
- digital marketing through the use of social media, SEO optimization, contextual advertising and other online promotional tools;
- crowdfunding and partnership programs as mechanisms for attracting investment and interacting with the audience;
- event marketing by organizing festivals, exhibitions, workshops that attract the attention of creative communities and business structures.

Creating a unique image of a product, region or company that focuses on the values and needs of the target audience is especially important for local brands and creative spaces seeking international recognition. Shaping the value proposition through quality, original and emotionally rich content promotes consumer engagement and loyalty. Social media, SEO optimization, contextual advertising and other online tools are used for effective promotion and personalized consumer interaction. Attracting investment and building a loyal community is possible through joint projects, funding and audience involvement in brand development. Organizing festivals, exhibitions, workshops and other events attract the attention not only of the general audience, but also of business representatives ready to invest in creative initiatives.

Another example of a successful marketing approach is the development of creative spaces such as co-working spaces, art clusters, and specialized festivals, which attract audiences and form new business models.

Modern technologies have a significant impact on the development of creative industries, and among the most significant innovative trends the following should be highlighted:

- Artificial intelligence and Big Data as content personalization and analysis of consumer preferences;
- augmented and virtual reality (AR/VR) by creating unique user experiences;
- NFT and blockchain through copyright protection and monetization of digital content;
- gamification as audience engagement through interactive elements.

Modern technologies have a significant impact on the development of creative industries, opening up new opportunities for marketing, consumer interaction and monetization of creativity. Digitalization is helping to expand markets, increase the effectiveness of marketing strategies and create new channels of communication with consumers. In a competitive global environment, the creative industries are becoming a driver of sustainable economic growth, fostering cultural diversity, innovative entrepreneurship and social integration.

Creative industries act as the most important factor of socio-economic development, integrating marketing strategies and innovative technologies, which allows them to form new business models adapted to the dynamically changing environment. They contribute to the development of cultural identity and the preservation of traditional values, as well as attract investment, creating favorable conditions for the development of entrepreneurship, startup ecosystems and creative

clusters.

In the context of global digitalization, creative industries marketing is becoming a powerful tool for competitiveness and sustainable growth. Digital platforms, artificial intelligence technologies and big data allow creative industries companies to analyze consumer trends, personalize content and increase audience engagement. In this regard, the creative industries are not only an economic phenomenon, but also a social one, capable of transforming society by changing the way people interact, shaping new values and supporting cultural diversity.

Their marketing strategies develop territories by stimulating tourist attractiveness, developing local brands and improving the quality of the urban environment. They form sustainable consumption patterns focused on sustainability, conscious consumption and the development of the experience economy, creating new value for society through unique products and services that combine culture, innovation and technology.

Список литературы:

1. Апрелева, Д. Д. Экономическое влияние креативных индустрий на региональное развитие / Д. Д. Апрелева, Д. А. Карапетян. – Текст : электронный // Научные исследования и разработки 2025: сборник статей Международной научно-практической конференции, Пенза, 23 января 2025 года. – Пенза: Наука и Просвещение (ИП Гуляев Г. Ю.), 2025. – С. 96-98. – URL: <https://naukaip.ru/wp-content/uploads/2025/01/MK-2243.pdf> (дата обращения: 30.03.2025). – EDN OLGQBX.
2. Бурова, Н. В. Вклад креативных индустрий в формирование валового внутреннего продукта страны / Н. В. Бурова, М. Бали. – Текст : электронный // Экономика и управление в сфере услуг: современное состояние и перспективы развития: материалы XXII Международной научно-практической конференции, Санкт-Петербург, 04 февраля 2025 года. – Санкт-Петербург: Санкт-Петербургский гуманитарный университет профсоюзов, 2025. – С. 16-18. – URL: https://elibrary.ru/download/elibrary_80447612_14910561.pdf (дата обращения: 30.03.2025). – EDN GJAIYA.
3. Гумерова, Г. И. Креативные индустрии в экономике данных / Г. И. Гумерова, Э. Ш. Шаймиева. – Москва: ООО "Издательство "КноРус", 2025. – 176 с. – EDN GZMXDF. – Текст: непосредственный.
4. Елисеева, К. Н. Проблемы и перспективы развития креативных индустрий в Архангельской области / К. Н. Елисеева. – Текст : электронный // Молодые учёные России: сборник статей XXIII Всероссийской научно-практической конференции, Пенза, 20 февраля 2025 года. – Пенза: Наука и Просвещение (ИП Гуляев Г.Ю.), 2025. – С. 199-202. – URL: https://elibrary.ru/download/elibrary_80369117_75688302.pdf (дата обращения: 30.03.2025). – EDN UMUXBS.
5. Иванов, М. В. Студенческие объединения как экосистема воспитательно-образовательной деятельности и профессиональной подготовки кадров для креативных индустрий / М. В. Иванов, А. Альмурзаев, Ю. В. Катрашова. – Текст: электронный // Государственное и муниципальное управление: актуальные проблемы и современные тренды: сборник научных трудов IV Международной

- научно-практической конференции. К 30-летию Законодательного Собрания Санкт-Петербурга, Санкт-Петербург, 21–22 ноября 2024 года. – Санкт-Петербург : Санкт-Петербургский университет технологий управления и экономики, 2025. – С. 199-204. – URL: https://elibrary.ru/download/elibrary_80465003_68014352.pdf (дата обращения: 27.03.2025). – EDN GGTGCV.
6. Курганова, Е. Б. Нейрогеймификация как метод подготовки специалистов в области креативных индустрий / Е. Б. Курганова // Стратегические ориентиры развития высшего образования: управление кадровым потенциалом: Сборник статей I Всероссийского форума преподавателей высшего образования, Москва, 18–19 ноября 2024 года. – Москва: Общество с ограниченной ответственностью «Издательство "КноРус"», 2025. – С. 307-311. – EDN DWYPDU.
7. Лаврухина, Н. Н. Современные вызовы государственного управления в сфере креативных индустрий / Н. Н. Лаврухина. – Текст : электронный // Российское государство и общество: особенности современного состояния: материалы XVI Всероссийской научно-практической конференции, Чебоксары, 07 февраля 2025 года. – Чебоксары: Издательско-полиграфическая компания «Новое время», 2025. – С. 154-159. – URL: https://elibrary.ru/download/elibrary_80449283_43799111.pdf (дата обращения: 1.04.2025). – EDN MBASIV.
8. Левашев, К. М. Креативная экономика: тенденции и перспективы развития / К. М. Левашев. – Текст : электронный // Социально-экономический ландшафт региона: инвестиции роста: сборник материалов Международной научно-практической конференции, Красноярск, 20 февраля 2025 года. – Чебоксары: ООО «Издательский дом "Среда"», 2025. – С. 41-45. – URL: https://elibrary.ru/download/elibrary_80480622_42876260.pdf (дата обращения: 01.04.2025). – EDN MXVLCR.
9. Матвеева, А. И. Социально-экономическое развитие Уральского региона и его влияние на развитие креативных индустрий / А. И. Матвеева. – Текст : электронный // Социально-экономический ландшафт региона: инвестиции роста: сборник материалов Международной научно-практической конференции, Красноярск, 20 февраля 2025 года. – Чебоксары: ООО «Издательский дом "Среда"», 2025. – С. 50-53. – URL: https://elibrary.ru/download/elibrary_80480624_18232552.pdf (дата обращения: 01.04.2025). – EDN WYINCR.
10. Мухаметшина, Ф. А. Экономика креативных индустрий: влияние на занятость и ВВП / Ф. А. Мухаметшина, Л. Т. Эскерханова, А. С. Поляков. – Текст: электронный // Экономика и управление: проблемы, решения. – 2025. – Т. 6, № 1(154). – С. 20-27. – DOI 10.36871/ek.up.p.r.2025.01.06.003. – URL: https://elibrary.ru/download/elibrary_80458545_23341195.pdf (дата обращения: 03.04.2025). – EDN PYIOJD.
11. Панасенко, С. В. Креативные индустрии как драйвер инновационного развития в условиях цифровой трансформации / С. В. Панасенко. – Текст : электронный // Менеджмент и маркетинг в условиях цифровой экономики: материалы Международной научно-практической конференции, Москва, 23 мая 2024 года. – Москва: Московский международный университет, 2024. – С. 142-

150. – URL: https://elibrary.ru/download/elibrary_68569186_96300027.pdf (дата обращения: 03.04.2025). – EDN HQFZUJ.

12. Сафонова, Н. Р. Тенденции и перспективы развития креативных индустрий / Н. Р. Сафонова. – Текст : электронный // Экономика и управление в сфере услуг: современное состояние и перспективы развития: материалы XXII Международной научно-практической конференции, Санкт-Петербург, 04 февраля 2025 года. – Санкт-Петербург: Санкт-Петербургский гуманитарный университет профсоюзов, 2025. – С. 49-51. – URL: https://elibrary.ru/download/elibrary_80447612_89292123.pdf (дата обращения: 3.04.2025). – EDN EUXFHJ.

13. Яковлев-Чернышев, В. А. Экономико-правовые аспекты развития креативного предпринимательства в России / В. А. Яковлев-Чернышев, А. Ю. Яковлева-Чернышева // Прометей: научный альманах Студенческого научного общества Сочинского филиала ВГУЮ (РПА Минюста России) : сборник научных трудов Всероссийской студенческой научной конференции, посвященной Г. Р. Державину, и V Всероссийской студенческой научной конференции, Сочи, 09 – 25 января 2024 года. – Киров: Межрегиональный центр инновационных технологий в образовании, 2025. – С. 77-80. – Текст : непосредственный.

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EXPLORING IMPLEMENTATION METHODS OF THE CIRCULAR ECONOMY FOR RUSSIAN BUSINESS MODELS

Abstract. This article analyzes how the circular economy can be applied to Russian companies with different business models. It focuses on the relevance of ESG principles, examines international and Russian practices, identifies typical methods of implementation, and discusses the main barriers companies face in the transition. The work highlights the need for adapting strategies to the Russian context and provides recommendations for more effective integration of sustainable practices.

Keywords: circular economy, sustainability, ESG, business models, Russian companies, implementation, transformation.

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ИССЛЕДОВАНИЕ МЕТОДОВ ВНЕДРЕНИЯ ЭКОНОМИКИ ЗАМКНУТОГО ЦИКЛА ДЛЯ БИЗНЕС-МОДЕЛЕЙ РОССИЙСКИХ КОМПАНИЙ

Аннотация. В статье рассматриваются способы применения экономики замкнутого цикла в российских компаниях с различными бизнес-моделями. Анализируются принципы ESG, международный и российский опыт, методы внедрения и ключевые барьеры. Автор подчеркивает необходимость адаптации

стратегий к российской действительности и предлагает рекомендации по интеграции устойчивых практик.

Ключевые слова: экономика замкнутого цикла, устойчивое развитие, ESG, бизнес-модели, российские компании, внедрение, трансформация.

Introduction

In the modern world, where ecological, social and economic stability is a global priority, the circular economy becomes an effective instrument of sustainable business. Russian companies, facing increasing pressure from environmental regulations and stakeholder expectations, are exploring new ways to reorganize their business processes. This article raises the issue of practical application of the circular economy in Russia, considering the challenges and opportunities for different types of business models. It draws on the ESG framework, which integrates environmental, social and governance principles as part of corporate development.

Methods and Materials

In order to form an objective understanding of modern methods of implementing sustainable practices of business models of the closed-cycle economy, we conducted a study of non-financial reports of international and Russian companies, publications of the Russian Union of Industrialists and Entrepreneurs, analyzed the effectiveness of implementing business models, and compared domestic and foreign experience.

The circular economy is an economic model focused on minimizing resource waste and closing material loops by reusing, repairing, recycling, and redesigning products and processes. It contrasts with the traditional linear model of extraction, production, use, and disposal. In the Russian context, circular economy is becoming relevant due to growing environmental problems, pressure from international partners, and national sustainability goals. It is not only an ecological initiative but also an opportunity for business optimization, reduction of dependence on imports, and innovation in logistics and production [1].

Sustainable development, in turn, is a broader concept encompassing the balance of environmental protection, social equity, and economic viability. For Russia, sustainable development has specific challenges, such as uneven regional development, resource-based economy, and complex regulatory structures. ESG – Environmental, Social and Governance – is a strategic framework that operationalizes sustainability principles in business. The ESG agenda in Russia is still evolving and often driven by large enterprises and state-owned corporations, especially in industries such as energy, metals, and retail. There is also increasing attention from regulators, banks, and institutional investors to companies' ESG performance.

Circular economy as a part of ESG strategy offers Russian companies practical ways to comply with sustainability expectations. In Russia, this approach is being actively promoted by state initiatives and supported by leading corporations such as Sibur, Rusal, and X5 Group. These companies have introduced closed-loop production cycles and reusable packaging systems, showing that transformation is possible even in traditional sectors. However, most Russian businesses still view ESG as environmental management only, often neglecting the “S” and “G” components. This narrow interpretation hinders comprehensive sustainable transformation [2-4].

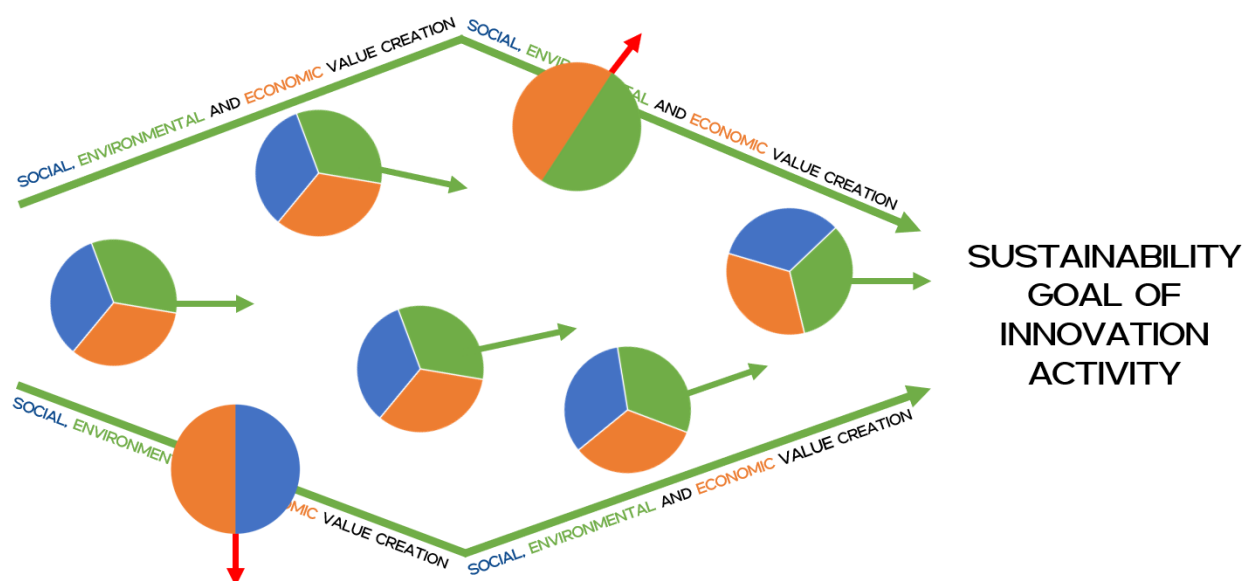


Figure 1 – Challenges of sustainable development projects

Despite the growing awareness, only a small share of Russian companies have implemented circular practices at scale. According to the Union of Russian Industrialists' 2024 report, the main barriers include lack of methodology, insufficient staff training, and low internal motivation (Figure 1) [5].

The Russian Union of Industrialists and Entrepreneurs has published the results of a 2024 survey on the relevance of sustainability agenda issues for companies in the new Russian realities, in which leading companies from various industries participated (Figure 2). 99 % of respondents confirmed that the sustainability and ESG agenda and projects are still relevant and remain important in the face of new challenges, while the priorities and implementation plans for the tasks at hand need to be clarified. According to business representatives, at the moment there are a number of challenges to the implementation of ESG in the practices of companies, among the main difficulties in the implementation of ESG projects are the following:

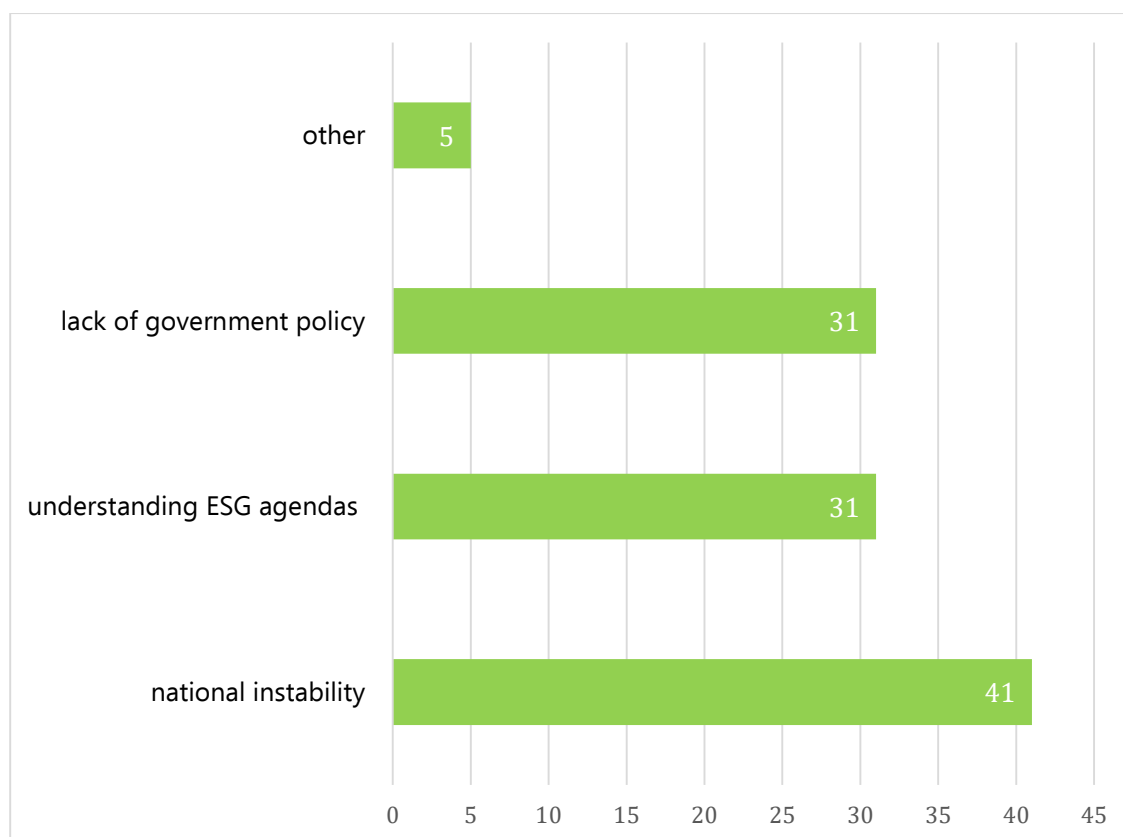


Figure 2 – Results of the survey of the Union of Industrialists and Entrepreneurs on the implementation of sustainable practices

– 41 % indicated as an important factor the constant updating of sanctions programs and the departure of many foreign companies from the Russian market, the reduction of sales and changes in traditional markets, which require the revision of business models and changes in logistics solutions, which affect the increase in project implementation time;

– 31 % identified a lack of awareness of ESG agenda initiatives, as well as a lack of staff qualifications, little understanding of the connection between environmental, social and corporate instruments and modern progressive management, low social awareness and environmental culture of the population;

– 31 % noted uncertainty of state policy and fixed state incentives for implementation of ESG projects, lack of regulatory rules, due to which there is a lack of understanding in target setting and priorities, lack of developed implemented documents/reports and criteria for them;

– 5 % identified a whole list of other factors: involvement of functional owners, transformation of business processes; insufficient popularization and support of social projects and initiatives implemented by business and non-governmental organizations on careful “environmentally friendly” attitude to man, society and nature [2, 5].

To overcome these obstacles, companies need clear guidelines, incentives, and industry-specific examples (see Table).

Table – Examples of circular economy implementation by company type [6-9]

Company	Country	Business Model	Circular Practice
IKEA	Sweden	Retail / Manufacturing	Furniture return and resale program
Patagonia	USA	Apparel / Services	Clothing repair and reuse
Apple	USA	Electronics / Hardware	Device disassembly and material recovery
Sibur	Russia	Chemicals / Industry	Recycled plastic production
X5 Retail Group	Russia	Retail	Reusable packaging system
Rusal	Russia	Metals / Heavy Industry	Aluminum closed-loop recycling

To better understand how circular economy can be embedded into business strategy, it is important to identify methods suitable for different models. First, companies can focus on one direction – for example, starting with a zero-waste initiative or transition to carbon neutrality. This allows them to test processes before scaling them. Second, employee training plays a key role in spreading sustainability culture inside the organization. Without awareness and motivation among staff, even the best initiatives may fail. Third, case studies and best practices from other companies help guide decisions and avoid common mistakes. Fourth, innovative partnerships – including with universities, startups, and NGOs – bring expertise, technology, and legitimacy. These methods support implementation and adaptation to market-specific conditions. However, most companies still lack a unifying methodology that links ESG principles with concrete business goals. Creating such a methodology would enhance adoption and long-term impact.

Results and Discussion

The circular economy is a necessary and realistic path for Russian companies seeking to achieve ESG compliance and long-term competitiveness. It offers not only environmental benefits but also strategic opportunities for innovation and cost reduction. Yet, without systemic support, adaptive methodologies, and cultural readiness, progress will remain slow.

The research of the obstacles to the development of closed-cycle economy in the Russian Federation shows a list of tasks that need to be solved in order to achieve the goals of sustainable development. Thus, to promote the concept of circular production, it is necessary to take the following measures:

- to specify the concept of “closed-cycle economy” and identify indicators that allow to assess the effectiveness of measures;
- to develop measures for objective financial support of existing waste collection and recycling systems;
- to form economic incentives for small and medium-sized enterprises that ensure economically feasible use of resources.

Russian businesses must move beyond isolated initiatives and adopt a holistic approach to sustainability through circular thinking.

Список литературы:

1. Единая платформа экономики замкнутого цикла: [сайт]. – 2025. – URL: <https://reo.ru/ezc> (дата обращения: 15.03.2025). – Текст : электронный.
2. Развития ESG в секторе МСП: результаты опроса в российских регионах // Институт развития предпринимательства и экономики – 2023. – 38 с. – URL: https://www.nifi.ru/images/FILES/Reports/Doklad_razvitie_ESG_v_regionah_.pdf (дата обращения: 15.03.2025). – Текст : электронный.
3. ESG и экономика: современные тренды. РБК Тренды : [сайт]. – 2025. – <https://trends.rbc.ru> (дата обращения: 15.03.2025). – Текст : электронный.
4. Повестка устойчивого развития (ESG повестка) в новых российских реалиях / Е. Н. Феоктистова, Г. А. Копылова, Д. Р. Пуртова, И. В. Тополя // по материалам опроса компаний май-июнь 2022 г. – 2022. – 12 с. – URL: https://rspp.ru/upload/iblock/33a/yrkiuv2gnz3mkzc0sqny5zeab7jrqbly/Publikatsiya-RSPP-_Povestka-ustoychivogo-razvitiya-v-novykh-rossiyskikh-realiyakh-_po-materialam-oprosa_.pdf?ysclid=l9e6tmqzlr203083917 (дата обращения: 17.03.2025). – Текст : электронный.
5. Отчет о деятельности Российского союза промышленников и предпринимателей в 2024 году. – URL: <https://clck.ru/3MStrX> (дата обращения : 11.04.2025). – Текст : электронный.
6. Ellen MacArthur Foundation. What Is a Circular Economy? : [сайт]. – 2023. – URL: <https://ellenmacarthurfoundation.org> (дата обращения: 17.03.2025). – Текст : электронный.
7. Экономика замкнутого цикла. Обзор международных подходов // Проектно-аналитический отдел. Департамент многостороннего экономического сотрудничества и специальных проектов Минэкономразвития России – 2021; опубли. 14.04.2022 – 11 с. – URL: <https://esg-library.mgimo.ru/publications/ekonomika-zamknutogo-tsikla-obzor-mezhdunarodnykh-podkhodov/> (дата обращения: 26.03.2025). – Текст : электронный.
8. Ассоциация содействия экономике замкнутого цикла «Ресурс»: [сайт]. – 2025. – URL: <https://resurs2030.ru/aboutresource> (дата обращения: 18.03.2025). – Текст : электронный.
9. Члены Ассоциации «Ресурс» : [сайт]. – 2025. – Режим доступа: <https://resurs2030.ru/associakomp> (дата обращения: 27.03.2025). – Текст : электронный.

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DEVELOPMENT TRENDS OF REGIONAL LEASING MARKET

Abstract. The leasing industry in Russia has been significantly impacted by unfavorable external factors such as tight monetary policy, exchange rate volatility, and other factors. The volume of new business for the 2024 year was lower in comparison with the previous year, the number of leasing contracts has decreased, too. One of the factors aimed at supporting the leasing industry is the preferential leasing program of the Ministry of Industry and Trade of the Russian Federation.

Keywords: leasing, amount of new business, preferential leasing, type of property, subject of leasing, leasing contract.

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ТЕНДЕНЦИИ РАЗВИТИЯ РЕГИОНАЛЬНОГО РЫНКА ЛИЗИНГОВЫХ УСЛУГ

Аннотация. На лизинговую отрасль в России существенное влияние оказали неблагоприятные внешние условия, такие как жесткая денежно-кредитная политика, волатильность валютного курса и другие. Объем нового бизнеса за 2024 год стал ниже в сравнении с аналогичным предыдущим периодом, количество заключенных договоров также сократилось по сравнению со значением годом ранее. Одним из факторов, нацеленных на поддержание лизинговой отрасли, является программа Минпромторга РФ.

Ключевые слова: лизинг, объем нового бизнеса, программа льготного лизинга, тип имущества, предмет лизинга, договор лизинга.

2024 has been a turning point for the leasing industry in Russia according to several significant changes.

Over the past year, the leasing industry has faced numerous challenges and disruptions, which have resulted in a slowdown in growth and development. Some of the main factors include:

1. The increase of the key interest rate by the Central Bank of the Russian Federation from 16 % to 21 % over the course of a year has had several implications [1]. Firstly, high interest rate increases the cost of borrowing for organizations, reducing their creditworthiness and ability to service existing debt obligations. As a result, launching of large investment projects requiring debt financing has been delayed, the of financing for ongoing projects has been terminated as well. This affects both large businesses and small and medium-sized enterprises.

2. The increase in the US dollar exchange rate set by the Russian Central Bank by 13 % during 2024 [2].

3. An increase in the amount of customs rates for wheeled vehicles imported into the country by an average of 70-85 % on October 1, 2024 [3].

Increased dollar exchange rate and custom fee rates has led to an increase in the cost of renting items. According to experts, the average cost of a rental agreement for one item has increased by 1.5 million rubles and it now amounts to around 5.5-5.8 million rubles, which is a 10 % increase compared to 2023 [4].

It is also important to consider several statistical trends for the year 2024. Firstly, for the first time since 2020, the growth of new businesses in the leasing market showed negative dynamics, amounting to 3.3 trillion rubles and a decrease of 5 % compared to the previous period. The number of new leasing contracts concluded in 2024 decreased by 7 %, reaching 452 thousand. This marks the second consecutive year of negative growth for this metric, with a decrease of approximately 22 % in 2022 (Figure 1).

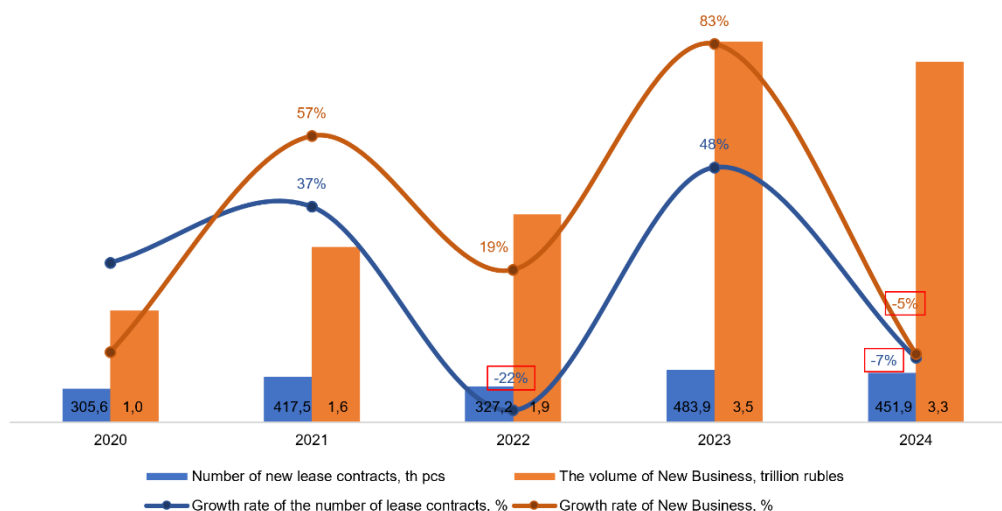


Figure 1 – The dynamics of changes in the number of lease contracts and the volume of new business from 2020 to 2024

The volume of new business in the expanded segment, which consists of passenger cars, buses, trucks, and special construction equipment, decreased in 2024, amounting to 2.1 trillion rubles (Figure 2). These leasing products continue to dominate the overall volume of new business, accounting for approximately 63 %.

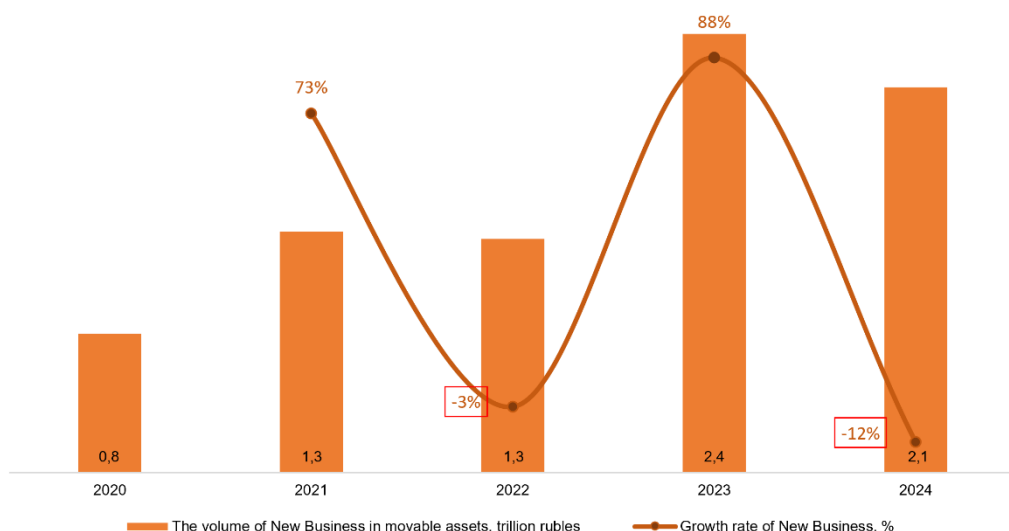


Figure 2 – The dynamics of changes in the volume of new business in the retail leasing market from 2020 to 2024

The main driver of growth among the listed leasing items was the passenger car category (an increase of about 9 % by 2024), the second most important was the bus category (an increase of about 10 % by 2024), as shown in Table 1.

Table 1 – The dynamics of changes in the volume of new business by category of leasing items

No	Segment	2020	2021	2022	2023	2024
1	The volume of New Business, trillion rubles	1 022 304	1 603 667	1 902 368	3 484 869	3 296 372
2	The volume of New Business in movable assets, trillion rubles	751 643	1 301 861	1 263 610	2 371 476	2 083 872
	Vehicles	277 387	454 747	333 901	587 510	637
	Buses	35 721	59 535	50 727	90 342	99 365
	Trucks	283 118	491 658	568 014	1 178 059	948 938
	Construction machinery and vehicles	155 418	295 922	310 969	515 565	398 038
3	The segment share of the total new business volume, %	73,52%	81,18%	66,42%	68,05%	63,22%
	Vehicles	27,13%	28,36%	17,55%	16,86%	19,34%
	Buses	3,49%	3,71%	2,67%	2,59%	3,01%
	Trucks	27,69%	30,66%	29,86%	33,80%	28,79%
	Construction machinery and vehicles	15,20%	18,45%	16,35%	14,79%	12,08%
4	Growth rate, %		73%	-3%	88%	-12%
	Vehicles		63,94%	-26,57%	75,95%	8,51%
	Buses		66,67%	-14,79%	78,09%	9,99%
	Trucks		73,66%	15,53%	107,40%	-19,45%
	Construction machinery and vehicles		90,40%	5,08%	65,79%	-22,80%

Also, it is necessary to pay attention to the concentration level of new business volume at the largest leasing companies on the Russian market (Figure 3). The list of the top 10 largest leasing companies has been prepared according to the Ra Expert rating [5]. Firstly, the Russian leasing market is highly concentrated among the top 10 companies, with their market share exceeding 75 % each year. Secondly, it has been observed that the level of concentration among these largest companies is decreasing. In 2024, the market share of these companies was 78 %, compared to approximately 90 % in 2020.

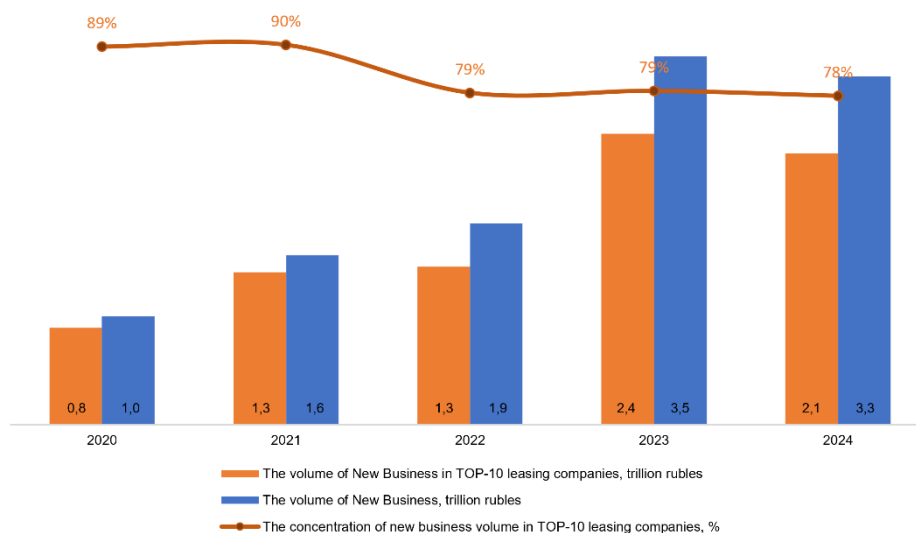


Figure 3 – The concentration of new business volume in TOP-10 leasing companies from 2020 to 2024

All in all, it is not accurate to say that leasing segment in Russia has completely slowed down its development. Nevertheless, there is one important aspect to consider. For 2025, the government has allocated a significant amount of money to support the leasing industry [6]:

- 20 billion rubles for preferential leasing of passenger cars and light commercial vehicles.

- 7 billion rubles for buses manufactured in Russia. This program covers intercity and tourist buses worth up to 2 million rubles. It is necessary to note that previously, subsidies for leasing items related to the development of social and recreational infrastructure were not specifically targeted.

- 50 billion rubles will be used to finance preferential leasing of road construction and utility equipment under the joint program of Bank DOM.RF and the Government of the Russian Federation [7].

Based on the results shown in Table 2, it can be noted that the most popular program is preferential leasing of wheeled vehicles, which includes electric vehicles, commercial vehicles, tractor units and tourist buses. However, not every key player in the leasing market has a subsidy program for Belarusian-made machinery.

Table 2 – List of preferential leasing programs offered by the Ministry of Industry and Trade of Russia

№	Government program	The amount of the subsidy	Lease term	Prepaid expense	Examples of leasing companies
1. Preferential leasing program for wheeled vehicles					
1.1	<i>Electric vehicles</i>	Up to 35 %, 925 thousand rubles	12 - 84 months	0 %-48 %	1. Gazprombank Leasing 2. VTB Leasing 3. Alfa-Leasing 4. Europlan 5. Baltic Leasing
1.2	<i>Commercial transport</i>	Up to 10 %, 500 thousand rubles	12 - 84 months	0 %-48 %	1. Gazprombank Leasing 2. VTB Leasing 3. Alfa-Leasing 4. Europlan 5. Baltic Leasing
1.3	<i>Tourist buses</i>	Up to 20 %, 2 million rubles	12 - 84 months	0 %-48 %	1. VTB Leasing 2. Alfa-Leasing 3. Europlan 4. Baltic Leasing
1.4	<i>Trucks</i>	Up to 10 %, 850 thousand rubles	12 - 84 months	0 %-48 %	1. Gazprombank Leasing 2. VTB Leasing 3. Alfa-Leasing 4. Europlan 5. Baltic Leasing
2. Preferred leasing program for vehicles powered by gas					
2.1	Vehicles powered by gas	From 105 thousand to 1.19 million rubles per unit	Up to 60 months	n/a	1. Gazprombank Leasing
3. Preferential leasing program for Belarusian-made machinery					
3.1	Belarusian-made vehicles (trucks, self-propelled, special vehicles)	Compensation of a part of the payment (unlimited)	12-60 months	Up to 10 %	1. Alfa-Leasing 2. Europlan 3. Baltic Leasing

It is assumed that preferential leasing will lead to an increase in demand for and sales of domestic brands and provide appropriate support for the leasing market. All in all, the future growth of the leasing industry in Russia will depend on government subsidies and support for preferential leasing from the Ministry of Industry and Trade, currency fluctuations, changes in the key interest rate set by the Central Bank of the Russian Federation, the scale of domestic production, and the cost of imported goods and components used in leasing.

Список литературы:

1. Ключевая ставка Банка России : [сайт]. – 2025. – URL: https://www.cbr.ru/hd_base/keyrate/ (дата обращения: 02.03.2025). – Текст : электронный.
2. Курс доллара ЦБ : [сайт]. – 2025. – URL: <https://www.rbc.ru/quote/ticker/72413> (дата обращения: 30.03.2025). – Текст : электронный.
3. Постановление Правительства Российской Федерации от 13.09.2024 № 1255 «О внесении изменений в некоторые акты Правительства Российской Федерации» : [сайт]. – 2024. – URL: <http://publication.pravo.gov.ru/document/0001202409130024?index=5> (дата обращения: 05.03.2025). – Текст : электронный.
4. Автолизинг в России: итоги 2024 года : [сайт]. – 2025. – URL: <https://assocleasing.ru/authors-articles/avtolizing-v-rossii-itogi-2024-goda/> (дата обращения: 03.03.2025). – Текст : электронный.
5. Рейтинг Эксперт Ра по итогам 2024 года : [сайт]. – 2025. – URL: <https://raexpert.ru/rankings/leasing/> (дата обращения: 05.03.2025). – Текст : электронный.
6. В РФ на программы льготных автокредитов и лизинга могут выделить 63 млрд рублей : [сайт]. – 2024. – URL: <https://tass.ru/ekonomika/22691555> (дата обращения: 05.03.2025). – Текст : электронный.
7. ДОМ.РФ вместе с Правительством РФ разработал механизм льготного лизинга коммунальной техники : [сайт]. – 2024. – URL: <https://xn--d1aqf.xn--p1ai/media/news/dom-rf-vmeste-s-pravitelstvom-rf-razrabotal-mekhanizm-lgotnogo-lizinga-kommunalnoy-tehniki/> (дата обращения: 06.03.2025). – Текст : электронный.

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ADVANTAGES OF IMPLEMENTING CORPORATE INFORMATION SYSTEMS

Abstract. The article examines both the material and nonmaterial benefits of implementing corporate information systems, including in the context of the educational process.

Keywords: corporation, information, integration, corporate information systems in the educational process.

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ПРЕИМУЩЕСТВА ВНЕДРЕНИЯ КОРПОРАТИВНЫХ ИНФОРМАЦИОННЫХ СИСТЕМ

Аннотация. В статье рассматриваются как материальные, так и нематериальные преимущества внедрения корпоративных информационных систем, в том числе в контексте образовательного процесса.

Ключевые слова: корпорация, информация, интеграция, корпоративные информационные системы в образовательном процессе.

The corporate information system can be considered at two levels. At the basic level, these are software and hardware tools for collecting, transmitting and storing information. At a higher level, these are information flows that provide the company's suppliers, its clients and employees with organizational, technical and commercial information of interest to them (Figure 1).

The implementation of corporate information systems (CIS) has both material and nonmaterial benefits. Material benefits include: reduction in personnel, reduction in inventory volume, reduction in infrastructure maintenance costs, increased labor productivity, increased revenue and profit, reduction in material procurement costs, optimization of production capacity utilization. Nonmaterial benefits include: improved quality and transparency of information flows, integration of business flows, optimization of business processes, standardization of information, increased response speed to customer requirements, support for the globalization of commercial activities, creation of infrastructure, facilitating innovative change.

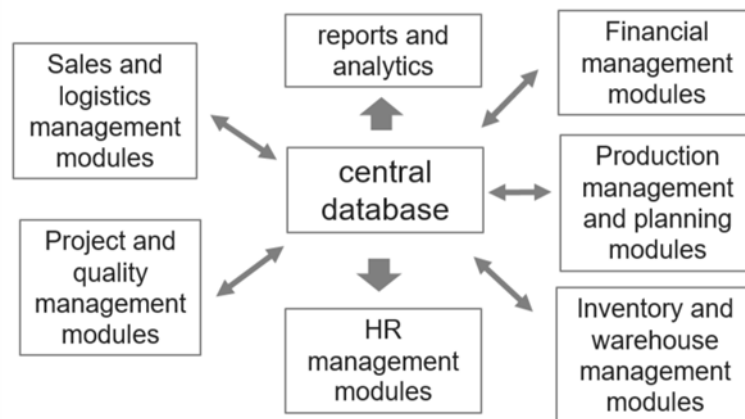


Figure 1 – Structure of the corporate information system

According to estimates made by domestic specialists back in the 80s of the 20th century, improvements in the information system ensured a reduction in losses, a reduction in equipment downtime, a reduction in defects and unproductive expenses, and a reduction in the need for working capital.

Today, the value of corporate information systems is assessed primarily through nonmaterial factors. The main ones are transparency of information flows and integration of business units within the corporation. Of the material advantages, the most important are the reduction of administrative personnel and costs for storing stocks, as well as for maintaining the corporation's infrastructure.

Thus, although corporate information systems allow optimizing and improving a large number of aspects of activity, they certainly will not help to increase the level of business profits immediately and directly. Therefore, first of all, the implementation of information systems implies obtaining such advantages as the ability to automate and simplify a number of business processes related to information processing. And it is through this advantage that the effectiveness and results of the implementation of the CIS are assessed today.

It is proposed to divide all the advantages of using corporate information systems, both material and nonmaterial, into five groups (operational, managerial, strategic, infrastructural and organizational) [1]. According to experts, infrastructural advantages were put forward in the foreground (83 % of respondents), followed by operational (73 %) and strategic (56 %) advantages. Infrastructural advantages include: the corporation's readiness for change, reduced information processing costs, and an

increase in the corporation's infrastructural potential. The components of operational advantages are: reduced costs, reduced business cycle duration, increased labor productivity, improved information processing quality, and improved customer service. Strategic advantages include supporting business growth and integration, supporting innovation, creating prerequisites for leadership in cost savings, product differentiation, supporting external relations with suppliers and customers, supporting expansion into international markets, and supporting new forms of business organization (Table 1).

Table 1 – Benefits of using corporate information systems

Group	Advantages
Operating	– information processing costs reduction; – information security; – data availability; – operational efficiency increase; – working time costs reduction; – increasing labor productivity.
Management	– quality of planning; – reduction of management costs; – objectivity and efficiency of control; – quality of decision making.
Strategic	– supporting growth and innovation; – external relations with suppliers' support; – expansion into new markets support; – new forms of business organization support; – analysis of strengths and weaknesses; – readiness for change.
Infrastructure	– improving interaction between departments; – attractiveness of jobs; – ease of scaling; – growth of infrastructure potential.
Organizational	– cost reduction; – the duration of the business cycle reduction; – increasing labor productivity; – improving the quality of information processing; – ensuring knowledge sharing; – employee satisfaction.

In accordance with the system approach, an important advantage of CIS is the synergistic effect. Synergistic effect is achieved with reliable and transparent information, free access to it by all participants, which include: employees of the corporation, its management, suppliers and clients.

Based on the experience of implementing CIS by domestic enterprises, the

advantages outlined above have different significance. In this case, significance reflects the fact of occurrence of one or another advantage. Table 2 presents the results of assessing the significance of benefits from using CIS by Russian enterprises.

Table 2 – Assessing the significance of benefits from using Corporate Information Systems [1]

Material benefits	% of answers	Nonmaterial benefits	% of answers
Staff reduction	44	Improving the quality and transparency of information	70
Decrease in stocks	42	Business-process integration	37
Reducing the cost of infrastructure maintenance	27	Optimization of business processes	37
Increased productivity	23	Standardization of information	31
Reduction of order fulfillment times	19	Increasing the speed of response to changes	29
Increase in income	15	Logistics management support	20
Reduced resource cost	12	Support for commercial activities	17
Optimization of equipment loading	8	Support for innovation	15

Thus, it can be confidently stated that the implementation of CIS in any case guarantees a number of advantages (mostly nonmaterial):

- Simplification of all processes related to receiving, storing, transmitting or processing information.
- Ensuring the reliability of information, eliminating cases where information transferred between departments contains inaccurate information.
- Reducing the volume of collected information, its repetitions and duplication of data.
- Creating a basis for implementing control and making management decisions.
- Making information and data available to a large number of users.

Whether a company will benefit from implementing CIS depends on many factors. The experience of many companies allows us to identify the following main difficulties [2]:

1. Insufficient competence of specialists and their level of skills in the field of implementation, configuration, optimization and control of the operation of corporate information systems.
2. Insufficient level of training of CIS users, difficulties with training.
3. Resistance to changes by users of the CIS, their opposition to new systems.
4. Low level of business readiness to interact with such an innovative solution as CIS.
5. Large size and fragmentation of the company.
6. A high degree of uniqueness of the company's activities, which does not allow

the use of ready-made solutions.

7. Incorrect choice of CIS, incorrect selection of its functions and characteristics.

8. The inability to combine all the information systems used by the company and integrate them.

9. Inconsistency between the CIS and the enterprise's business processes.

10. Too high costs for implementation and maintenance of CIS, lack of economic feasibility.

However, the difficulties and their severity largely depend on the specifics of the organization and the specifics of the information system. For example, a 2021 study conducted in Moscow universities showed that the development of information systems is hampered by factors such as inconsistency with the financial module, insufficient functionality, and the inability to transfer information between departments (Figure 2) [3].

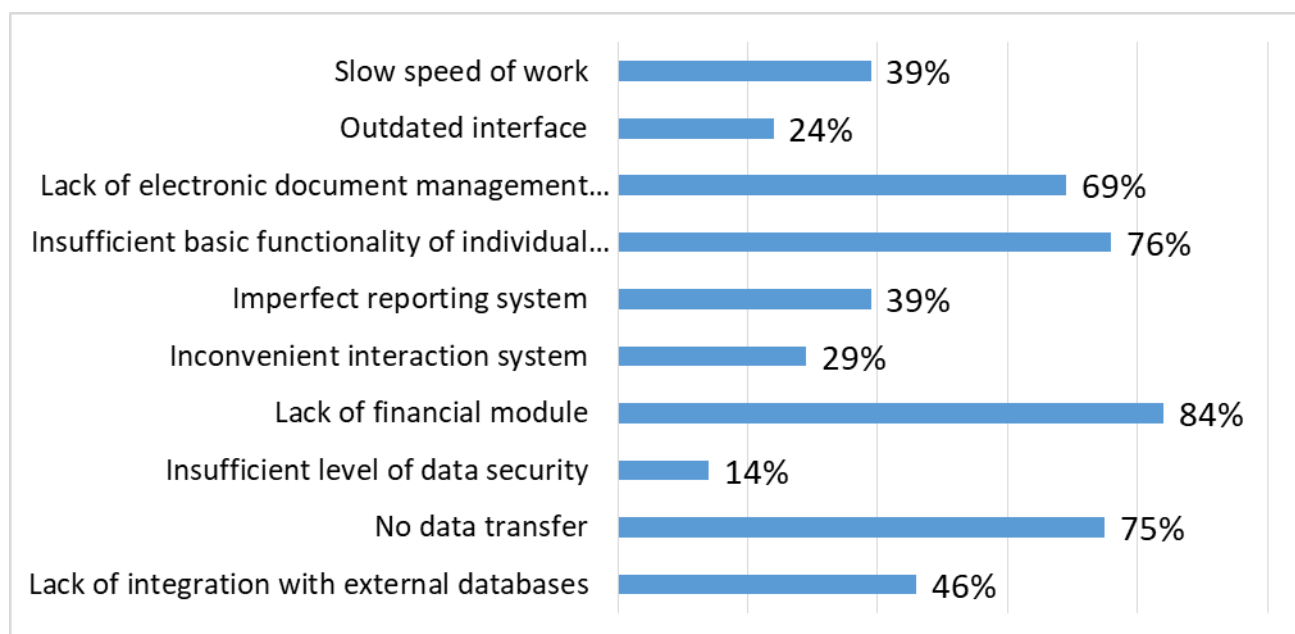


Figure 2 – Factors hindering the development of information systems at universities

For an industrial enterprise or a small art center, the complexity of implementing an information system can differ significantly.

If we approach the analysis of advantages more fundamentally, we can conclude that the information system can be considered the most important economic resource. This resource is not characterized by rarity, since information can be infinitely replicated at very low costs. In addition, when used, information is not destroyed. Its value is determined not by production costs or quantitative parameters, but by its meaningful potential. The effect of consumption is determined primarily by the quality of management in the receiving organization.

The shapes of the curves of supply and demand for information are transformed into coinciding straight lines parallel to the price axis and fixing the same conditional amount of information [4, pp.100-105]. Information is created mainly by the “general

intellect”. Restriction of access to information as intellectual property is allowed only for a limited period and is circumvented in various ways. Private property does not correspond to the nature of this economic resource. As foreign researchers note, “in a society saturated with knowledge and information, the boundary between ‘mine’ and ‘yours’ becomes less and less clear and more and more incomprehensible” [5, p. 38].

The price of knowledge is quite conditional “due to its organically inherent variety” [5, p. 37]. The assessment of intellectual and innovative products by methods of capitalization of projected income, expert and comparative analog assessments does not form an equilibrium market price.

Thus, it can be concluded that corporate information systems are the most important resource for the development of efficiency of any company. And the significant advantages of their implementation and use make investments in the CIS attractive and justified.

Список литературы:

1. Хадеева, Е. Е. Преимущества корпоративных информационных систем в автоматизации предприятия / Е. Е. Хадеева, М. В. Перова. – Текст : электронный // Экономика и управление в XXI веке: тенденции развития. – 2015. – № 24. – URL: <https://cyberleninka.ru/article/n/preimuschestva-korporativnyh-informatsionnyh-sistem-v-avtomatizatsii-predpriyatiya> (дата обращения: 07.04.2025).
2. Суходолова, Е. М. Информационная система как основа эффективного управления вузом / Е. М. Суходолова. – Текст : электронный // МНКО. – 2021. – № 2 (87). – С. 353-356. – URL: <https://cyberleninka.ru/article/n/informatsionnaya-sistema-kak-osnova-effektivnogo-upravleniya-vuzom-1> (дата обращения: 07.04.2025).
3. Лобанова, Т. М. Проблемы внедрения корпоративных информационных систем на предприятиях / Т. М. Лобанова, Т. А. Ткалич. – Текст : электронный // Вестник Белорусско-Российского университета. – 2006. – № 4. – URL: <https://cyberleninka.ru/article/n/problemy-vnedreniya-korporativnyh-informatsionnyh-sistem-na-predpriyatiyah> (дата обращения: 08.04.2025).
4. Николаева, Т. П. Информационная экономика: тенденции развития за рубежом и в России. – СПб., 1999. – 190 с. – Текст : непосредственный.
5. Ходжсон, Дж. Социально-экономические последствия прогресса знаний и нарастания сложности / Дж. Ходжсон. – Текст : непосредственный // Вопросы экономики. – 2001. – № 8. – С. 32-45.

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SPECIFICS OF IMPLEMENTATION OF EDUCATIONAL PROGRAMS ON MANAGEMENT AND ECONOMICS FOR PARTICIPANTS OF THE SPECIAL MILITARY OPERATION

Abstract. The article deals with the peculiarities of the implementation of educational programs in “Management” and “Economics” for participants of the Special Military Operation (SMO) on the example of a pilot project organized by the initiative group of the Higher School of Technology and Energy of Saint Petersburg State University of Industrial Technologies and Design (HSTE SPbSUITD). The legal, social and organizational barriers identified in the process of training the first set of students are analyzed, and proposals for improving state support mechanisms are formulated.

Keywords: Special Military Operation (SMO), social adaptation, educational programs, professional retraining, management, economics, legal regulation, participants of the Special Military Operation (SMO).

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СПЕЦИФИКА РЕАЛИЗАЦИИ ОБРАЗОВАТЕЛЬНЫХ ПРОГРАММ ПО УПРАВЛЕНИЮ И ЭКОНОМИКЕ ДЛЯ УЧАСТНИКОВ СВО

Аннотация. В статье рассматриваются особенности реализации образовательных программ по направлениям «Менеджмент» и «Экономика» для участников специальной военной операции (СВО) на примере пилотного проекта, организованного инициативной группой Высшей школы технологий и энергетики Санкт-Петербургского государственного университета промышленных технологий и дизайна (ВШТЭ СПбГУПТД). Анализируются правовые, социальные и организационные барьеры, выявленные в процессе обучения первого набора студентов, а также формулируются предложения по совершенствованию механизмов государственной поддержки.

Ключевые слова: специальная военная операция, социальная адаптация, образовательные программы, профессиональная переподготовка, менеджмент, экономика, правовое регулирование, участники СВО.

Since 2022, the Russian Federation has actualized the issues of social support for citizens who took part in the Special Military Operation (SMO). In addition to medical and material assistance, the task of integrating combatants into civilian life, including through professional and higher education, is becoming increasingly important [1].

One of the tools of such integration is professional retraining and training programs implemented by state educational institutions. The most promising areas of training for the adaptation of combat veterans are management and economics, which is due to both the personal preferences of the participants themselves and the state strategy for the formation of a personnel management reserve [2].

The pilot educational project was initiated by HSTE SPbSUITD. The main goal of the project was to provide an opportunity for participants of the Special Military Operation to obtain higher education with subsequent employment in the field of training.

To determine the target audience and its needs, a questionnaire survey was conducted among veterans attached to the St. Petersburg branch of the state fund “Defenders of the Fatherland” [3]. The results showed a high interest in management and economics programs, as well as a preference for a flexible form of training – part-time (including distance learning) with elements of face-to-face interaction with lecturers.

Thanks to the coordinated work of the initiative group and the staff of the Defenders of the Fatherland Foundation, 11 fighters were enrolled in HSTE. A total of 13 participants of the SMO were admitted in the 2024 enrollment stream. Only one student is studying under the budget quota provided to the university, the rest are studying on a contractual basis at the expense of the university’s own funds. This indicates that there is a shortage of budget places for this category of citizens, despite formal guarantees from the state [4].

Of all the students, 77 % chose management-related directions, including the profile “Logistics and Supply Chain Management”, as well as “Financial

Management”. The remaining 23 % opted for technical directions.

One of the main barriers was the lack of possibility to enroll without the results of the Unified State Examination (USE). Until recently, even with a high school diploma, participants of SMO could not be enrolled in a university without passing the USE or obtaining a vocational education diploma. This legal mishap was eliminated only with the adoption of the RF Government Decree of 17.11.2023 № 1931 [4], according to which from 2025 admission to training is allowed based on the results of internal examinations of universities.

Despite the declarations about the right to free education for participants of SMO, the current legislation limits the number of preferential places to 20 % of the total number of state-funded places [5]. Thus, if there are 20 state-funded places in the direction of “Management”, only 2 of them can be provided to this category of students. The rest are forced to study on a contractual basis.

To ensure the sustainability of the project it is necessary to involve charitable organizations and private partners. Of the 20 foundations that were approached, only the “I am for Our Own” Foundation («Я – за Своих!») [6], which became a strategic partner of the project, provided support. According to the results of additional surveys conducted by the representatives of this foundation among the current participants of the Special Military Operation, a high interest in education upon return was confirmed.

One of the key initiatives put forward in the framework of the project implementation was the proposal to introduce special educational certificates financed by the state. Such certificates could be issued by the Ministry of Defense of the Russian Federation and/or the Ministry of Science and Higher Education of the Russian Federation to the participants of the Special Military Operation to pay for education in accredited universities [7].

Another direction was the creation of an association of state universities focused on the implementation of professional adaptation programs for veterans. This will allow not only to scale the successful experience of the Higher School of Technology and Energy, SPbSUITD, but also to ensure coordination at the interregional level.

The analysis of the pilot project showed high motivation of the participants of the Special Military Operation to get higher education and their readiness for professional transformation. At the same time, the implementation of such programs requires systemic government support, removal of legal barriers and sustainable funding. In the context of post-conflict adaptation, educational initiatives become an integral part of shaping a peaceful and sustainable future for the veterans of the Special Military Operation.

It should be emphasized that the implementation of educational programs for the participants of the Special Military Operation cannot and should not be considered solely as a social initiative. Given the shortage of qualified management personnel, especially in the regions, such programs acquire strategic importance. Thus, the project being implemented at the Higher School of Technology and Energy, SPbSUITD can be regarded as a form of advanced personnel policy aimed at forming a new type of manager – disciplined, capable of making decisions under uncertainty and possessing a high degree of responsibility.

It is important to take into account the pedagogical and methodological features

of the implementation of programs for this category of students. In contrast to classical undergraduate students, the participants of the Special Military Operation as a rule, have a pronounced life experience, a formed system of values and high motivation for learning. This requires adaptation of the content and format of educational programs. In particular, emphasis was placed on practice-oriented modules, active forms of learning (cases, project work, business games), as well as regular inclusion of mentoring elements.

The need for flexible educational trajectories should also be noted. Thus, according to the results of surveys and individual consultations with the participants of the Special Military Operation, the aspiration of some students to obtain not full higher education, but short-term professional qualifications with the possibility of further education was recorded. This confirms the relevance of the introduction of modular programs and mechanisms for re-crediting learning outcomes, corresponding to the principles of the concept of “lifelong learning”.

The issue of psychological and pedagogical support for students who have participated in combat operations deserves special attention. In this regard, a program of optional psychological support was initiated, including individual and group consultations and seminars on stress management.

It is also worth paying attention to the formation of students’ professional identity. Transition from military identity to civilian one requires not only new knowledge and skills, but also transformation of self-perception, building a new image of oneself in the professional and social space. Thus, university education becomes not only a way to acquire competencies, but also an essential element of socio-cultural reintegration.

The scaling potential of the project is confirmed not only by the response from potential trainees, but also by the positive assessment from employers. According to a survey conducted among representatives of small and medium-sized businesses in St. Petersburg, about 65 % of respondents expressed their willingness to hire graduates of professional retraining programs if they have experience of participation in the Special Military Operation and confirmed a high level of discipline and responsibility.

Thus, the described pilot project of the Higher School of Technology and Energy, SPbSUITD can be considered as a model for replication in other regions of Russia. This would require regulatory enshrinement of a simplified admission procedure, expansion of state funding mechanisms (including personal educational certificates), as well as institutional support from the Ministry of Science and Higher Education of the Russian Federation.

Список литературы:

1. Указ Президента Российской Федерации от 03.05.2023 № 326 «О мерах по обеспечению социальной поддержки участников специальной военной операции» // Собрание законодательства РФ. – 2023. – № 18. – Ст. 2901. – Текст: непосредственный.
2. Послание Президента Российской Федерации Федеральному Собранию от 29 февраля 2024 года. – URL: <https://www.kremlin.ru/events/president/news/73351> (дата обращения: 01.04.2025). – Текст : электронный.

3. Фонд «Защитники Отечества»: [Официальный сайт]. – URL: <https://fondzashita.ru/> (дата обращения: 01.04.2025). – Текст : электронный.
4. Об образовании в Российской Федерации: федеральный закон от 29.12.2012 № 273-ФЗ (ред. от 01.04.2025) // Собрание законодательства РФ. – 2012. – № 53 (ч. 1). – Ст. 7598. – Текст : непосредственный.
5. О внесении изменений в правила приема в образовательные организации высшего образования: постановление Правительства РФ от 17.11.2023 № 1931 // Собрание законодательства РФ. – 2023. – № 47. – Ст. 7992. – Текст : непосредственный.
6. Фонд межрегионального взаимодействия и поддержки ветеранов боевых действий частей специального назначения: [Официальный сайт]. – URL: <https://izasvoih.ru/> (дата обращения: 01.04.2025). – Текст : электронный.
7. Международный московский образовательный салон – 2025: [Официальный сайт]. – URL: <https://mmco-expo.ru> (дата обращения: 01.04.2025). – Текст : электронный.

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APPLICATION OF NEURAL NETWORK TECHNOLOGIES IN THE PROCESS OF VOCATIONAL TRAINING

Abstract. The article discusses the practice of applying neural networks in educational institutions based on the use of data analysis and comparative analysis methods. The authors identify the key factors contributing to the successful integration of neural networks in the educational process and draw conclusions about the impact of neural network technologies on this process.

Keywords: neural networks in the learning process, advantages and limitations of artificial intelligence.

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ПРИМЕНЕНИЕ НЕЙРОСЕТЕВЫХ ТЕХНОЛОГИЙ В ПРОЦЕССЕ ПРОФЕССИОНАЛЬНОГО ОБУЧЕНИЯ

Аннотация. В статье рассматривается практика применения нейросетей в учебных заведениях на основе использования методов анализа данных, сравнительного анализа. Авторы выделяют ключевые факторы, способствующие успешной интеграции нейросетей в учебный процесс, и делают выводы о влиянии нейросетевых технологий на этот процесс.

Ключевые слова: нейросети в учебном процессе, преимущества и ограничения искусственного интеллекта.

Informatisation is a dominant feature of modern education development. Information technologies are actively implemented in various spheres both in the Russian Federation and abroad, and professional education is no exception. The increasing number of online courses and access to educational resources is a characteristic of education globalisation [1].

Technological development makes technologies such as cloud computing and machine learning algorithms available for application in the educational process. However, their use requires the necessary level of digital literacy among teachers and students. Investments from the state and private business act as political and economic support for wider implementation of IT and educational technologies.

The use of neural networks in economic education can improve the quality of teaching, as it allows modelling and analysing complex economic situations, automating the process of processing economic information, introducing simulations and games for practical training.

According to many researchers, neural networks allow for wider application of adaptive learning, which makes it possible to adjust the process of professional training to the level of knowledge of each student. Also, their application allows for the simplification of the processes of learning management and assessment of students' knowledge through automation, facilitates access to learning resources and supports self-education.

Combining traditional pedagogical technologies with AI technologies qualitatively changes the didactic process, orienting it towards individualisation of learning. The latter means training taking into account the individual characteristics of the student, which in the best form provides the disclosure of his/her abilities for activity in the professional sphere.

The use of neural networks as an AI technology allows grouping the student population according to the indicators reflecting their cognitive abilities and other characteristics, and on this basis differentiate the teaching material, design individual learning trajectories and, if necessary, change the trajectories taking into account the dynamics of individual learning. For the practical implementation of such an approach, it is important to develop appropriate computer-based neural network learning technologies.

Innovative teaching methods based on neural networks are designed to help students form new ideas and develop creative thinking in the professional sphere. At

the same time, neural networks are able to analyse students' individual work, highlight mistakes, and help them develop. AI technologies are of particular importance in the process of professional education of students in regions where there are no prestigious universities and their branches. In the conditions of organising students' education remotely, the most acceptable, in our opinion, is the use of neural network technologies that provide students with the opportunity to learn from qualified teachers.

Along with the above mentioned, the application of neural networks to improve the quality of professional training in the conditions of individualisation of the educational process becomes an equally promising area of research [2].

As the analysis of domestic and foreign practice has shown, neural networks make it possible to automatically develop learning routes that dispose students to active learning and development of critical thinking. The increase in the level of students' engagement is manifested in their active participation in discussions and seminars when their learning was supported by neural network tools. Classes become more accessible for them to understand. Moreover, students equipped with neural network assistants learn new material faster and cope with the learning load. Under these conditions, instructors can devote more time to individual work with students by reducing the time spent on administrative tasks, checking assignments, and so on.

As factors of influence, as well as criteria for assessing the effectiveness of the application of neural network technologies in the learning process, the following can be identified:

- 1) the trajectory and level of influence of neural networks on student performance;
- 2) the trajectory and level of influence on students' motivation;
- 3) the trajectory and level of influence on students' activity in the learning process;
- 4) the trajectory and level of influence on the transformation of the instructor's role in student learning;
- 5) other factors.

The level of student performance as a criterion for assessing the effectiveness of neural network technology application can be considered in the context of comparing grades and performance before and after the implementation of neural networks. As for the assessment of the level of satisfaction of teachers and students, its measurement is possible on the basis of focus group surveys. The effectiveness of integrating new technologies into the learning process can also be evidenced by indicators characterising the time spent on the learning process, comparing the time spent on learning in traditional and new (adaptive) systems.

In the Russian Federation, the Uchi.ru platform uses neural networks and AI to create adaptive assignments and tests, and automated assessment. Leading Russian universities organise various online courses.

Coursera, IBM Watson platforms are known abroad. DreamBox platform is used in US primary schools to teach mathematics using adaptive algorithms that analyse positive changes in students' learning indicators in real time.

Teaching innovations include:

- 1) interactive lectures where students can ask questions in real time;

- 2) adaptive learning models that tailor instructional material to each student's learning level and speed to achieve better results;
- 3) blended learning, which involves combining traditional and online formats to track progress;
- 4) gamification, which involves incorporating game elements into the learning process.

According to a McKinsey report, the introduction of AI technologies into teaching can increase teaching productivity by 5-30 %. In the US, 78 % of educational institutions are planning to implement AI in the learning process. According to the EdTech study, 65 % of students would prefer to use AI technologies to receive personalised study recommendations [3].

The main barriers to the practical implementation of neural networks in the learning process include:

- 1) technical difficulties with the integration of neural network technologies into existing educational systems;
- 2) insufficient competence of teachers to work with neural network technologies;
- 3) the need to ensure data confidentiality, protection of personal data of users (students, etc.) when using AI;
- 4) resistance to change that some faculty and administrators may show to the introduction of new technologies;
- 5) the high financial costs that need to be incurred to build an AI infrastructure.

It should also be noted that when introducing neural networks in education, it is important to take into account certain limitations and dangers of ethical, legal, and social nature [4]. Among them we can mention the ones listed below.

- 1) Lack of transparency and explainability

Neural network models can be 'black boxes' whose results are difficult to explain. This creates difficulties when trying to understand the basis on which certain decisions were made.

- 2) Data quality

The effectiveness of neural networks depends on the quality and quantity of training data. Poor or biased data can lead to inadequate results or even discrimination against some groups of students.

- 3) Learning errors

Neural networks can make errors in interpreting data, which can negatively affect student learning. For example, automated systems may incorrectly grade assignments, which may result in unfair consequences for students.

- 4) Dependence on technology

The advent of high technology can lead to dependence on it, reducing critical thinking skills and independence in students.

- 5) Humanities

Undoubtedly, neural networks and AI cannot replace human interaction and emotional support, which are important in the educational process.

It seems to us that compliance with data privacy requirements is one of the most essential factors for the application of neural networks and AI in the learning process. Particular attention should be paid to carrying out activities listed below.

1) Protection of personal information

Educational institutions must comply with data protection laws, such as GDPR (General Data Protection Regulation) in Europe or FZ-152 'On Personal Data' in Russia. This requires the development of clear policies on the collection, storage and use of data from students and other users of neural network and AI platforms.

2) Ensuring secure data storage

Storing large amounts of data collected through neural networks can be a target of cyberattacks. Educational institutions need to ensure that data is adequately protected from data breaches.

3) Eliminating risks due to misuse of data

There are risks associated with the use of collected data for economic purposes. Moreover, unreliable or inconsistent information in neural networks can be used to create deceptive content (e. g. fake reports or even exam papers), which in turn can lead to unfair learning. On the other hand, students may try to manipulate the model to achieve their own goals. And we need to consider that AI algorithms can reproduce and amplify biases that exist in the training data. And this can be detrimental to the use of new technologies in teaching.

A number of researchers, referring to the manifold negative factors (arguments against) associated with the introduction of neural networks in the learning process, oppose their introduction and replacement of teachers by AI [5]. Another argument against the introduction of neural networks in education is the argument about the decrease in the quality of knowledge due to the replacement of student labour by AI capabilities. However, it is important to consider the undisputed advantages of neural networks and the fact that they do not replace the teacher – teachers are indispensable for interpersonal interaction with students, their motivation and individual support. Neural networks act only as a tool in teaching, which makes it possible to facilitate the learning process and make it more interesting.

Therefore, when introducing neural networks into the educational process, it is crucial to take into account the possibility of their misuse, as well as the risks associated with the confidentiality and accuracy of data. It is necessary to introduce clear regulations and ethical standards to minimise the risks of error and deception, as well as to ensure that students' rights are respected. The balance between innovation and security should be the basis for the successful implementation of new technologies in education.

Список литературы:

1. Батунова, И. В. Интеграция цифровизации в образовательный процесс / И. В. Батунова, С. В. Кокорина, Х. Чан Тхи Тху. – Текст : электронный // Международный научно-исследовательский журнал, 2024. – № 7. – С. 1-5. – URL: <https://research-journal.org/archive/7-145-2024-july/10.60797/IRJ.2024.145.97> (дата обращения: 06.02.2025).
2. Никова, М. А. Формирование мотивации к самостоятельному обучению студентов / М. А. Никова, Н. П. Гусева, И. И. Бочарова [и др.] // Мир науки, культуры, образования. – 2022. – № 2. – С. 222-224. – Текст : непосредственный.

3. Саенко, Е. С. Artificial neural networks as the latest trend in foreign language education at university level / Е. С. Саенко // Диалог языков и культур в современном образовательном пространстве : материалы V национальной научно-практической конференции, Воронеж, 29 мая 2023 года. – Воронеж : Воронежский государственный аграрный университет им. Императора Петра I, 2023. – С. 63-65. – URL: https://elibrary.ru/download/elibrary_54394170_76468331.pdf (дата обращения: 10.02.2025).
4. Ивахненко, Е. Н. ChatGPT в высшем образовании и науке: угроза или ценный ресурс? / Е. Н. Ивахненко, В. С. Никольский. – Текст : электронный // Высшее образование в России. – 2023. – № 4. – С. 9-22. – URL: <https://cyberleninka.ru/article/n/chatgpt-v-vysshem-obrazovanii-i-nauke-ugroza-ili-tsennyy-resurs> (дата обращения: 10.02.2025).
5. Ярошенко, Г. В. Социальные последствия применения систем искусственного интеллекта в образовании / Г. В. Ярошенко, И. А. Савушкин. – Текст : электронный // Государственное и муниципальное управление. Ученые записки. – 2023. – № 3. – С. 278-284. – URL: <https://doi.org/10.22394/2079-1690-2023-1-3-278-284> (дата обращения: 10.02.2025). – EDN QWUVMZ.

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IMPLEMENTING OPEN INNOVATION IN THE MODERN RUSSIAN CONTEXT

Abstract. This paper explores the current practice of implementing the concept of open innovation in Russia. Based on the analysis of statistical data, scientific and expert publications this paper identifies the main trends of open innovation strategies and tools used by Russian organizations, as well as factors hindering the implementation of this concept at the corporate and state levels.

Keywords: open innovation, science-industry linkages, ecosystem, innovation activity, R&D.

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РЕАЛИЗАЦИЯ КОНЦЕПЦИИ ОТКРЫТЫХ ИННОВАЦИЙ В СОВРЕМЕННЫХ РОССИЙСКИХ УСЛОВИЯХ

Аннотация. Статья посвящена рассмотрению практики реализации концепции открытых инноваций в современной России. Результаты анализа статистических данных, публикаций научного и экспертного сообщества позволили выделить основные тенденции в применении российскими организациями стратегий и инструментов открытых инноваций, а также факторы, препятствующие реализации данной концепции на корпоративном и на государственном уровне.

Ключевые слова: открытые инновации, научно-производственная кооперация, экосистема, инновационная активность, НИОКР.

In today's volatile economic environment, innovation is one of the key factors in the sustainable development of companies and the country's economy. Russia lags far behind many countries in terms of innovation activity, ranking 59th according to the WIPO rating, which takes into account such criteria as innovation infrastructure, human capital and research, market sophistication, business sophistication, knowledge and technology outputs, creative outputs [1]. Russian companies face the challenges of

technological and economic development in the context of foreign sanctions and serious shortage of financial and human resources. This context should encourage companies to adopt the open innovation model, which was pioneered by G. Chesbrough. According to G. Chesbrough, “Open Innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology” [2, p. 3]. External sources of information, knowledge, and ideas can be any third-party organizations and individuals: suppliers of equipment, materials, and services; organizations of science and education, customers, competitors, investors, other enterprises, government agencies, exhibitions, and conferences. The most important tool in the open innovation model is the relationship with partners, which enables joint research or joint operational activities.

Firms may have the following open innovation strategies [3]:

- innovation seekers: firms searching for innovation solutions beyond its boundaries;
- innovation providers: large companies, small and medium-sized enterprises seeking partners to sell intellectual property or to jointly develop new products; “counterpart to an innovation seeker”;
- intermediaries: innovative brokers, often in the form of digital platforms;
- open innovators: firms act simultaneously as innovation seekers (e.g., to “fill” technology gaps) and innovation providers.

According to A. V. Vasina [4, pp. 297-298] four modern models of open innovation can be identified:

1. Cross-organizational collaboration networks based on contracts or informal interaction between organizations.
2. Open innovation ecosystems created by large companies. These ecosystems include both relatively inexpensive tools: innovation project competitions, scouting, corporate accelerators, and more expensive ones – corporate business incubators, corporate venture funds, corporate technology parks, financing of external innovation projects, spin-offs of internal developments, Mergers & Acquisitions.
3. Innovation and production clusters based on the territorial approach (areas of advanced socio-economic development, incubators, technology and industrial parks, clusters).
4. Open digital platforms for the implementation of collaborative R&D involving multiple participants: business, science and government. Digital platforms take into account the weak structuring of business interests in the development and implementation of new technologies, in personnel training; the need to coordinate interests and define requirements for technologies, the cross-disciplinary nature of the research, the ambiguity of existing scientific and technological competencies, the presence of divisional barriers between scientific organizations.

The 2023 data show a low level of overall involvement of Russian enterprises in innovation activities – the average level of innovation activity of manufacturing organizations is 22.5 %. Among those engaged in R&D, only 30.8% do so on a regular basis [5]. “Openness” and collaboration networks are practiced only by a small number of actively developing companies. For them, these activities are an important part of

their business model [6, p. 85]. According to the official statistics, the share of organizations that developed innovations in cooperation in 2023 was 18.4 % of the total number of organizations that were engaged in innovation activities [5]. Most Russian companies prefer to develop innovations using internal business units.

Figure 1 shows the distribution of organizations that had cooperative ties in the field of innovation by type of partners. It shows that 55 % (2023) and 36.3 % (2020) of companies develop innovation with organizations in the same business group as them, followed by collaboration with scientific organizations. Cooperation with suppliers, consulting firms and competitors has increased over the last three years. Examples of competitors' cooperation are the following projects: "Intelligent Field" (several Russian oil and gas companies have joined forces to develop and implement new technologies and control systems to increase production efficiency and reduce dependence on imported equipment); cooperation between "Sibur", "EuroChem", "Gazprom Neft" and "NOVATEK", which have teamed up to replace imports of HYSYS – a platform for mathematical modelling of real technological processes in chemical and oil refineries, developed by the US company AspenTech over 30 years [7].

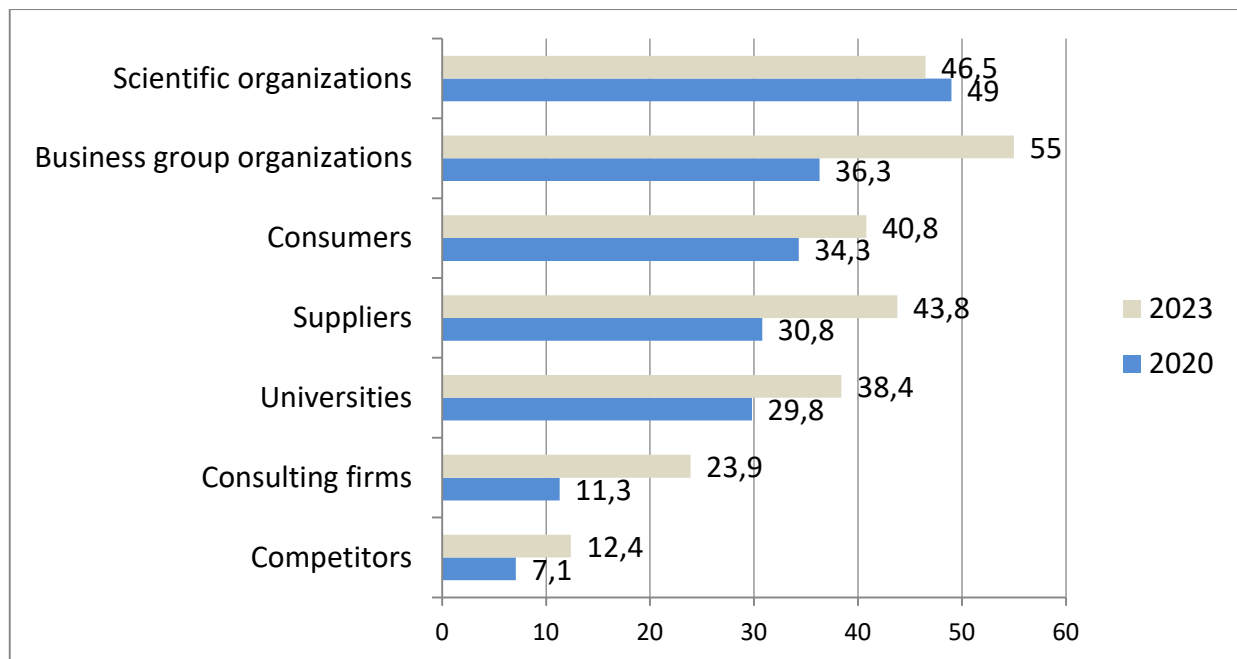


Figure 1 – Distribution of organizations that had cooperative ties in the field of innovation by type of partners, % (Author's own representation based on [5])

Examples of competitors' cooperation are more common in high-tech and medium high-tech industries, characterized by complexity and high cost of innovation. There are also many obstacles to such cooperation – competitors often have different sets of production facilities, and therefore different needs for customised technological development.

Enterprises with a high degree of labor specialization and complex production chains are more likely to increase collaboration with suppliers for the purpose of developing and implementing innovations.

The results of the analysis of Open Innovation practices in Russian organizations show a certain expansion of interaction with competitors, suppliers and consumers, largely due to the need for import substitution. The majority of companies currently use already established Open Innovation practices (internal entrepreneurship, cooperation with universities and scientific organizations), while inexpensive and targeted tools (technology scouting, hackathons, competitions, digital platforms) are more often used to search for new ideas.

The decline in corporate venture capital investment that began in 2020 continued in 2023, with a 10-fold decrease in volume compared to 2022, with the largest drop from \$424 million in 2022 compared to \$15 million in 2021 [8]. Instead of venture capital investments, Russian corporations are increasing the use of a more familiar tool – M&A deals, with their number increasing by 25 % in 2023 compared to 2021 [9]. Venture strategies of companies remaining in this market and M&A transactions are mainly aimed not at asset diversification, but at developing products that complement the core business – for example, for “Rostelecom” it is cybersecurity and software development, for “Severstal” – automation and robotics [8].

Thus, the development or acquisition of needed technological solutions is the main strategy for implementing Open Innovation by Russian companies. Over the last three years, this segment has been driven by the need to substitute imports, save on resources and reduce risk. This is reflected in some changes in the Open Innovation tools used.

In addition to the high cost of investment resources, which, in general, has a negative impact on the innovative activity of companies, other barriers to implementing Open Innovation at the corporate level should be noted: lack of information on science achievements; difficulties in finding partners; bureaucratic obstacles; risks of disclosure and use of commercial secrets; difficulties in technology integration; organization’s insufficient innovation capacity (management, corporate culture, R&D skills, marketing, technology forecasting) [4, 10, 11].

Given the objective factors hindering the development of Open Innovation at the firm level, it is relevant to ask whether the state provides sufficient support and incentives.

At the state level, a number of programs are being implemented to support cooperation between the scientific and business communities and cooperation between industrial companies. These include the digital platform of the National Association for Technology Transfer (NATT), programs to support the National Technology Initiative (NTI), the development of university-based engineering research centers, the creation of industrial clusters and parks, the activities of development funds and institutions (FSI, ATR, Skolkovo, SME Corporation), and grants for scientific and production cooperation. However, judging by the low level of cooperation between the innovative organizations, as mentioned above, there is not enough support from the state.

According to an HSE' survey, only 9.3 % of industrial enterprises that carried out innovations in 2022–2024 received state support for innovation [12]. As Figure 2 shows, technology parks and industrial clusters turned out to be the most popular measure of government support. At the same time, according to the statistics, only 26 % of the technology parks in the country are owned by the state [13].

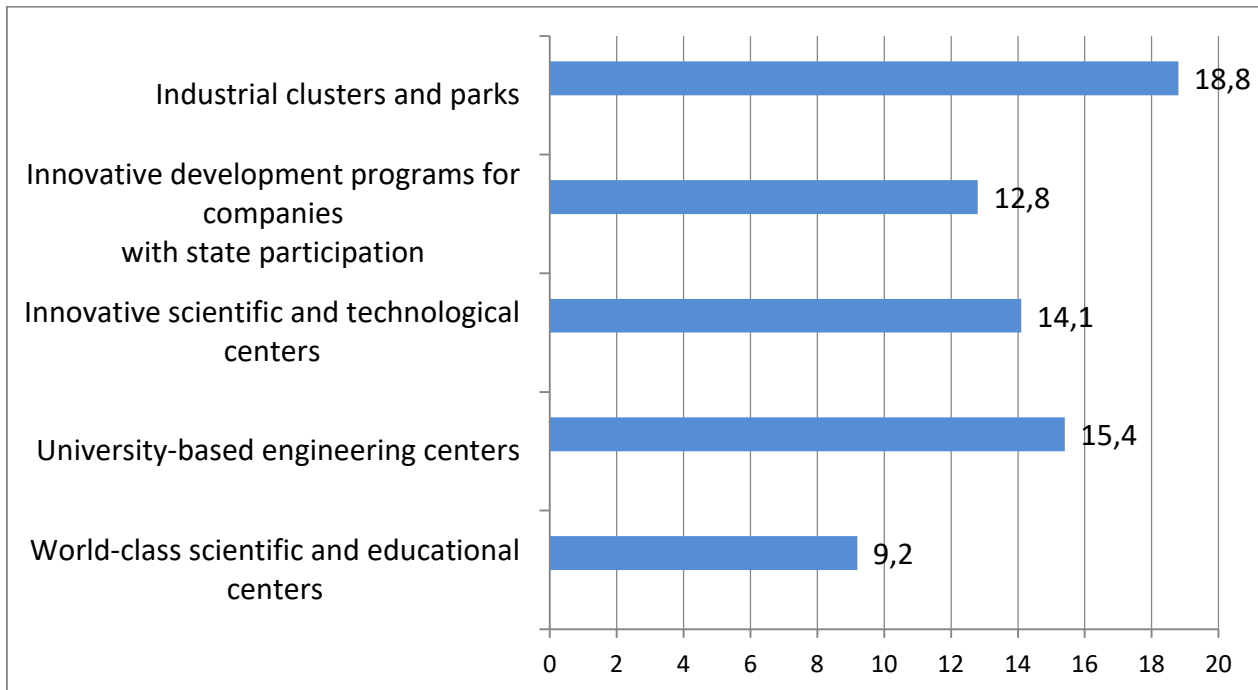


Figure 2 – Innovative organizations by used state support tools for cooperation, 2023, % (Author's own representation based on [5])

The decrease in the total number of technology parks operating in Russia in 2021–2022 (see Figure 3), which can be explained by the sanctions and other economic challenges, also indicates a decrease in the infrastructure for Open Innovation – first of all, the opportunities for small and medium enterprises to participate in it, which currently account for 90 % of the technology parks residents.

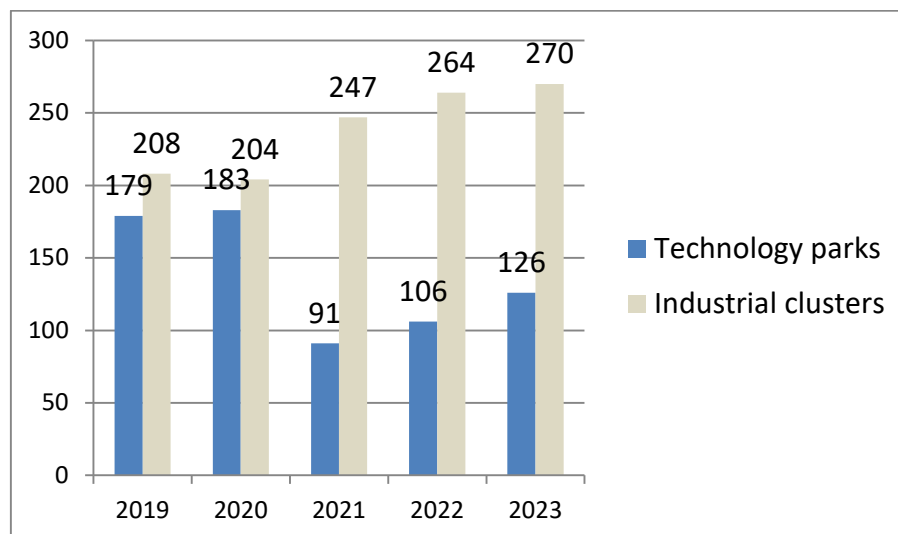


Figure 3 – Number of technology parks and industrial clusters (Author's own representation based on [13, 14])

Venture capital investment is an important measure to support innovative startups. The volume of state venture investments still accounts for about 40 % of the total Russian venture capital, in 2023 it decreased by 99 % compared to 2022 [9].

An analysis of the results of surveys of innovative organizations and expert publications on state support for innovation and industrial cooperation reveals the following problems: reduced funding, insufficient tax and customs incentives, “complexity of the procedure” and “unclear rules” for receiving support, under-developed institutional and legal framework [4, 12].

In conclusion, it can be said that the number of organizations involved in the application of open innovation in Russia is not very large. In principle, this corresponds to the low level of innovation of the Russian economy as a whole. Open Innovation strategies vary according to the size of the enterprise and the resources available to it. SMEs are more likely to be suppliers of innovation to large enterprises, to seek partners for the sale of intellectual property through digital platforms, and to use technology parks and industrial clusters for the development and production of new products. Large companies use a wide range of open innovation tools (some are ecosystem-based), but in today’s challenging political and economic environment, they mainly act as innovation seekers, filling their own technology gaps and investing in high-impact growth drivers.

Список литературы:

1. Global Innovation Index Database, WIPO, 2024. URL: <https://www.wipo.int/web-publications/global-innovation-index-2024/en/> (date accessed: 24.03.2025)
2. Alänge, S., Steiber, A. (2018) Three operational models for ambidexterity in large corporations // Triple Helix, 5. URL: <https://doi.org/10.1186/s40604-018-0053-9> (date accessed: 15.03.2025)
3. Gianiodis, P., Ellis, S., Secchi, E. (2010). Advancing a typology of open innovation // International Journal of Innovation Management. 14, 531-572.
4. Васина, А. В. Практика реализации концепции открытых инноваций в России: государственный, региональный и корпоративный уровни / А. В. Васина, О. Н. Киселева, О. В. Сысоева. – Текст: непосредственный // Регионология. – 2023. – Т. 31, № 2. – С. 294–312.
5. Индикаторы инновационной деятельности: 2025: стат. сб. / В. В. Власова [и др.]; Нац. исслед. ун-т «Высшая школа экономики». – М.: ИСИЭЗ ВШЭ, 2025. – 196 с. – URL: <https://issek.hse.ru/news/1015093288.html?ysclid=m9931hs7qs652183122> (дата обращения: 30.03.2025). – Текст : электронный.
6. Vlasova, V., Roud, V. (2020) Cooperative Strategies in the Age of Open Innovation: Choice of Partners, Geography and Duration // Foresight and STI Governance. Vol. 14, No. 4, 80-94.

7. Технологический суверенитет и промышленная кооперация в 2024 году : [сайт]. – 2025. – URL: <https://indpages.ru/prom/tehnologicheskij-suverenitet/> (дата обращения: 2.04.2025). – Текст : электронный.
8. Селизарова, В. Венчурные чаяния: как корпорации пробовали себя в венчуре и куда это их привело : [сайт] / В. Селизарова. – 2024. – URL: <https://www.forbes.ru/svoi-biznes/524962-vencurnye-caania-kak-korporacii-probovali-seba-v-venture-i-kuda-eto-ih-privelo> (дата обращения: 2.04.2025). – Текст : электронный.
9. Рынок венчурных инвестиций России 2023. – URL: https://portal.inno.msk.ru/uploads/agency-sites/analytics/research/Venture_report_Russia_2023.pdf/ (дата обращения: 2.04.2025). – Текст : электронный.
10. Открытые инновации в России – исследование Высшей школы бизнеса НИУ ВШЭ РБК Компании : [сайт]. – 2024. – URL: <https://companies.rbc.ru/news/XHT3j9Y4Cu/otkryityie-innovatsii-v-rossii---issledovanie-vyisshej-shkolyi-biznesa-niu-vshe/> (дата обращения: 30.03.2025). – Текст : электронный.
11. Kratzer, J., Meissner, D., Roud, V. (2017) Open innovation and company culture: Internal openness makes the difference // Technological Forecasting and Social Change. Vol. 119, 128-138.
12. Гершман, М. А. Спрос на господдержку инноваций – Новости – Институт статистических исследований и экономики знаний – Национальный исследовательский университет «Высшая школа экономики» : [сайт] / М. А. Гершман, М. В. Евсеева, Н. Ю. Чичканов. – 2025. – URL: <https://issek.hse.ru/news/1031162659.html?ysclid=m94dbws58b497487310> (дата обращения: 5.04.2025). – Текст : электронный.
13. Атлас промышленности : [сайт]. – 2025. – URL: <https://gispr.gov.ru/gisip/#/sections/parks/map/36.494527,55.234452/6/parks:wkeC?lng=ru&stats=parks.2336> (дата обращения: 3.04.2025). – Текст : электронный.
14. Где живут инновации: обзор технопарков России // ФТМИ ИТМО; Дзен : [сайт]. – 2024. – URL: <https://dzen.ru/a/ZdScIf7WWQb6bVRc> (дата обращения: 3.04.2025). – Текст : электронный.

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THE GLOBAL MARKET OF OIL AND GAS PRODUCTS

Abstract. The article examines the role of the Russian oil and gas industry, taking into account the current global situation. The largest oil exporting countries are analyzed according to data for 2024, as well as the formation of new transport corridors.

Keywords: oil and gas industry, sanctions, export, Russia, transport, risks.

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МИРОВОЙ РЫНОК НЕФТЕГАЗОВОЙ ПРОДУКЦИИ

Аннотация. В статье рассматривается роль российской нефтегазовой промышленности с учетом текущей мировой конъюнктуры. Анализируются крупнейшие страны-экспортеры нефти по данным на 2024 год, а также формирование новых транспортных коридоров.

Ключевые слова: нефтегазовая отрасль, санкции, экспорт, Россия, транспорт, риски.

The environment in which modern Russian business operates is characterized by a high level of uncertainty. Along with the uncertainty factors that formed in the early years of the 21st century, this is greatly facilitated by the sharp increase in geopolitical

tensions since the end of February 2022 [1, p. 55].

International sanctions are an instrument in the field of international relations that involves restriction or suspension (prohibition) of any ties in economic, commercial or other fields (for example, transport and communications or diplomatic relations, etc.) with a specific state, company, organization or group of persons. They are part of the diplomatic efforts of countries, multilateral or regional organizations aimed at protecting the interests of national security, international law, as well as protecting against threats to international peace and security [2, p. 257].

The events have led to an unprecedentedly harsh sanctions policy and economic pressure on the Russian Federation from Western countries and a number of other regions, while more and more restrictive measures are being taken. First of all, the sanctions have increased the risks of the largest domestic oil and gas companies supplying raw materials and other products to European countries [1, p. 55].

In early October 2022, the European Union adopted the 8th package of sanctions, lifting the ban on freight and insurance of marine supplies of oil and petroleum products from Russia at a price below the marginal price from December 5, 2022. Starting from December 5, the maximum price for crude oil is \$60 per barrel, excluding freight, insurance, taxes and other charges, i.e. the price of shipment from a Russian port. In 2021, crude oil shipments by sea to the EU accounted for ~70 % of exports. The West wants to provide itself with Russian oil and petroleum products, limiting Russia's income. According to a January study, the EU's GDP would increase by 0.6 % by the end of 2023. The European economy has adequately endured the expected crisis, avoiding recession due to lower gas prices and restrictions on coronavirus previously lifted by China [3, p. 52].

The restrictive conditions in which the Russian economy is forced to function, according to many experts, have become an incentive for its qualitatively new development, including domestic industry. It is known that for many years the Russian economy has depended heavily on imports, primarily of high-tech equipment. There was also a shortage of domestic technologies, as most of the advanced developments and equipment were purchased abroad. Currently, an urgent task in the development of the Russian economy is to ensure import substitution, provided technological leadership is achieved in all key areas, including industry, particularly the oil and gas sector. The foreign trade relations of the Russian Federation have changed significantly during the sanctions period. New foreign business partners (from Belarus, India, China, and other countries) replaced international companies that had left the Russian market [4, p. 65].

Accelerated import substitution in the field of oil and gas engineering can serve as a basic measure to reduce the risks of dependence of the oil and gas industry on traditional Western equipment suppliers. The main focus is on developing its own technologies that Russia previously imported (deepwater mining, gas turbines, large-capacity natural gas liquefaction technologies, etc.), as well as on finding alternative suppliers. For example, after the refusal of the American company Baker Hughes to provide supplies and maintenance of the Arctic LNG-2 project in terms of gas turbines, the project found itself in a difficult position. NOVATEK – the operator of the project

– was able to determine how to get out of the situation. Russia turned to the Turkish company Karpowership. It was decided that a Turkish builder, operator and owner of a fleet of power plants would produce a floating power plant. It will run on gas piston engines. Further, it is planned to produce such equipment at Russian enterprises [5, p. 114].

In the context of severe sanctions restrictions, it is necessary to ensure the sustainable development of the petrochemical industry by creating conditions for the stable functioning and expansion of processing capacities of domestic oil and gas companies, allowing them to increase the volume of existing products and expand their range. To this end, oil and gas companies are currently optimizing technological processes in projects that were launched jointly with Western partners from “unfriendly” countries, and most of them subsequently terminated their participation. Despite this, the domestic industry already has positive experience related to the continuation of construction and operation of facilities after the exit of foreign organizations. So, in 2022, after the German gas producer Linde left the Russian market, ceasing to implement new projects in the Russian Federation, Gazprom PJSC, which jointly with this company carried out the construction of the Amur Gas Processing Plant, continued to implement the project after the licensor left it. In August 2023 two gas separation production lines and one helium production line were successfully put into commercial operation. All other helium production lines are planned to be put into operation by the end of 2025, and then the design capacity will be 42 billion m³ of helium per year [6, p. 47].

Below is the structure of the leading oil exporting countries in 2024, expressed in millions of barrels per day. The analysis of the presented data allows us to draw a number of significant conclusions (Table).

Table – The largest oil exporting countries according to data for 2024, million barrels per day (Compiled by the authors based on [7])

Saudi Arabia	Russia	Iraq	USA	Canada	UAE	Kuwait	Norway	Nigeria	Brazil
7,363	4,780	3,712	3,604	3,350	2,717	1,878	1,558	1,388	1,346

Saudi Arabia ranks undisputed first among oil exporting countries with a volume of 7.363 million barrels per day, which significantly exceeds the volume of oil exported by other countries. This confirms its key role in the global energy market.

Russia and Iraq occupy the second and third places, respectively, exporting 4.780 and 3.712 million barrels per day. Russia, demonstrating significant volume, maintains its position as one of the leading oil suppliers, which also underlines the importance of its energy sector in the global economy.

The United States of America and Canada are close to each other with figures of 3.604 and 3.350 million barrels per day, respectively. This indicates the significant presence of North American countries in the oil market, despite their focus on domestic consumption.

Countries such as the UAE, Kuwait, Norway, Nigeria and Brazil show more modest volumes, ranging from 1.346 to 2.717 million barrels per day. This suggests that although these countries are present on the market, their export opportunities are

much less significant compared to the leaders.

Given the current data, it can be assumed that changes in politics, economics, or technological aspects in any of these countries could have a major impact on global oil markets. Countries dependent on oil exports should also consider the risks associated with climate change and the transition to alternative energy sources [7].

Overall, the data from the table highlights the current hierarchy in the oil market, where some countries continue to dominate, while others have lower export capacity. This indicates the complex structure of the global oil market and potential changes in the future.

Список литературы:

1. Лазич, Ю. В. Рисковая Среда российских предприятий нефтегазовой отрасли / Ю. В. Лазич, И. Н. Попова. – Текст : электронный // Beneficium. – 2024. – № 1(50). – С. 54-62. – URL: <https://cyberleninka.ru/article/n/riskovaya-sreda-rossiyskih-predpriyatiy-neftegazovoy-otrasli> (дата обращения: 09.04.2025).
2. Мячин, В. В. Меры санкционного давления и противодействие им со стороны Российской Федерации / В. В. Мячин. – Текст : электронный // Стратегия предприятия в контексте повышения его конкурентоспособности. – 2024. – № 13. – С. 257-261. – URL: https://www.elibrary.ru/download/elibrary_68512108_97225625.pdf (дата обращения : 09.04.2025). – EDN AWGNOK.
3. Сапунова, Т. А. Прогнозирование отраслевой структуры экспорта России в период экономический санкций / Т. А. Сапунова. – Текст : электронный // Наука и практика регионов. – 2023. – № 2(31). – С. 51-55. – URL: https://www.elibrary.ru/download/elibrary_54096745_85129678.pdf (дата обращения : 09.04.2025). – EDN KHMFTS.
4. Говор, П. С. Новые возможности развития нефтегазовой промышленности России / П. С. Говор, Е. С. Палкина. – Текст : электронный // Актуальные проблемы экономики и управления. – 2023. – № 1(12). – С. 63-67. – URL: https://www.elibrary.ru/download/elibrary_54369042_58840768.pdf (дата обращения : 10.04.2025). – DOI 10.52899/978-5-88303-660-5_63. – EDN NFNCEQ.
5. Трегубенко, Ф. А. Устойчивое развитие ТЭК в условиях санкций коллективного Запада / Ф. А. Трегубенко. – Текст : электронный // Научные обзоры. Российский внешнеэкономический вестник. – 2024. – С. 109-115. – URL: <https://cyberleninka.ru/article/n/ustoychivoe-razvitie-tek-rossii-v-usloviyah-sanktsiy-kollektivnogo-zapada> (дата обращения: 10.04.2025).
6. Афанасьев В. Я. Создание стимулов для развития нефтегазохимии в условиях санкционной экономики / В. Я. Афанасьев, О. В. Байкова, О. И. Большакова, А. А. Романцов. – Текст : электронный // Вестник университета. – 2024. – № 6. – С. 45-54. – URL: https://www.elibrary.ru/download/elibrary_68622343_19241921.pdf (дата обращения: 11.04.2025). – DOI 10.26425/1816-4277-2024-6-45-54. – EDN CEWBLT.
7. Авторский сетевой журнал – top-antropos : [сайт]. – 2025. – URL: <https://top-antropos.com/rating/item/1512-oil-export> (дата обращения: 25.03.2025). – Текст : электронный.

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RELEVANT PROBLEMS OF FINANCIAL SECURITY OF SMALL AND MEDIUM-SIZED BUSINESSES IN RUSSIA

Abstract. This work is devoted to the analysis of current problems of small and medium-sized enterprises (SMEs) in Russia. The key challenges faced by Russian entrepreneurs, including limited access to finance, a complex bureaucratic system, high competition, and an unstable economic environment are examined. The effectiveness of government support programs is analyzed and the main obstacles to the development of SMEs are identified. The work suggests possible solutions to these problems and justifies the need for an integrated approach to the development of entrepreneurial activity in Russia to stimulate economic growth and create new jobs.

Keywords: access to finance, regulation, infrastructure, government support, economic environment, competition, innovation, bureaucracy.

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АКТУАЛЬНЫЕ ПРОБЛЕМЫ ФИНАНСОВОГО ОБЕСПЕЧЕНИЯ МАЛОГО И СРЕДНЕГО БИЗНЕСА В РОССИИ

Аннотация. Данная статья посвящена анализу актуальных проблем малого и среднего бизнеса (МСБ) в России. Рассматриваются ключевые вызовы, с которыми сталкиваются российские предприниматели, включая ограниченный доступ к финансированию, сложную бюрократическую систему, высокую конкуренцию и нестабильность экономической среды. Анализируется эффективность государственных программ поддержки и выявляются основные препятствия на пути развития МСБ. Авторы статьи предлагают возможные пути решения обозначенных проблем и обосновывают необходимость комплексного подхода к развитию предпринимательской деятельности в России для

стимулирования экономического роста и создания новых рабочих мест.

Ключевые слова: доступ к финансированию, регулирование, инфраструктура, государственная поддержка, экономическая среда, конкуренция, инновации, бюрократия.

With the development, strengthening and establishment of small and medium-sized businesses, there are also problems with supporting small enterprises. Among them, we can single out the problem of financing, which is necessary for the expansion of small business. Most owners cannot afford to purchase a loan due to high interest rates and contractual conditions [1]. However, the Department for the Development of Small and Medium-sized Enterprises and Tax Incentives of the Ministry of Economic Development of the Russian Federation analyzed this problem and ensured the development of proposals in the field of state investment policy, including in terms of improving business conditions in Russia. If we consider the Sberbank Business platform, Sberbank offers several loan programs for small businesses:

- “Negotiable”. This program is designed to replenish working capital and finance current expenses, refers to short- and medium-term loans, and is provided for a maximum of 3 years. The issue amount starts from 100 thousand rubles;
- “Investment”. The program is designed for the purchase of commercial real estate, vehicles, and equipment for economic activities. Long-term loan for up to 15 years. The amount of the issue starts from 100 thousand rubles;
- “Overdraft”. A loan that allows you to make payments when there are insufficient funds in the account. The maximum period is 36 months. The maximum overdraft limit is 17 million rubles;
- “Project loan”. The program is intended for new business, modernization of production. The loan is granted for a period of up to 10 years. You can take from 2.5 million rubles.

In Sberbank, a loan for sole proprietors and LLCs can be issued if their annual revenue does not exceed 400 million rubles. The owners of the business must be residents of the Russian Federation, the sole proprietor must have Russian citizenship [2]. The business period starts from 6 months. You can apply for a loan online. To sign a contract, you need to visit a bank branch.

As a result, it can be concluded that the Sberbank Business platform is convenient, since an entrepreneur will save not only time (all services are assembled in one application, which allows efficient management of finances and operations), but also money (a large staff is not required, since all operations can be carried out through online accounting). It is worth noting the security of this platform, because the “Document Designer” service will help you create and issue a legal document in several stages that complies with the rules of the regulatory framework. The platform also provides an opportunity to insure a business, which is an advantage for a small business entrepreneur. Users also have access to the Business Environment database, which provides courses, webinars, trainings, and workshops. This database will help entrepreneurs find both business partners and clients [3].

However, this platform has significant drawbacks. For example, there is a common problem with EDS (electronic signature). The platform may not detect the

electronic signature and may not allow the user to enter the personal account [1]. In this case, the problem will have to be solved at the bank branch, which will be inconvenient for the entrepreneur. The solution to this problem can be a certain course of action: complete identification in your personal account, write to the support chat and resolve this issue [4]. It should be added that not all the services of this platform can be mastered easily and quickly, for this an entrepreneur should spend a certain amount of time. Mentoring and curation on this Sberbank platform can be a solution to this problem, that is, the coordinator will help a novice entrepreneur master basic services.

It is also worth noting the level of infrastructure development, which is reflected in roads requiring major repairs, electricity and gas supply, and underdeveloped logistics, which is determined by the lack of a rational delivery system for goods, and insufficient storage facilities.

For small businesses, time is a necessary and important resource. Due to the huge number of permits that need to be collected in all instances, the entrepreneur does not have time to invest in the business idea itself. The lack of basic knowledge in the regulatory framework leads to additional difficulties and problems for entrepreneurs. To eliminate these problems, business owners have to hire specialists who will professionally help solve all existing problems and risks in the future. An example is the Moy Biznes regional centers, which combine the entire infrastructure for supporting small and medium-sized businesses on one site. The main purpose of these centers is to help entrepreneurs solve business development tasks. The main tasks include the following:

- information and consulting support (assistance in obtaining public services, for example, in registering a legal entity, obtaining extracts from registers);
- educational support (providing a wide range of programs focused on the needs of the target group: current and potential entrepreneurs, students, women, former military personnel, and others);
- property support (assistance in preferential rental of an equipped workplace, office or industrial premises, state or municipal property (premises, land, equipment, transport));
- financial support (provision of sureties and guarantees under loan and leasing agreements);
- support in the field of innovation and modernization of production (assistance to SMEs operating in this field);
- export support (organization of exhibitions that facilitate the conclusion of export contracts by entrepreneurs, assistance in patenting, export analytics, insurance, payment for participation in international exhibitions).

It should be added that there is also a set of measures aimed at progressing entrepreneurship and providing financial, property, and educational support, such as government programs to support small and medium-sized businesses [5]. Financial support can include subsidies, benefits, and grants that will help entrepreneurs improve certain aspects of their business. If we consider property support, then this is preferential leasing, which allows us to purchase new machinery and equipment on

more favorable terms, which will lead to an increase in production volumes [2]. Educational support is the education and training of specialists, advanced training courses at the expense of the state. Let us look at some government programs for doing business that are in effect in 2025:

- Grant support

Grants are provided to young entrepreneurs (14-25 years old) (from 100,000 to 500,000 rubles), for social business (up to 500,000 rubles, and in the Arctic zone – up to 1 million rubles). There are also grants for agribusiness: support for family farms, projects in the field of agrotourism, processing of agricultural products.

- Import support

The Ministry of Economic Development has developed a “Navigator on import support measures”, which is relevant in 2025. The main measures include priority customs clearance of consumer goods and non-prosecution of foreign trade participants for violating the conditions of temporary importation.

- IT support

The government encourages the development of IT companies through tax incentives and other measures. For example, a reduced income tax rate of up to 5% will apply to IT companies from 2025 to 2030.

- A social contract for starting a business

In 2025, the maximum payment for sole proprietors is 350,000 rubles, and for citizens who run a private subsidiary farm – 200,000 rubles.

One should not forget about the competition, which is changing and improving over time. It is important to take into account the field of activity, area or region of development of the product of entrepreneurial work. All aspects are necessary to create a group, an audience of consumers who will be interested in purchasing this particular product [6]. New technologies, changing consumer preferences, globalization and the emergence of new players in the market – all this creates a continuous process of adaptation. Small businesses must be prepared for rapid change and constantly analyze the competitive environment in order to remain competitive.

One should pay attention to the following aspects: geographical (cultural traditions, purchasing power of the population in different regions), demographic (age, gender, income, education, marital status), psychographic (lifestyle, values, interests, worldview – these factors determine the motivation of consumers and their attitude to the product). It is necessary to interest the audience, attract their attention and form a positive attitude towards the product [7]. This is achieved through an effective marketing strategy (using various communication channels such as advertising, social media, and content marketing), high-quality product and service (positive reviews and recommendations play an important role in attracting new customers), and establishing strong customer relationships (customer loyalty is the key to long-term success).

The listed problems have a solution in the form of an integrated approach, an analysis of entrepreneurial activity, which represents a willingness to change and improve. Providing affordable financing is a key solution to most of entrepreneurs' problems. Infrastructure changes in the form of road construction, improved electricity and gas supply, and the creation of logistics centers will provide comfortable conditions for the progression of small businesses, which will be reflected in the

development of the financial market and the improvement of the competitive environment.

Support for small businesses is essential for economic growth, as it is a strategically important factor in progress. The development of small businesses contributes to the diversification of the economy, reducing dependence on large companies and enterprises, which makes the economy more stable internationally. Small businesses are the main employer, creating a significant number of jobs, especially for young professionals. Support for small enterprises contributes to the development of regions by attracting investments and creating local jobs. This is especially important for regions with limited infrastructure and economic difficulties. In the regions of the country, thanks to small businesses, the unemployment rate is decreasing and the quality of life of the population is improving. This is due to the fact that small businesses are the main source of new jobs. In addition, small businesses often provide jobs for people with disabilities or without work experience, which contributes to social integration. The improvement in the quality of life of the population is due to the fact that the development of small businesses leads to an increase in tax revenues to the budget. These funds can be used for social and infrastructural programs, which ultimately improves the quality of life of the population.

Despite the availability of government support programs, access to financing, bureaucratic barriers, imperfect legal framework and unstable economic environment remain significant obstacles to the development of small and medium-sized businesses. High competition, both from large companies and between representatives of small businesses themselves, also increases the pressure. To ensure sustainable growth and increase the competitiveness of Russian enterprises, a comprehensive solution to these problems is needed: simplification of administrative procedures, improved access to financial resources on favorable terms, and development of infrastructure to support and train entrepreneurs. Only a systematic approach that takes into account the specifics of various industries and regions will allow us to unlock the full potential of small and medium-sized businesses and ensure their significant contribution to the Russian economy. Solutions to current problems in the modern world will create a favorable environment for the development of the financial sector both domestically and internationally, which will lead to the economic progress of society as a whole.

Список литературы:

1. Воронина, Л. И. Социальное партнерство. Взаимодействие власти, бизнеса и наемного персонала : учебное пособие для вузов / Л. И. Воронина ; под научной редакцией Г. Б. Инванцова. – Текст : электронный // Образовательная платформа Юрайт: [сайт]. – Москва : Издательство Юрайт, 2024. – 246 с. – URL: <https://urait.ru/bcode/540158> (дата обращения: 30.03.2025).
2. Зацаринная, Е. И. Налогообложение субъектов малого бизнеса : учебник для вузов / Е. И. Зацаринная, О. Н. Тарасова, Н. А. Проданова. – Текст : электронный // Образовательная платформа Юрайт : [сайт]. – Москва : Издательство Юрайт, 2025. – 174 с. – URL: <https://urait.ru/bcode/568530> (дата обращения: 30.03.2025).
3. Кузнецова, Г. В. Россия в системе международных экономических

отношений : учебник и практикум для вузов / Г. В. Кузнецова. – 3-е изд., перераб. и доп. – Текст : электронный // Образовательная платформа Юрайт: [сайт]. – Москва : Издательство Юрайт, 2025. – 541 с. – URL: <https://urait.ru/bcode/560620> (дата обращения: 30.03.2025).

4. Кузьмина, Е. Е. Предпринимательская деятельность : учебник для среднего профессионального образования / Е. Е. Кузьмина. – 5-е изд., перераб. и доп. – Текст : электронный // Образовательная платформа Юрайт: [сайт]. – Москва : Издательство Юрайт, 2025. – 469 с. – URL: <https://urait.ru/bcode/562636> (дата обращения: 30.03.2025).

5. Роик, В. Д. Заработная плата, оплата труда и пенсионное страхование в России : учебник для вузов / В. Д. Роик. – Текст : электронный // Образовательная платформа Юрайт: [сайт]. – Москва : Издательство Юрайт, 2025. – 692 с. – URL: <https://urait.ru/bcode/567840> (дата обращения: 30.03.2025).

6. Салмина, Д. В. Проблемы современного терминоведения. Лингвистические термины за пределами специального текста : учебник для вузов / Д. В. Салмина, И. С. Куликова. – Текст : электронный // Образовательная платформа Юрайт: [сайт]. – Москва : Издательство Юрайт, 2025. – 325 с. – URL: <https://urait.ru/bcode/565847> (дата обращения: 30.03.2025).

7. Сологубова, Г. С. Составляющие цифровой трансформации : монография / Г. С. Сологубова. – Текст : электронный // Образовательная платформа Юрайт: [сайт]. – Москва : Издательство Юрайт, 2025. – 147 с. – URL: <https://urait.ru/bcode/565559> (дата обращения: 30.05.2025).

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ARTIFICIAL INTELLIGENCE AS A TOOL FOR LOGISTICS DIGITALIZATION

Abstract. The digitalization of the world economy is one of the main trends and one of the most important directions in the development of global trade of goods and services. And artificial intelligence is already a catalyst for the explosive development of science and technology. The synergy of these two vectors of the technological development should bring a new level in the idea of business efficiency and personalization of its product to the needs of the customer. This article gives a brief description of digitalization as a process of enterprise transformation and provides the most relevant and common ways to apply artificial intelligence in the implementation of digital tools to create new or modify existing products, services and operations.

Keywords: logistics, logistics digitalization, artificial intelligence.

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ИСКУССТВЕННЫЙ ИНТЕЛЛЕКТ КАК ИНСТРУМЕНТ ЦИФРОВИЗАЦИИ ЛОГИСТИКИ

Аннотация. Цифровизация мировой экономики – один из главных трендов и одно из важнейших направлений развития глобальной торговли товарами и услугами, а искусственный интеллект уже сегодня является катализатором взрывного развития науки и техники. Синергия этих двух векторов технологического развития должна вывести на новый уровень идеи об эффективном ведении бизнеса и персонализации его продукта под потребности клиента. В данной статье дается краткое описание цифровизации как процесса трансформации предприятия и приводятся наиболее актуальные и

распространенные способы применения искусственного интеллекта в ходе внедрения цифровых инструментов для создания новых или модификации существующих продуктов, услуг и операций.

Ключевые слова: логистика, цифровизация логистики, искусственный интеллект.

Introduction

The last 5 years have been transformational for both the global economy and businesses due to the COVID-19 global pandemic and subsequent lockdown, protests, political instability and the threat of economic crisis in several regions at once. All these factors forced companies to reconsider their approach to daily operations and their vision of future development. The logistics industry has taken one of the heaviest blows from the changing economic and geopolitical situation in the world. Previous logistics chains, trading routes and established relationships with counterparties have all undergone fundamental changes. Those companies that were able to survive the initial shock and begin to adapt started to look for new tools and new practices to become more sustainable structures. And it just so happens that numerous crises and turbulences have steered global business toward digital transformation and the adoption of digital tools.

Each new round of technological progress brings tools that, if properly used, can allow for the fastest and most adaptive way to make a breakthrough: the taming of fire, the transformation of the wheel from a clay wheel into part of the mechanism of a vehicle, the introduction of the conveyor belt into production, the emergence of computers, etc. And now digitalization – the adoption of digital tools to create new or modify existing products, services and operations – is clearly becoming such a disruptor.

Digitalization

Digitalization includes a long list of actions and innovations that are aimed at increasing labor efficiency, compensating for human weaknesses by delegating some tasks to computers, algorithms and sensors. Humans are amazingly adaptive creatures with many strengths and advantages over other living beings and computing technology, but collecting and working with large data sets and forming conclusions based on it is not our biggest competitive advantage, and we could use some help here. From this request grew the main directions of digital transformation: automation, platformization and the introduction of artificial intelligence. The goal of this article is to determine how the modern economy is dealing with the use of artificial intelligence using the logistics industry as an example, but the tools of digitalization are so complex and interconnected that a brief definition of automation and platformization, respectively, is necessary to fully understand the topic.

One of the first stages of digitalization is the attempt to delegate as many routine operational tasks as possible to various sensors, mechanisms and computers. As technology evolves, the tasks amenable to such delegation become more complex and diverse, but the basic idea remains the same: to compensate for the high risk of human error, to strengthen humans where their abilities are limited, and to increase the overall stability of product or service creation. Taking the logistics industry as an example,

with the rise of Internet commerce and the development of 3 & 4 party logistics, companies are deploying various sensors, adopting the Internet of Things technologies, and running simulations using digital twins to determine optimal routes, driver workload, and even optimal vehicle fleet composition. The use of automation has evolved from a competitive advantage to a minimum requirement for business success. Thus, such tools are already used by 60 percent of companies in the Russian market, and about 20 percent of companies implement robotization in their warehouses [1].

The growth of online commerce and the movement of the global economy towards the digitization of most commercial relationships has presented the industry with the challenge of providing the appropriate online infrastructure. Current digital platforms cover a significant part of modern life: whether you want to order a taxi or buy a plane ticket, order groceries, clothing or takeaway, arrange personal or commercial freight transportation, there is at least one platform that brings together hundreds of potential service providers. Platforms allow for seamless and uninterrupted interaction between the shipper, the consignee, the carrier and the platform itself in order to meet the interests of each party and improve the quality of the service received. As they develop and grow in number, companies are coming up with new competitive advantages: the ability to track your cargo in real time, guaranteeing the safety of your cargo and choosing specific transportation conditions – temperature, packaging, length of the journey, the ability to insure it directly on the company's website, and much more.

As mentioned earlier, the digitalization tools are closely related to each other, but there is one of them that is not only an independent area of research, but also a powerful multiplier of the effectiveness of the other tools – artificial intelligence and neural networks. And logistics, as an industry, is slowly but surely becoming one of the drivers of this technology.

Artificial intelligence as a digitalization instrument

Digitalization aims to collect and process accurate and relevant information in real time from as many trusted sources as possible to identify bottlenecks of the current organization of internal processes and to find points of growth with the minimum investment required. To work effectively with the obtained data, it is necessary to be able to identify anomalies, dropouts and differences from the desired organization of processes. With the increasing globalization of the world economy, with the growing number of potential customers and the need to adapt to their unique requests, the amount of information required for a full-fledged analysis becomes truly impressive. And it is here that the human disadvantage – the human factor, namely the growing chance to make a mistake in the conditions of working with large arrays of data – manifests itself. Of course, not every time a person will make a mistake, but the higher the price of such a mistake is, the more time is required for proper fulfillment of the task. In addition, there is no point in collecting information if it will not be processed and included in the analysis. This is where modern technologies – computers, artificial intelligence and neural networks – come to the rescue. Those companies that adopt advanced technologies are able to allocate resources, utilize assets, manage staff and deal with customer demands in a smarter way. Such actions significantly reduce costs and expenses, increase profits and improve the overall efficiency of the enterprise.

The trend towards AI integration has taken over the world: about 14 % of global supply chain management leaders are already implementing generative AI in their business processes, and 50 % plan to introduce these solutions in the next 12 months [2]. Experts estimate that this is just the beginning, and the global AI in logistics market is expected to grow to \$549 billion by 2033 from \$12 billion in 2023, with a compound annual growth rate of 46.7 % during 2024-2033 [3]. In Russia, the demand for digital technologies in transportation and logistics will grow annually by 21 % in 2021-2030 and will reach 626.6 billion rubles by 2030, compared to 89.4 billion rubles in 2020. At the same time, the share of AI technologies in the total market of digital technologies for transportation and logistics will amount to 35 %, or 220 billion rubles, by 2030.

Artificial intelligence is a tool that can be applied in almost any sphere and in any conditions, so the implementation of this technology, as well as the area of its application will vary depending on the region, industry and company size. But it seems possible to highlight the main directions of such integration and briefly describe their features and expected results.

AI application in logistics

1. Route optimization

The number of factors influencing the choice of a route is difficult to calculate, moreover, these factors are inconstant, and their change is difficult to predict due to their mutual influence on each other. Modern navigation systems, if simplified, consider each connected device as an independent vehicle and collect data on where, at what speed and on what roads it is moving. Analyzing the data allows you to see where the current high congestion, accidents, and other traffic complications are. But such analysis has weak predictive power, as it involves only limited retrospective analysis of previously obtained data. And AI tools, which would use, in addition to the data described above, information from public service portals, weather forecasts, upcoming or past holidays, public events and any other data, would make it possible to build more accurate forecasts and take into account factors that a human might miss. Thus, transportation companies can build optimal routes taking into account the specifics of the city, the cargo being transported and the situation on the road, which significantly reduces associated costs and saves the company time and money.

Modern logistics platforms, especially representatives of the 4PL industry, undertake to determine routes and make recommendations on logistics optimization. Such services are already offered by market leaders: SAP, Oracle, IBM and many other companies use scenario and simulation modeling methods as part of the task at hand.

2. Vehicle fleet optimization

Although freight vehicles are largely standardized, there is room for optimization, as many companies need to shrink rather than expand their vehicle fleet. But, firstly, humans tend to do business the same way they used to do it, with as little variation as possible, and secondly, humans take fewer determining factors into account during the analysis. Artificial intelligence can optimize the average route of travel, which, for example, will reduce the number of vehicles in possession, the cost of their maintenance and drivers' salaries.

3. Warehouse and fulfillment management

Warehouse management systems – WMS – are becoming increasingly widespread, helping companies to optimize not only the process of order picking, but also the process of storage. One of the main drivers of this trend has been large multifunctional warehouses, which have spread with the growth of online commerce and now bring together under their roof thousands of items with different required temperature conditions and packaging made of different materials of different sizes. Artificial intelligence is able to predict the upcoming supply and demand for each of the goods much faster than a human and, together with data on storage conditions, distribute millions of individual goods in such a way that the picker spends less time searching for them, assembling them and loading them into the vehicle.

4. Delivery optimization

With consumers in developed countries being able to order almost any product from a number of sellers for more or less the same price, customer service and, above all, speed of delivery are gaining more and more weight as a competitive advantage. The involvement of artificial intelligence in the allocation of goods to distribution centers and vehicles can reduce the expected delivery time by hours or even days, which will not only attract more customers, but also allow more goods to pass through the company per unit of time, increasing its working capital and revenue, respectively. Artificial intelligence is also able to react faster to changing circumstances, quickly adapt the route and notify the customer of possible delays, increasing the accuracy of delivery forecasts and the transparency of the service.

5. Supply and demand forecasting

No matter how much a person would like to think that he or she and, in particular, his or her buying behavior is unique and woven from the subtle threads of his or her personality, any person can be assigned to several groups at any time, depending on the criteria – it is only necessary either to bring the perspective close enough or far enough away. And it is quite difficult to analyze another person in an objective manner, because part of our behavior and decision-making process remains in silence, within ourselves, and in order to highlight it, it is necessary to abandon our own subjective patterns of thinking for a while. Both the best marketers and analysts are capable of this but their efficiency of data processing is significantly inferior to artificial intelligence, which is able to take into account thousands and millions of factors. Thus, the introduction of AI into the procurement and forecasting process will make it possible to significantly reduce costs and fill warehouses with what is needed in the first place in a certain period.

6. Prevention of breakdowns and technical malfunctions of vehicles

The spread of IoT (Internet of Things) technology, which includes the collection and processing of data from a variety of sensors, is gradually finding application in the transportation sector [4]. Sensors make it possible to prevent breakdowns and technical failures by analyzing the current wear and tear of a vehicle, and to draw conclusions not only about the quality of its production, but also about the driving style of an employee.

7. Road accident prevention

Artificial intelligence-based tools such as virtual or voice assistants, coupled

with vehicle-mounted sensors, can significantly reduce the number of accidents. And the more vehicles that utilize such tools, especially within a single ecosystem or systems that share information, the greater the predictive power of artificial intelligence and the greater the effectiveness of such measures.

8. Automation of routine operational tasks

One of the main reasons for making minor mistakes in routine tasks among professionals of any level and any qualification is fatigue and inability to keep focus on the task for a long time. And this is where artificial intelligence is far superior to humans – it does not get tired. If AI is “trained” beforehand and routine, predictable tasks are delegated to it, some employees can be reduced or retrained to meet the company’s needs, and some can be redirected to work that is not yet available to AI – creative activity.

9. Automatization of workload distribution

The simplest example of such a distribution is the drivers’ schedule. Based on the data on previously worked time, time spent on the road during the reporting period, last vacation or day off can be taken into account by AI. As a result, the driver experiences less fatigue, less risk of accidents, lower costs, lower repair costs, plus, importantly for logistics companies owning expensive vehicles, cheaper insurance for both the driver and the vehicle.

10. Personalization of customer experience

As mentioned earlier, the globalization of the economy and its subsequent digitalization are gradually leveling the playing field between sellers of goods and services and making life easier for the customer. But if products are all similar, delivery times vary within the margin of error, and last-mile delivery is often carried out by the same contractors, how do you engage the customer with minimal additional costs? The answer was found in personalizing the entire customer experience: from the customer’s first touch to personalized discounts and unusual bundling options. Artificial intelligence here, again, is useful for its ability to efficiently process large data sets and generate non-obvious suggestions.

11. Optimization of decision-making process

All of the examples above basically solve the same problem – optimizing the process of making managerial decisions based on large data sets. More and more companies are emerging whose business is based on developing products that help achieve this result and “tame” artificial intelligence for the benefit of customers. These can be both specialized CRM platforms or new solutions for existing systems. The common task of all these products is to create a logistics tool that helps automate routine decision-making and optimize the process of solving problems. Each of the companies and products has its own competitive advantages: some are implementing voice assistants, some are using Blockchain technology, while others are developing smart contracts.

But there are a number of potential challenges a company may face when implementing AI-based tools. First of all, the issue of confidentiality of collected data and compliance of the data collection process with legislation often complicates the digitalization process, as government regulation can vary significantly from country to country. And the data collection process itself can become a bottleneck of

digitalization, because in order to guarantee correct recommendations from AI, it is necessary to provide it with high-quality, relevant data in sufficient volumes, sometimes – to maintain the consistency of data collection and its quality for weeks and even months, and this requires both monetary investments and a large amount of staff time, as well as significant computing power for data processing. In addition, employees working with AI need to be properly trained and their knowledge regularly updated in line with the development of technologies. The market is currently experiencing a shortage of relevant quality staff, and this shortage will only grow given the ever-increasing penetration of technology into business. In case a company is going to rely on someone else's product rather than develop its own AI solution, it is important to realize that the closer someone else's product is to the top of the technology at the moment, the more expensive the license to use it will be and the more effort it will cost to fit into the ecosystem of the product provider.

But no matter what obstacles are encountered on the way to using AI as a business digitalization tool, no matter how much the investment costs, the fact remains that in a few years, those companies that ignore this decision will remain on the sidelines of history or be swallowed up by competitors for one simple reason – you cannot overlook a technology that is highly likely to yield efficiency gains that far exceed the time and money spent. Of course, AI's prospects depend on the industry and region, however, the future of logistics is definitely human, but only the one that will not hesitate to use AI as a decision-making assistant.

Список литературы:

1. Склады оцифровываются : [сайт]. – 2023. – URL: <https://www.retail.ru/articles/sklady-otsifrovyyayutsya/> (дата обращения: 06.04.2025). – Текст : электронный.
2. Технологические тренды в российской логистике : [сайт]. – 2025. – URL: <https://strategy.ru/research/research/tehnologicheskie-trendy-v-rossijskoj-logistike/> (дата обращения: 04.04.2025). – Текст : электронный.
3. Global AI in Logistics Market By Technology (Machine Learning, Natural Language Processing (NLP), Computer Vision, Others), By Application (Inventory Control & Planning, Transportation Network Design, Purchasing & Supply Management, Demand Planning & Forecasting, Others), By Industry Vertical (Automotive, Food and Beverages, Manufacturing, Healthcare, Retail, Others), By Region and Companies - Industry Segment Outlook, Market Assessment, Competition Scenario, Trends, and Forecast 2024-2033. 2024. URL: <https://market.us/report/ai-in-logistics-market/> (date accessed: 05.04.2025).
4. Poell, T. & Nieborg, D. & van Dijck, J. (2019). Platformisation // Internet Policy Review, 8 (4). URL: <https://doi.org/10.14763/2019.4.1425> (date accessed: 05.04.2025).

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УДК 628

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MOBILE SNOW MELTING PLANT

Abstact. Snow disposal is the urgent problem in all metropolises. The authors offer a kind of economically viable and environmentally friendly alternative technology using a mobile snow melting plant.

Keywords: snow disposal, flame tube, melting chamber, snow melting plant.

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МОБИЛЬНАЯ СНЕГОПЛАВИЛЬНАЯ УСТАНОВКА

Аннотация. Утилизация снега является насущной проблемой всех современных мегаполисов. Авторами предлагается альтернативная экономически целесообразная и экологически чистая технология с использованием мобильной снегоплавильной установки.

Ключевые слова: утилизация снега, жаровая труба, плавильная камера, снегоплавильная установка.

The natural and climatic conditions of a significant part of the territory of Russia are characterized by a large amount of precipitation in winter. Therefore, one of the most important tasks of the urban economy is to remove snow from urban highways in winter.

Snow recycling technologies are determined, first of all, by the method of snow melting – *natural*, during thaws and in spring, or *forced* – by using energy from various heat carriers:

- warm urban sewage;
- waste water of the heat power plant;
- different types of fuel.

The defining moment in the development of snow disposal technologies is the conditions for the discharge of meltwater, which are dictated by environmental and technical requirements for the intake of waste water into wastewater disposal systems or into water bodies. Compliance with these requirements is possible provided that meltwater is cleaned of pollutants exceeding discharge standards.

There are three main ways to dispose of snow [1]:

- snow removal outside the city;
- snow disposal by a snow melting point at low-potential heat sources, for example, at the waste water of a thermal power plant;
- snow disposal in mobile snow melting installations.

The most economical way to dispose of snow exported from the city's highways is to store it and then naturally melt it. Natural snowmelt is characterized by a significant duration of the melting period and a gradual outflow of meltwater at low cost. In this regard, the real scheme is the purification of meltwater by filtration through specially designed filters. When snow melts in a waterproof natural or specially created container, it is possible to organize long-term settling and filtration of meltwater, which reliably purifies water from almost all types of pollutants. There is only one disadvantage to this method – the significant areas required for storing snow. Depending on the height of the installation, the disposal of 100 thousand m³ of snow on a “dry” snow garbage requires from 0.3 to 1.0 hectares of area.

For each of the snow disposal methods, the optimal capacity of structures is determined based on the features of the adopted technological scheme. However, patterns related to the costs of snow removal and transportation are common to all methods. These costs are significant and, in most cases, exceed the cost of processing the collected snow. They consist of a part that is independent of the area served by the facility (the cost of loading snow), and another part that depends on the distance of transportation and, consequently, on the size of the area served and the capacity of the facilities.

The difference between winter cleaning of urban highways and cleaning roads outside the city is the lack of places to store snow. Therefore, snow must be removed from urban highways, and this is an expensive process. For example, the removal of 10 m³ of snow outside a megalopolis such as St. Petersburg costs 4...6 thousand rubles.

In developed countries (Canada, USA, Finland, Denmark, etc.), advanced technologies for snow disposal with simultaneous on-site snow melting are used to

reduce the number of operations, virtually eliminate transportation costs, and reduce the number of equipment, personnel, and operating costs.

During their operation, a number of *disadvantages* were revealed:

- high noise level;
- increased requirements for the quality of recycled snow;
- significant cost.

The *advantages* of mobile snow melting plants (MSMP) are [2]:

- relatively low cost (in terms of 1 m³ of daily productivity, their cost is 3000...6000 rubles, while the cost of stationary SMPs is 8000...30000 rubles);
- seasonality of placement without the need for land acquisition, complex approvals and permanent connection to utility networks;
- preservation of expensive urban lands for use;
- maximum possible reduction or even exclusion of the snow removal shoulder (transportation distance).

The most appropriate and simple solution for snow disposal would be to use hot water from the hot water supply system, however, this approach is met with serious obstacles from various technical services (Vodokanal, etc.) and the city administration.

The specifics of human activity in Russian megacities cause additional difficulties in the operation of MSMP: there is a fairly large amount of difficult-to-dispose of waste in snowdrifts, for example, bottles, bags and other household items. The disposal of such snow naturally causes difficulties [3].

An alternative design of the MSMP, in which the compartment for loading recycled snow (melting chamber) is separated from the hot water chamber, is shown in the Figure.

The snow melting plant is based on the principle of a hot-water double-circuit heat-tube boiler. Diesel fuel is supplied with air through a diesel burner to the combustion chamber, which is a fire tube. Fuel is burned in the combustion chamber. From the combustion chamber (fire pipe), flue gases enter the bypass channel, turning 180 °, and enter the convective shaft, where the bundle of tubes is located. After giving heat to the heated water, the flue gases are removed through the chimney.

Thus, the installation is divided into two compartments: a hot water chamber and a melting compartment. The water heated to a temperature of 60 °C is poured from the coolant chamber into the melting chamber through a dividing wall. Snow melts in the melting chamber. Large debris and suspended matter contained in the snow are collected in pallets installed at the bottom of the melting chamber, and due to cascade cleaning, meltwater is economically and efficiently separated from debris, which is subsequently discharged into the sewer. The bottom layer of water is pumped from the melting compartment into the coolant chamber using mud pumps.

When installing a snowmelt unit in a new location, care must be taken to ensure that a manhole is located nearby. It is worth noting that the snow melting installation can also operate offline, as it has its own generator.

The MSMP is simple and unpretentious in operation, it is enough to follow the basic instructions. For the successful operation of the snowmelt, it is necessary to choose a flat horizontal platform, check the fastenings of the main mechanisms, the oil

and fuel levels, and ground the housing.

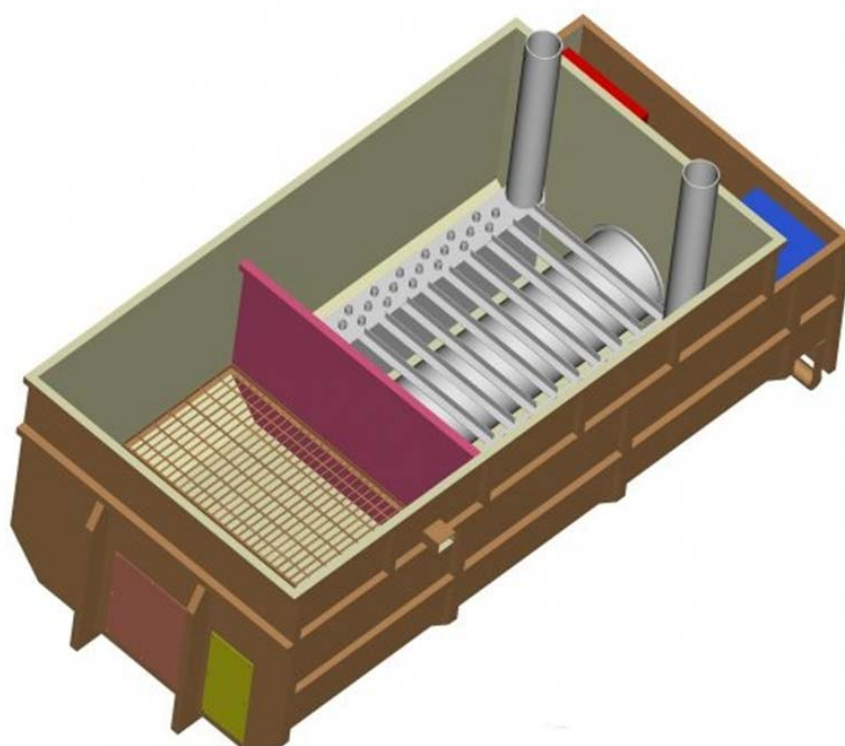
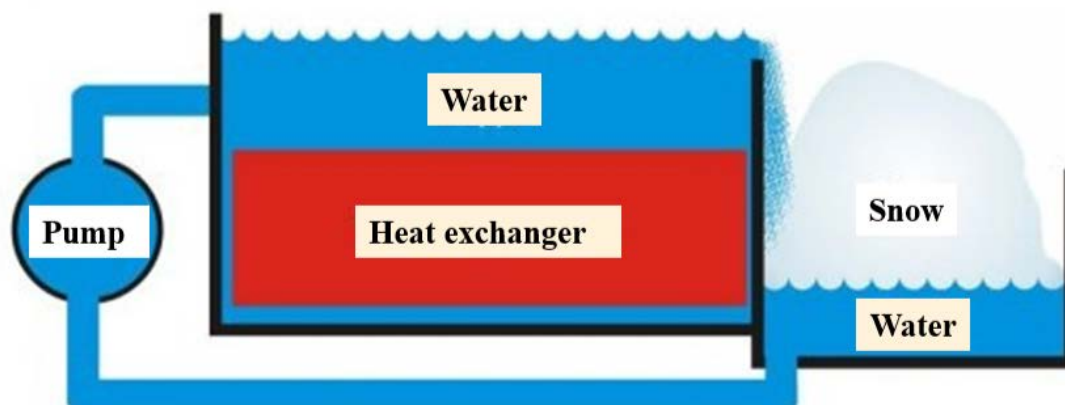


Figure – Alternative snow melting plant

Emissions of combustion products of diesel fuel into the atmosphere are minimal. The original filtration technology makes this MSMP much more environmentally friendly than imported ones: the amount of waste substances is significantly lower than the permissible standards.

The delivery of mobile snow melt installation to the place of operation and their return to the base after completion of work is carried out using bunkering trucks.

The *advantages* of this MSMP in comparison with foreign analogues are:

- ease of designing and maintaining;
- possibility of installation on a wheelbase and transportation on the territory by snow removal equipment;
- separate snow melting and water heating tanks;

- low cost;
 - thanks to the cleaning system, there are fewer requirements for snow quality.
- The *disadvantages* of MSMP include:
- the need for refueling;
 - contamination of the bunker, the need for its prompt cleaning of solid deposits;
 - the frequency of discharge of meltwater in the urban sewerage or drainage network;
 - the sewer network is heavily clogged, and at the end of the winter season, you have to spend a lot of money on cleaning it;
 - it is possible to form “snow jams” on the collectors if the snow melt is not properly organized.

The elimination of these shortcomings can be carried out as the structural elements of the installation are improved.

The main technical and economic indicators of the MSMI are as follows:

- the cost of MSMI is 700...900 thousand rubles;
- the average hourly productivity is 10 m³;
- payback period is 1...2 seasons.

Список литературы:

1. Корецкий, В. Е. Геоэкологические проблемы северных мегаполисов и крупных городов / В. Е. Корецкий. – Текст : непосредственный // Вестник МГСУ. – 2007. – № 3. – С. 19-23.
2. Корецкий, В. Е. Моделирование процесса таяния снега в снегоплавильной камере / В. Е. Корецкий. – Текст : непосредственный // Вестник МГСУ. – 2008. – С. 173-179.
3. Коммунальная экология. Энциклопедический справочник / А. Н. Мирный, Л. С. Скворцов, Е. И. Пупырев, В. Е. Корецкий. – М.: Изд. Прима-Пресс-М., 2007. – 806 с. – Текст : непосредственный.

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ANALYSIS OF HUMAN ABNORMAL BEHAVIOR IN VIDEO BASED ON NEURAL NETWORKS

Abstract. This paper discusses the analysis of human abnormal behavior in videos using neural networks. It describes the key stages of developing an anomaly detection system, including data collection and preprocessing (augmentation, labeling, segmentation), designing hybrid neural network architectures with attention mechanisms, and applying advanced learning strategies. Particular attention is paid to optimizing the model for scalability and evaluating its performance using standard metrics, inference speed, and real-world deployment scenarios with user feedback integration.

Keywords: video analysis, neural networks, attention mechanisms, data augmentation, regularization, curriculum learning, model optimization, quantization, precision, benchmarking.

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АНАЛИЗ АНОМАЛЬНОГО ПОВЕДЕНИЯ ЧЕЛОВЕКА В ВИДЕО НА ОСНОВЕ НЕЙРОННЫХ СЕТЕЙ

Аннотация. В данной статье рассматривается анализ аномального поведения человека на видео с помощью нейронных сетей. Описываются основные этапы разработки системы обнаружения аномалий, включая сбор и предварительную обработку данных (увеличение, маркировка, сегментация),

проектирование гибридных нейросетевых архитектур с механизмами внимания и применение передовых стратегий обучения. Особое внимание уделяется оптимизации модели для масштабируемости и оценке ее производительности с помощью стандартных метрик, скорости вывода и сценариев развертывания в реальном мире с интеграцией обратной связи с пользователем.

Ключевые слова: видеоанализ, нейронные сети, механизмы внимания, аугментация данных, регуляризация, куррикулярное обучение, оптимизация модели, квантование, точность, бенчмаркинг.

Introduction

In the field of computer vision, the analysis of human abnormal behavior in video has received significant attention in recent years. This area aims to develop systems capable of automatically detecting and understanding behaviors that deviate from normal patterns in various environments. Neural networks have emerged as a powerful tool for this task, enabling high-accuracy performance. This article will introduce some key concepts and techniques used in the research “Analysis of Human Abnormal Behavior in Video Based on Neural Networks”, which is based on the following theoretical framework.

Dataset Collection

Curating a diverse dataset is the cornerstone of any successful machine-learning project. In the context of human abnormal behavior analysis, the dataset should consist of both normal and abnormal behaviors captured under various environmental conditions. As stated by Choo et al. in their research [1, p. 3195], “A comprehensive dataset with a wide range of normal and abnormal scenarios is crucial for training a robust model that can generalize well to different real-world situations.”

For instance, abnormal behaviors can include acts of violence, theft, or unusual crowd movements. Normal behaviors, on the other hand, cover typical daily activities such as walking, talking, and shopping. By incorporating various environmental conditions like indoor and outdoor scenes, different lighting conditions, and diverse camera angles, the model can learn to adapt to different visual inputs.

Preprocessing Steps

Data Augmentation

Data augmentation is a technique employed to artificially increase the size and diversity of the dataset. According to Shorten and Khoshgoftaar in “A Survey on Image Data Augmentation for Deep Learning” [2, p. 65], “Data augmentation helps prevent overfitting by introducing new variations of the existing data.” Common data augmentation methods for video data include flipping (both horizontally and vertically), rotation, zooming, and adding noise. For video sequences, operations such as frame skipping or time-warping can also be performed.

Labeling

Labeling is the process of assigning a class or category to each data point in the dataset. In the case of abnormal behavior analysis, each video segment needs to be labeled as either normal or abnormal. Precise labeling is essential as it provides the ground truth for the model during training. As stated by Li et al. in “Weakly-supervised abnormal event detection in videos via multi-instance learning” [3, p. 185], “Incorrect

or inconsistent labeling can lead to poor model performance and misclassification.”

Segmentation

Video segmentation involves dividing the video into smaller, meaningful segments. This can be done at the frame level or at a more semantic level, such as segmenting a video into different actions or events. For abnormal behavior analysis, segmenting the video into relevant parts helps the model focus on specific regions or time intervals where abnormal behavior might occur. As described by Wang et al. in [4], “Effective segmentation can improve the model’s ability to detect and analyze abnormal behaviors by reducing the complexity of the input data.”

Model Design and Training

Hybrid Neural Network Architectures

The research combines Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) to create a powerful hybrid architecture. CNNs are highly proficient at extracting spatial features from images or video frames. They can identify objects, shapes, and textures in the visual data. As stated by Krizhevsky et al. in [5, p. 1097], “CNNs have revolutionized the field of computer vision by automatically learning hierarchical feature representations.”

On the other hand, RNNs are designed to capture temporal dependencies in sequential data, making them suitable for analyzing video sequences where the order of frames is crucial. As Hochreiter and Schmidhuber mentioned in [6, p. 1738], “RNNs can remember past information and use it to make predictions about future states in a sequence.”

By integrating these two types of neural networks, the model can effectively analyze both the spatial and temporal aspects of human behavior in videos.

Attention Mechanisms

Attention mechanisms are incorporated into the model to enhance its focus on critical video segments. These mechanisms assist the model in allocating more computational resources to the parts of the video that are most relevant for detecting abnormal behavior. According to Vaswani et al. in [7, p. 5998], “Attention mechanisms can significantly improve the performance of neural networks by enabling them to selectively attend to different parts of the input data.”

For example, in a crowded scene, the attention mechanism can direct the model’s focus to a small area where a potential abnormal behavior is taking place, rather than being distracted by the numerous normal activities in the background.

Advanced Training Strategies

Regularization Techniques

Preventing overfitting is a key concern when training neural networks. Beyond data augmentation, regularization techniques like Dropout and Weight Decay play a pivotal role in enhancing model generalization. Dropout randomly deactivates neurons during training, forcing the network to learn redundant representations and reducing reliance on specific features. This concept was introduced by Srivastava et al. in [8, p. 1933], highlighting its effectiveness in improving performance on complex datasets. Weight decay, on the other hand, penalizes large weights by adding a regularization term to the loss function. This helps control the complexity of the model and ensures that it does not overfit to noise in the training data. Together, these techniques form a

robust training framework for neural networks.

Curriculum Learning

Curriculum learning, inspired by human learning processes, involves training the model on progressively more difficult tasks. Initially, the model is trained on simpler data samples (e. g., clearly distinguishable abnormal behaviors) before being exposed to more challenging scenarios. This staged approach accelerates learning and improves model robustness. As stated by Bengio et al. in [9, p. 43], “Gradual exposure to complexity enables models to generalize better to unseen data.”

Evaluation Beyond Benchmarks

Real-world Deployment Scenarios

Evaluation metrics like precision and recall are invaluable but must be complemented with scenario-specific tests. For example, in a retail environment, the model could be tested on identifying thefts in live surveillance feeds, assessing not only its detection rate but also its ability to function under varying lighting conditions or camera angles. Similarly, for public safety in urban areas, detecting crowd stampedes or unusual gatherings under extreme weather conditions is crucial. Such real-world tests reveal insights into the model’s practical utility beyond standard benchmarks like UCF-Crime or ShanghaiTech datasets.

User Feedback Integration

Another often-overlooked evaluation dimension is integrating human feedback loops. By allowing end-users (e.g., security personnel) to flag false positives or negatives in real-time, the model can iteratively refine its predictions. Semi-supervised learning algorithms can incorporate this feedback to enhance the system’s performance over time. As discussed in Zhu’s study on [10, pp. 397-422], user-assisted model updates can lead to more adaptive and resilient systems.

Optimization for Scalability

Model Pruning

Model pruning is a technique used to remove unnecessary connections or neurons from the neural network. As Molchanov et al. explained in [11], “Pruning can reduce the size of the model without significant loss of performance, making it more suitable for deployment on resource-constrained devices.” By eliminating redundant parts of the model, we can decrease the computational requirements and memory footprint of the model.

Quantization

Quantization is another technique for optimizing the model for scalability. It involves reducing the precision of the numerical values used in the model. For example, instead of using 32-bit floating-point numbers, 8-bit integers can be used. As Jacob et al. stated in [12, p. 2707], “Quantization can significantly reduce the memory requirements and computational complexity of the model while maintaining acceptable accuracy.” This makes it possible to deploy the model on devices with limited resources, such as edge computing systems.

Evaluation Metrics

Precision, Recall, and F1-score

Precision, recall, and F1-score are commonly used metrics to evaluate the performance of a classification model. Precision measures the proportion of correctly

predicted positive instances (abnormal behaviors in this case) out of all the instances predicted as positive. Recall, on the other hand, measures the proportion of actual positive instances that are correctly predicted. The F1-score is the harmonic mean of precision and recall, providing a balanced evaluation of the model's performance. As Davis and Goadrich mentioned in [13, p. 234], "These metrics help assess the model's ability to correctly identify abnormal behaviors and avoid false positives and false negatives."

Inference Speed

Inference speed is also a crucial metric, especially when considering the real-time application of the model. A fast inference speed ensures that the model can process video data in a timely manner, enabling immediate detection of abnormal behaviors. As Sun et al. stated in [14], "Inference speed is essential for practical applications, as it determines how quickly the system can respond to potential threats."

Benchmarking on Datasets

Benchmarking the model on publicly available datasets (e.g., UCF-Crime, ShanghaiTech) and custom datasets is essential to validate its effectiveness. Public datasets provide a standard platform for comparing the performance of different models. By testing the model on these datasets, we can determine how well it performs compared to other state-of-the-art methods. As stated by Idrees et al. in [15, p. 3748], "Benchmarking on well-known datasets helps establish the credibility and performance level of the proposed model."

Conclusion

The analysis of human abnormal behavior in video based on neural networks is a complex yet rewarding field. Through proper dataset collection and preprocessing, innovative model design and training, optimization for scalability, and comprehensive evaluation, effective systems can be developed for detecting and understanding abnormal behaviors. The techniques and concepts described in this article form the basis of the research in this area and are expected to contribute to the development of more intelligent and reliable video analysis systems in the future.

Список литературы:

1. Choo, J., Jung, W., & Kim, T. (2018). Abnormal Event Detection in Video Surveillance Using Deep Neural Networks // *IEEE Transactions on Circuits and Systems for Video Technology*, 28(11), 3193-3206.
2. Shorten, C., & Khoshgoftaar, T. M. (2019). A Survey on Image Data Augmentation for Deep Learning // *Journal of Big Data*, 6(1), 60.
3. Li, Y., Yang, X., Wang, X., & Zhang, Y. (2018). Weakly-supervised abnormal event detection in videos via multi-instance learning // *Pattern Recognition*, 81, 180-192.
4. Wang, L., Chen, X., & Yu, F. (2015). Semantic Video Segmentation with Deep Convolutional Networks and Fully Connected CRFs // *ICLR*, 2015.
5. Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). ImageNet Classification with Deep Convolutional Neural Networks // *Advances in neural information processing systems*, 25.
6. Hochreiter, S., & Schmidhuber, J. (1997). Long Short-Term Memory // *Neural computation*, 9(8), 1735-1780.

7. Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., & Polosukhin, I. (2017). Attention Is All You Need. *Advances in neural information processing systems*, 30.
8. Srivastava, N., Hinton, G., Krizhevsky, A., Sutskever, I., & Salakhutdinov, R. (2014). Dropout: A Simple Way to Prevent Neural Networks from Overfitting // *Journal of Machine Learning Research*, 15(1), 1929-1958.
9. Bengio, Y., Louradour, J., Collobert, R., & Weston, J. (2009). Curriculum Learning // *Proceedings of the 26th Annual International Conference on Machine Learning*, 41-48.
10. Zhu, X. (2005). Semi-Supervised Learning. *Annual Review of Statistics and Its Application*, 2, 397-422.
11. Molchanov, P., Tyree, S., Karras, T., Aila, T., & Lempitsky, V. (2016). Pruning Convolutional Neural Networks for Resource Efficient Inference // *arXiv preprint arXiv:1611.06440*.
12. Jacob, B., Kligys, S., Chen, B., Zhu, M., Tang, M., Howard, A., & Adam, H. (2018). Quantization and Training of Neural Networks for Efficient Integer-Arithmetic-Only Inference // *Proceedings of the IEEE conference on computer vision and pattern recognition*, 2704-2713.
13. Davis, J., & Goadrich, M. (2006). The Relationship between Precision-Recall and ROC Curves // *Proceedings of the 23rd international conference on machine learning*, 233-240.
14. Sun, Y., Wang, X., Tang, X., & Tang, X. (2014). Deep Learning Face Representation from Predicting 10,000 Classes // *arXiv preprint arXiv:1411.7923*.
15. Idrees, H., Saleemi, I., Shah, M., & Srinivasan, G. (2017). UCF-Crime: A New Dataset for Abnormal Event Detection in Surveillance Videos // *2017 IEEE international conference on image processing (ICIP)*, 3747-3751.

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DETECTION OF CAR PARKING SPACES USING YOLO NETWORK

Abstract. The paper addresses the problem of parking space shortage in cities and proposes a solution based on a video surveillance system using the YOLOv8 neural network to detect free and occupied parking spaces in real time. The authors analyze the principles of YOLO, discuss the advantages and disadvantages of the system, and consider the possibilities of its integration into smart parking systems. The proposed system is a scalable, cost-effective, and efficient alternative to traditional parking detection systems.

Keywords: parking detection, computer vision, smart parking, deep learning, video surveillance, scalability, model training, data augmentation, transfer learning.

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ОБНАРУЖЕНИЕ МЕСТ ПАРКОВКИ АВТОМОБИЛЕЙ С ИСПОЛЬЗОВАНИЕМ СЕТИ YOLO

Аннотация. В статье рассматривается проблема нехватки парковочных мест в городах и предлагается решение, основанное на системе видеонаблюдения с использованием нейронной сети YOLOv8 для определения свободных и занятых парковочных мест в режиме реального времени. Авторы анализируют принципы работы YOLO, обсуждают преимущества и недостатки системы, а также рассматривают возможности ее интеграции в

интеллектуальные парковочные системы. Предложенная система является масштабируемой, экономичной и эффективной альтернативой традиционным системам обнаружения парковок.

Ключевые слова: обнаружение парковки, компьютерное зрение, интеллектуальная парковка, глубокое обучение, видеонаблюдение, масштабируемость, обучение модели, аугментация данных, трансферное обучение.

The rapid increase in vehicle ownership and urbanization has led to severe parking space shortages in cities worldwide. Traditional parking detection systems rely on expensive sensor-based infrastructures, which are challenging to scale and maintain. This paper presents a vision-based parking detection system utilizing the You Only Look Once (YOLO) network, specifically YOLOv8, for real-time detection of vacant and occupied parking spaces. By leveraging the capabilities of deep learning and computer vision, this system offers a scalable, cost-effective, and efficient alternative to traditional systems. The study comprehensively analyzes YOLO's operational principles, discusses its benefits and challenges, and explores its integration into smart parking solutions to alleviate urban traffic congestion and improve parking efficiency.

Introduction

The rapid expansion of urban populations and increasing vehicle ownership have intensified parking challenges in cities. A significant portion of urban traffic congestion is attributed to drivers searching for available parking spaces. Inefficient parking management leads to traffic congestion, environmental pollution, and driver frustration [1, p. 5]. Traditional parking detection systems – using sensors such as ultrasonic devices, magnetic detectors, or RFID – are widely implemented but suffer from high installation and maintenance costs.

Vision-based detection systems, enhanced by deep learning techniques, provide a more adaptable and scalable alternative. Leveraging existing surveillance infrastructure, these systems can offer real-time detection of parking occupancy without the need for additional hardware [2, p. 4]. The YOLO (You Only Look Once) network, known for its speed and accuracy in object detection tasks, presents an ideal solution for real-time parking space detection.

Traditional parking management systems face scalability, maintenance, and cost challenges. Vision-based systems can overcome these limitations but require highly efficient and accurate detection models to be viable. The study focuses on applying the YOLOv8 network to detect parking spaces in real-time using image data. It covers system architecture, working principles, advantages, limitations, and practical applications in smart parking systems.

YOLO Network Overview

The YOLO network revolutionized object detection by treating it as a regression problem, enabling real-time detection of objects within an image. Unlike traditional region-based detection methods, YOLO processes the entire image in a single pass, significantly improving speed and accuracy [3, p. 13].

The YOLO network has undergone several iterations, each enhancing its detection capabilities. YOLOv1 introduced the concept of unified detection, YOLOv2

and YOLOv3 focused on improving accuracy and detecting smaller objects, YOLOv4 optimized speed and performance, and YOLOv5 introduced customization for various applications. YOLOv8, the latest version, offers advanced feature extraction, multi-scale detection, and faster processing speeds, making it ideal for parking space detection.

YOLOv8's architecture includes a CSPDarknet backbone for feature extraction, a PANet neck for feature fusion, and optimized detection heads for multi-scale object detection. These components work together to enable accurate and efficient detection of vehicles in parking spaces under diverse environmental conditions [4, p. 8].

YOLO-Based Parking Space Detection

Traditional parking detection systems are typically sensor-based, using technologies like ultrasonic sensors, infrared detectors, and RFID. While effective, these systems face high installation and maintenance costs and are challenging to scale across large parking facilities. In contrast, YOLO-based vision systems utilize existing surveillance infrastructure, making them more cost-effective and easier to deploy. The YOLOv8 model processes real-time video feeds from parking lots, identifying vehicles and determining parking space occupancy. This approach offers high accuracy, scalability, and the ability to adapt to different parking lot configurations. The detection process involves data acquisition, preprocessing, real-time detection, and post-processing. YOLOv8 analyzes video frames to detect vehicles and classify parking spaces. Non-Maximum Suppression (NMS) is applied to eliminate redundant detections, ensuring accurate and efficient performance [5, p. 7].

YOLO-based parking detection systems offer several advantages, including reduced operational costs, high scalability, and real-time monitoring capabilities. However, challenges such as occlusion, lighting variations, and perspective distortion can affect detection accuracy. These issues can be mitigated through optimized camera placement, advanced image enhancement techniques, and fine-tuning of the YOLO model [6, p. 4].

When considering the practical implementation of YOLO-based parking detection systems, it is crucial to understand the importance of each step in the detection process. Data acquisition is the foundation, and it requires a reliable and comprehensive set of video feeds from strategically placed cameras throughout the parking lot. Preprocessing is equally important, as it involves enhancing the quality of the video data to make it more suitable for analysis. This can include noise reduction, contrast enhancement, and other image processing techniques that improve the visibility of vehicles and parking spaces. Real-time detection is where the YOLOv8 model truly shines, as it can quickly and accurately identify vehicles within the video frames. The post-processing step, including the application of NMS, ensures that the system provides the most accurate and relevant information to the end-users, such as drivers looking for available parking spaces.

The challenges faced by YOLO-based systems are not insurmountable. Occlusion, for example, can occur when vehicles are parked closely together or when other objects block the view of a parking space. Advanced camera placement strategies can help minimize this issue, such as using multiple cameras with overlapping fields of view to ensure that every parking space is visible from at least one angle. Lighting

variations can be addressed through the use of image enhancement techniques that can adjust the brightness and contrast of the video feeds in real-time, depending on the ambient lighting conditions. Perspective distortion, which can make it difficult to accurately determine the size and position of vehicles, can be corrected through calibration techniques and the use of specialized lenses or camera setups. Fine-tuning the YOLO model is also an ongoing process, as it allows the system to adapt to the specific characteristics of the parking environment and improve its detection accuracy over time.

Data Collection and Model Training

Accurate detection relies on high-quality data. A comprehensive dataset is crucial for effective model training. Images of parking lots are collected under various conditions (day/night, different weather, and angles). These images are annotated to label occupied and vacant parking spaces. Data augmentation techniques such as rotation, scaling, and brightness adjustment are applied to improve model robustness.

The YOLOv8 model is trained using transfer learning, where pre-trained weights are fine-tuned with the annotated dataset. Hyperparameters like learning rate, batch size, and epochs are optimized to enhance model performance.

The process of data collection for training a YOLOv8 model for parking space detection is a meticulous one. It involves capturing images from a wide range of scenarios to ensure that the model can handle any situation it might encounter in a real-world parking environment. This includes not only different times of day, such as day and night, but also various weather conditions like sunny, cloudy, rainy, or snowy days. The angles from which the images are captured are also varied to simulate the different perspectives that the cameras in a parking lot might have. The annotation of these images is a critical step, as it provides the ground truth data that the model will learn from. Each parking space in the images must be carefully labeled as either occupied or vacant, and the boundaries of the parking spaces must be accurately defined.

Data augmentation plays a vital role in enhancing the robustness of the model. By applying techniques such as rotation, scaling, and brightness adjustment, the model is exposed to a wider variety of image transformations. This helps the model to learn more generalized features that are not dependent on the specific conditions of the training data. For example, by rotating the images, the model learns to recognize vehicles and parking spaces from different orientations. Scaling allows it to handle vehicles of different sizes and distances from the camera, while brightness adjustment helps it to adapt to varying lighting conditions.

Transfer learning is a powerful technique that is used to train the YOLOv8 model for this specific task. It involves taking a pre-trained model that has already learned general features from a large dataset, such as ImageNet, and fine-tuning it on the annotated parking lot dataset. This approach significantly reduces the amount of training time and data required, as the model can leverage the knowledge it has already gained from the pre-training phase. The fine-tuning process involves adjusting the hyperparameters of the model, such as the learning rate, batch size, and number of epochs. The learning rate determines how quickly the model updates its weights based on the training data, and finding the right learning rate is crucial for achieving a good balance between convergence speed and model accuracy. The batch size refers to the

number of images that are processed together in each iteration of the training process, and it can affect the stability and speed of the training. The number of epochs is the number of times the entire training dataset is passed through the model, and it needs to be optimized to ensure that the model has enough iterations to learn the patterns in the data without overfitting.

Model evaluation is an essential part of the training process, as it provides feedback on the model's performance and helps to identify areas for improvement. Metrics such as mean Average Precision (mAP), precision, and recall are commonly used to assess the accuracy of object detection models. mAP is a comprehensive measure that takes into account both the precision and recall of the model across different confidence thresholds. Precision measures the proportion of true positive detections out of all positive detections, while recall measures the proportion of true positive detections out of all actual positive instances [7, p. 6]. By monitoring these metrics during the training process, the model can be fine-tuned to achieve a better balance between precision and recall, ultimately improving its overall detection accuracy.

Integration with Smart Parking Systems

Integrating YOLO-based detection with smart parking systems can significantly improve urban parking management. A smart parking system typically consists of detection, data processing, communication, and management modules. YOLOv8 serves as the core detection component, identifying parking space occupancy in real-time.

The system can transmit real-time occupancy data to drivers through mobile applications or smart displays, guiding them to available spaces and reducing search time. This integration helps alleviate traffic congestion and minimizes vehicle emissions, contributing to more sustainable urban mobility.

Smart parking systems can also incorporate automated payment systems, dynamic pricing strategies, and reservation services to enhance user convenience. Case studies have demonstrated the effectiveness of YOLO-based detection in various environments, highlighting its potential for widespread adoption [8, p. 14].

Future advancements could focus on predictive analytics for parking demand, improved data processing through cloud computing, and enhanced integration with Internet of Things (IoT) devices for dynamic space management.

Comparative Analysis with Other Detection Methods

Comparing YOLO-based detection with traditional methods highlights its advantages. Sensor-based systems, while accurate, are costly and lack scalability. Machine learning models using handcrafted features struggle with environmental adaptability. In contrast, YOLO's deep learning architecture allows it to learn complex patterns, making it robust in various conditions.

YOLOv8 outperforms earlier YOLO versions and other detection models like SSD and Faster R-CNN in terms of speed and accuracy. Its single-pass detection and multi-scale capabilities make it ideal for detecting vehicles in diverse parking layouts [9, p. 19].

Case Studies and Real-World Applications

Several cities have successfully implemented YOLO-based smart parking systems. Tokyo's dynamic space allocation system, powered by YOLO, has reduced search time for parking and alleviated congestion. Berlin has deployed YOLOv8 in commercial parking lots, improving space utilization and customer experience. In San Francisco, YOLO-based systems have been integrated with autonomous parking, guiding self-driving cars to available spaces [10, p. 14].

These implementations demonstrate YOLOv8's scalability and adaptability in diverse real-world scenarios, offering cost-effective solutions for intelligent parking management.

Future Directions

Future research could focus on improving detection accuracy under challenging conditions through data augmentation and hybrid models. Integrating YOLO-based systems with IoT devices and autonomous vehicles could further enhance parking management. Predictive analytics could optimize parking space allocation, and cloud computing could support large-scale data processing.

Conclusion

The YOLOv8 network presents a scalable, efficient, and accurate solution for real-time parking space detection. Its high-speed object detection capabilities make it superior to traditional sensor-based systems. YOLO-based detection systems offer cost-effective, scalable solutions that improve urban parking management by reducing traffic congestion, lowering emissions, and enhancing user experience. Future advancements should focus on integrating YOLO with smart city infrastructures and autonomous vehicle technologies to fully realize its potential in intelligent urban mobility solutions.

Список литературы:

1. Shankar, V., Singh, V., Choudhary, V., Agrawal, S., & Awadhiya, B. (2024, August). An enhanced car parking detection using yolov8 deep learning capabilities // 2024 First International Conference on Electronics, Communication and Signal Processing (ICECSP), 1-5. IEEE.
2. Al-batat, R., Angelopoulou, A., Premkumar, S., Hemanth, J., Kapetanios, E. (2022) An End-to-End Automated License Plate Recognition System Using YOLO Based Vehicle and License Plate Detection with Vehicle Classification. *Sensors* 2022, 22, 9477. URL: <https://doi.org/10.3390/s22239477> (date accessed: 23.03.2025).
3. Zhao, N., Wang, K., Yang, J., Luan, F., Yuan, L., Zhang, H. (2024) CMCA-YOLO: A Study on a Real-Time Object Detection Model for Parking Lot Surveillance Imagery. *Electronics*. 2024; 13(8):1557. URL: <https://doi.org/10.3390/electronics13081557> (date accessed: 23.03.2025).
4. W.A.P.N. Weerasinghe, N.H. Kalupahana, Shifak M.R.M, W.M.D.P Gunathilake, Harinda Fernando, Samanthi E.R Siriwardana (2024) Intelligent CCTV-Based Motorbike Theft Detection System in Bike Parks with 3D Slot Identification and Posture Monitoring // 2024 9th International Conference on Information Technology Research (ICITR), 1-6.

5. Li, Z., & Wei, H. (2023, October). Research on parking detection algorithm based on yolov8 // Sixth International Conference on Computer Information Science and Application Technology (CISAT 2023). Vol. 12800, 257-260. SPIE.
6. Wang, L. et al. (2023) Holistic Parking Slot Detection with Polygon-Shaped Representations // 2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Detroit, MI, USA, 2023, 5797-5803, doi: 10.1109/IROS55552.2023.10342486.
7. Li, M., Zhang, L. (2023) Deep Learning-based License Plate Recognition in IoT Smart Parking Systems using YOLOv6 Algorithm[J] // International Journal of Advanced Computer Science & Applications, 2023, 14(12).
8. Shamsmohammadi, N., Shaffiee Haghshenas, S., Guido, G. and Astarita, V. (2024). Enhancing Operational Efficacy of Smart Parking Facilities through Intelligent License Plate Recognition // Journal of Soft Computing in Civil Engineering, 2024, 8(4), 94-115. doi: 10.22115/scce.2024.416135.1716
9. Ibrahim, I. M., Elghafar, M., Mohamed, M., et al. (2024) AI-Powered Parking Management Systems: A Review of Applications and Challenges[J] // Advanced Sciences and Technology Journal, 2024, 1(2): 1-22.
10. Li, Y., Huang, Y., Tao, Q. (2024) Improving real-time object detection in Internet-of-Things smart city traffic with YOLOv8-DSAF method[J] // Scientific reports, 2024, 14(1): 17235.

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DYNAMICS OF STANDARDIZATION OF AUTOMATED CONTROL SYSTEMS

Abstract. This article explores the critical role of data security in automated control systems (ACS), which manage vital infrastructure and processes. It highlights the severe consequences of data breaches, including financial losses, reputational damage, and safety risks. The article emphasizes the importance of preventive measures, including the use of government and international and national standards to mitigate these risks. It also discusses the evolution of information security standards in Russia, with a focus on recent updates and their integration with international norms.

Keywords: information security, enterprise, business, automated control systems, information systems.

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ДИНАМИКА СТАНДАРТИЗАЦИИ АВТОМАТИЗИРОВАННЫХ СИСТЕМ УПРАВЛЕНИЯ

Аннотация. В статье рассматривается критическая роль безопасности данных в автоматизированных системах управления (АСУ), которые управляют жизненно важными инфраструктурами и процессами. Анализируются серьезные последствия утечки данных, включая финансовые потери, репутационный ущерб и риски для безопасности. Подчеркивается важность превентивных мер, включая использование государственных, международных и национальных стандартов для снижения этих рисков. Также рассматривается эволюция стандартов информационной безопасности в России с акцентом на последние обновления и их интеграцию с международными нормами.

Ключевые слова: информационная безопасность, предприятие, бизнес, автоматизированные системы управления, информационные системы.

Automated control systems are one of the primary targets of attack by cybercriminals because these systems often directly control physical equipment. Cyberattacks on automated control systems can lead to, for example, changes in equipment operation parameters, reprogramming of devices, and other consequences that affect the safety of users or the environment.

Consideration of data security in the design of automated control systems is critical because such systems are often involved in critical processes, including the management of manufacturing plants, power grids, transportation systems, infrastructure, and other areas. Ignoring data security issues can lead to serious consequences that can have an extremely negative impact on business. Automated control systems handle large amounts of data, including sensitive information such as personal data of employees and customers, trade secrets and other sensitive information. Leakage or unauthorized access to such data can lead to serious consequences for a company, including financial losses and reputational damage [1].

Data security failures result in huge costs for system recovery, loss compensation, remediation of attacks and implementation of additional security measures. Preventing such incidents by properly implementing security in automated control systems is a more cost-effective approach. External cyberattacks can not only pose a threat to automated control systems, but also the actions of internal attackers, including employees who have access to the system. Developing effective security measures helps prevent misconduct both externally and internally.

Implementing security measures can minimize the risks of unauthorized access or malicious attacks on equipment. If attackers gain access to automated control systems, they can disrupt production lines, transportation systems, or power grids, which can lead to process shutdowns, major financial losses, and even endanger lives. A breach of the confidentiality, integrity or availability of data processed by automated control systems can disrupt the entire production process or the operation of a company. This is relevant for both large manufacturing enterprises and small businesses [2].

One of the most common practices for security measures is the use of government or international standards in this area. The use of standards not only helps organizations protect their assets, but also builds trust among stakeholders by demonstrating the use of sound cybersecurity practices. The use of standards encourages collaboration between businesses, information security professionals and end users, promoting a unified approach to security across the entire chain of operations and value chain [3].

The need for cybersecurity standards for automated control systems emerged in the 2010s around the world, when the number of cyberattacks on this particular type of information systems made it possible to unambiguously distinguish them as a separate category of information systems from the point of view of digital security. The following groups of standards are mainly used in the United States:

ISA/IEC 62443 Series

The ISA/IEC 62443 series of standards is a comprehensive framework specifically designed to address cybersecurity in automated control systems. Developed by the International Society of Automation (ISA) and adopted by the

International Electrotechnical Commission (IEC), these standards provide recommendations that address various aspects of cybersecurity throughout the life cycle of industrial automation systems. First and foremost, the series of these standards establishes basic concepts, including terminology, risk assessment methodologies, and security levels, which creates a common understanding and approach to security. In addition, the standards describe requirements for establishing effective safety management programs that can be tailored to meet the unique risks and threats faced by organizations. At the system requirements level, the standards detail design requirements that ensure the secure integration and operation of control systems, which is critical to protecting against potential threats. Finally, component requirements establish technical specifications for the products used in automated control systems, ensuring that they meet the established security standards. Thus, ISA/IEC 62443 is a comprehensive approach to security, covering everything from strategic management to technical details, making it an indispensable tool for organizations seeking to improve their security [4].

ISO/IEC 27001

ISO/IEC 27001 is one of the most significant international standards providing a unified approach to information security management through the establishment, implementation and maintenance of an information security management system. Although the standard was not originally designed specifically for automated control systems, its provisions and recommendations are widely used in various sectors, including those that utilize automated control systems. The versatility of ISO/IEC 27001 allows it to be adapted to many needs, making it particularly important for organizations seeking to minimize information security risks. The standard emphasizes the need for systematic risk assessment processes that help identify vulnerabilities and implement appropriate controls. This allows organizations to not only protect their data, but also minimize potential threats, which is especially relevant in a rapidly changing technological landscape [5].

The regulatory framework and standards in the field of information security in the Russian Federation have also been developed for a very long time. Information security standards in Russia began to take shape in the early 1990s, when the need to protect information, especially state secrets, arose. The first documents were aimed at protecting classified information and did not take into account the needs of business. During this period, the focus was on developing standards that met the requirements of protecting state secrets. In 1996, three articles were introduced into the Criminal Code of the Russian Federation concerning unauthorized access to information and the development of malicious software. This was the first step towards legal regulation of information security issues. However, the first standards did not take into account the specifics of the business segment and were focused on government needs. The first significant step towards the creation of more universal standards was GOST R 15408, which was adopted as an analog of the international standard ISO/IEC 15408 (Common Criteria). This standard became the basis for assessing the security of information technologies and was adopted in Russia in the early 2000s. It initiated the transition from exclusively governmental approaches to more flexible and adapted for business [6].

Over time, Russian standards have begun to integrate with international norms. Today, there are many up-to-date information security standards in Russia that regulate various aspects of information protection. The year of major work on updates and “actualization” of state standards was 2022. The 34th series of standards was significantly changed. New standards of the series cover all stages of development of automated systems, rules for compiling documentation, terminology and requirements for the content of project documents. For example:

- GOST R 59793-2021 replaced GOST 34.601-90 and regulates the sequence of stages in the creation of automated systems;
- GOST R 59792-2021 replaced GOST 34.603-92 and defines the types of tests for automated systems;
- GOST 34.201-2020 and GOST R 59795-2021 replaced regulations that had been outdated since the late 1980s and 1990s.

New-generation state standards now clarify approaches to compiling documentation for automated systems. For example, GOST 34.201-2020 details the types of documents, their completeness and designation, which makes it easier for developers and customers to understand the requirements. The changes take into account modern threats and approaches to information protection. For example, the Terms of Reference for GOST R 59793-2021 and GOST R 59795-2021 necessarily include information security measures based on an up-to-date threat model.

With the update of the standards, the requirements to the composition and execution of project documentation have been standardized. This makes it possible to develop an exhaustive set of documents, taking into account the peculiarities and specifics of the automated system. The use of standards acts as a checklist for all project participants and reduces the likelihood of omissions in the design of automated control systems. New-generation standards now clarify approaches to compiling documentation for automated systems. For example, GOST 34.201-2020 details the types of documents, their completeness and designation, which makes it easier for developers and customers to understand the requirements.

The year 2024 also saw a number of important changes in government standards, but they mostly concern government systems and personal data, rather than automated control systems. Also, according to the activity report from the Federal Service for Technical and Export Control (FSTEC) in 2025 we can expect a new standard GOST R “Information Protection. Protection of information from unauthorized transfer or distribution from information and automated systems. General Provisions” and several other standards devoted to information security in information systems [7].

According to the amendments to the Code of Administrative Offences and the Criminal Code of the Russian Federation, the liability for violations in the field of personal data processing has been increased by introducing stricter fines and penalties for organizations and individuals violating data processing rules. In December 2024, new standards GOST R 56939-2024 и GOST R 71753-2024 came into force, which address the development of secure software and automated account management systems, respectively. These standards establish general requirements for information protection and user access management. Also, from the beginning of 2025, there is a ban on the use of information protection means from unfriendly countries for public

authorities and strategic companies, caused by the need to increase the level of security of the national infrastructure.

Russian companies have started to apply more advanced information security solutions such as artificial intelligence and machine learning to detect anomalies and prevent cyberattacks in real time. This includes the use of new systems to analyze user behavior and protect against ransomware adapted to Russian conditions. Also worth mentioning is the trend towards localization of data and information systems. Leading companies in Russia have started to actively switch to domestically developed software and services in order to ensure greater independence from foreign solutions and protection from external threats.

Thus, state standards provide clear instructions and recommendations for designers, developers and contractors. Government and national standards have a recommendatory nature for most organizations, unless otherwise provided by regulations (for example, when working with government information systems or automated management systems of critical facilities). However, they can be included in the requirements of the Terms of Reference and become mandatory. For commercial organizations, the standards serve as a reference point and can be adapted to their needs and business requirements. Only a responsible approach to data security can minimize risks, prevent potential threats and ensure sustainable business development in today's high-tech environment. Ultimately, investments in cybersecurity are not an expense, but a strategically important investment that protects a company's assets and contributes to its continued success in the market.

Список литературы:

1. Защита информации в автоматизированных системах // Официальный сайт консалтинговой компании Смарт-Софт : [сайт]. – 2025. – URL: https://www.smart-soft.ru/blog/zaschita_informatsii_v_avtomatizirovannyh_sistemah/ (дата обращения: 19.03.2025). – Текст : электронный.
2. Защита информации в АСУ ТП на критически важных объектах // Официальный сайт консалтинговой компании АРинтег : [сайт]. – 2025. – URL: https://arinteg.ru/services/asu_tp.php (дата обращения: 19.03.2025). – Текст : электронный.
3. ANSI/ISA-62443-2-1-2024, Security for Industrial Automation and Control Systems – Part 2-1: Security Program Requirements for IACS Asset Owners // Официальный сайт международного общества автоматизации (The International Society of Automation) : [сайт]. – 2025. – URL: <https://www.isa.org/products/ansi-isa-62443-2-1-2024-security-industrial-automa> (дата обращения: 20.03.2025). – Текст : электронный.
4. ISA/IEC 62443 Series of Standards // Официальный сайт международного общества автоматизации (The International Society of Automation) : [сайт]. – 2025. – URL: <https://www.isa.org/standards-and-publications/isa-standards/isa-iec-62443-series-of-standards> (дата обращения: 20.03.2025). – Текст : электронный.

5. ISO/IEC 27001:2022 // Официальный сайт международной организации по стандартизации (The International Organization for Standardization) : [сайт]. – 2025. – URL: <https://www.iso.org/ru/standard/27001> (дата обращения: 20.03.2025). – Текст : электронный.
6. ГОСТ Р ИСО/МЭК 15408: Эволюция и современное состояние стандарта безопасности ИТ // Официальный сайт консалтинговой компании RMT Group : [сайт]. – 2025. – URL: <https://rtmtech.ru/articles/gost-15408/> (дата обращения: 21.03.2025). – Текст : электронный.
7. Отчет о результатах деятельности технического комитета по стандартизации «Защита информации» (ТК 362) за 2024 год // Официальный сайт федеральной службы по техническому и экспортному контролю: [сайт]. – 2025. – URL: <https://fstec.ru/tk-362/deyatelnost-tk362/otchety-o-rezultatakh-deyatelnosti/otchet-o-rezultatakh-deyatelnosti-za-2024-god> (дата обращения: 24.03.2025). – Текст : электронный.

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NON-WOOD RAW MATERIALS FOR THE PRODUCTION OF MICROCRYSTALLINE CELLULOSE: OVERVIEW AND PROSPECTS

Abstract. Microcrystalline cellulose is an odorless powdered cellulose hydrolysis product that can be used in pharmacy, food and paint production. In the context of global climate change and depletion of forest resources, it is imperative to look for alternative sources of cellulose raw materials. In this article, the possibilities of using non-wood raw materials for the production of microcellulose are considered.

Keywords: microcrystalline cellulose, MCC, non-wood materials.

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НЕДРЕВЕСНОЕ СЫРЬЕ ДЛЯ ПРОИЗВОДСТВА МИКРОКРИСТАЛЛИЧЕСКОЙ ЦЕЛЛЮЛОЗЫ: ОБЗОР И ПЕРСПЕКТИВЫ

Аннотация. Микрокристаллическая целлюлоза – это порошкообразный продукт гидролиза целлюлозы без запаха, который может быть использован в фармацевтике, пищевой промышленности и производстве красок. В условиях глобального изменения климата и истощения лесных ресурсов крайне важно искать альтернативные источники целлюлозного сырья. В данной статье будут рассмотрены возможности использования недревесного сырья для производства микроцеллюлозы.

Ключевые слова: микрокристаллическая целлюлоза, МКЦ, недревесное сырье.

Microcrystalline cellulose is a cellulose hydrolysis product with unique properties: it is widely used in various industries, including medicine, food industry and packaging. The main areas of application are pharmaceuticals as an excipient for tablets, the food industry as a food additive to increase nutritional value, and as a filler

for paints [1].

There are several ways to classify sources base for microcrystalline cellulose, they are presented in the Figure.

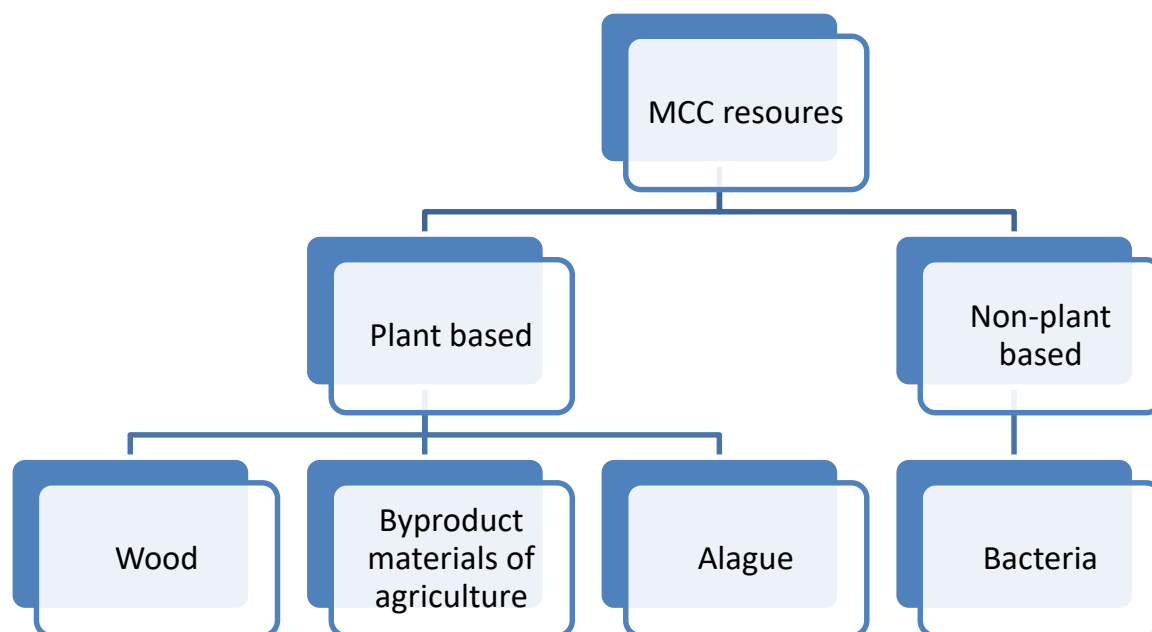


Figure – Microcrystalline cellulose source classification

Traditionally MCC is produced from wood cellulose from wood via hydrolysis with mineral acids. This method makes it possible to produce high quality product. However, there are several disadvantages. First of all, production relies on cellulose manufacturing, which is not so environmentally-friendly itself. Thus, to produce MCC in areas where there is no paper industry, the producer has to import commercial pulp first and that would lead to price increase and make country's industry rely on foreign economy. Secondly, microcrystalline cellulose production in desert and semi-desert, savannas and steppes regions faces difficulties with resource base [2].

By-product or agricultural waste are wheat stalks pulp, bamboo pulp, sugar beet pulp, potato tubers, hemp, banana, rutabaga, swede root, flax, and soybean stock. Their manufacture in Russia is shown in Table [3, 4]. These raw materials have been applied for the production of nano-cellulosic structures as they are not suitable for paper production due to low bulk density, high lignin content and short fibers.

Table – Production of agricultural crops in Russia

Agricultural crop	Production, MT	Reference
Wheat stalks	93	[3]
Sunflower	17	[3]
Soybean	6,7	[3]
Potato	8,6	[4]

Microcrystalline cellulose from raw cotton sliver. The hydrolysis of cotton stalks pulps is usually carried out with HCl or H₂SO₄ [5]. This raw material makes it possible

to obtain high quality microcrystalline cellulose via a simple, direct process. The direct processing of microcrystalline cellulose from raw material is complicated by the presence of lignin. In order to remove it, special kinds of pre-treatment are developed, for example, alkaline pretreatment with NaOH, that helps to improve purity. However, cotton is not a cheap material and pretreatment increases the price of the product.

Microcrystalline cellulose from wheat stalks pulp. Wheat is a wide-spread agricultural plant. Grain is the main product, but its stems are waste. So, it is the second option to consider for microcrystalline cellulose production, which is usually carried out with HCl or H₂SO₄ [6]. The direct processing of microcrystalline cellulose from raw material is complicated by the presence of lignin. Moreover, high silica present in powder product makes it non-applicable for pharmaceuticals. To improve the quality different pretreatments are required.

Microcrystalline cellulose (MCC) is derived from *oil palm biomass residues*, such as empty fruit bunches and fronds. It has been extensively studied for its structural, thermal, and morphological properties. MCC is isolated from oil palm residues through multi-step processes involving delignification, bleaching, and acid hydrolysis. Common methods for isolation are totally chlorine-free [7, 8], chlorine-based treatments [8], alkali-ultrasonic treatments [9]. Crystallinity depends on the way of pretreatment and isolation. The crystallinity of microcrystalline cellulose from palm biomass varies from 60 % [10] up to 87 % [7, 8, 9].

Microcrystalline cellulose from soybean hulls is a promising alternative to traditional MCC sources. MCC can be produced from soybean hulls using a simplified and cost-effective approach. This involves treating the hulls with alkali and acid to remove lignin and hemicellulose, followed by bleaching and milling to obtain MCC. [11, 12]. Soybean hull-derived MCC (SBH MCC) exhibits larger particle sizes, broader particle size distributions, higher degrees of polymerization, and crystallinity compared to commercial MCC. It also shows better thermal stability, flowability, and compressibility.

Microcrystalline cellulose can be also obtained *from potato tubers* through a process that utilizes waste products from the potato starch industry. Most of methods require delignification followed by hydrolysis [13]. Bacterial cellulose can be obtained using potato juice, waste from starch industry. Potato juice is used directly without pretreatment as a culture medium for cellulose-synthesizing bacteria. Then it produces cellulose with properties comparable to conventionally produced bacterial cellulose.

Microcrystalline cellulose (MCC) can be derived *from alfa grass fibers*, for example, from *Stipa tenacissima* (esparto grass) The process includes delignification and removal of hemicellulose, followed by acid treatment to break down cellulose chains into crystalline regions [14].

Microcrystalline cellulose can be efficiently produced *from sunflower seed husks* (SFH), which are agricultural waste generated during oil extraction. Sunflower seed husks contain 41–50 %: The sunflower seed husks need to be pretreated with a NaOH solution to eliminate impurities. Hydrolysis is held with modified organosolvent oxidation technique, involving peroxyacetic acid. This gentler method reduces chemical concentrations by 50 %, making it eco-friendly. Microcrystalline cellulose from sunflower seed husks has a crystallinity index of 72.9 %. The average particle

size is 1971 nm in length and 266 nm in width [15].

Microcrystalline cellulose derived from algae is not common as algae is heavily used for alginate production. Modern technology is required to remove cellulose from solution by sorption to purify it.

All in all, standard MCC from wood or cotton is typically optimized for high cellulose content (>90 %) through controlled processing. Other non-wood cellulose materials may require tailored purification to match this purity due to their compositional complexity. Functional differences in composites (e. g., water retention, gel strength) suggest structural variations rather than direct purity disparities.

Список литературы:

1. Аутлов, С. А. Микрокристаллическая целлюлоза: структура, свойства и области применения (обзор) / С. А. Аутлов, Н. Г. Базарнова, Е. Ю. Кушнир. – Текст : электронный // Химия растительного сырья. – 2013. – № 3. – С. 33-41. – URL: <https://doi.org/10.14258/jcprm.1303033> (дата обращения: 30.03.2025).
2. Husgafvel, R., Vanhatalo, K., Rodriguez-Chiang, L., Linkosalmi, L., Dahl, O. (2016) Comparative global warming potential assessment of eight microcrystalline cellulose manufacturing systems. 2016. No 126, 620-629. URL: <https://doi.org/10.1016/j.jclepro.2016.03.091> (date accessed: 01.04.2025).
3. Overview of the Russian agricultural market in 2023. ROS AGRO PLS. – 2025. URL: <https://ar2023.rusagrogroup.ru/en/performance-overview/> (date accessed: 14.04.2025).
4. По итогам 2023 года производство картофеля в организованном секторе составило 8,6 млн тонн // Отраслевой портал Аграрная наука : [сайт]. – 2024 – URL: <https://ar2023.rusagrogroup.ru/en/performance-overview/> (дата обращения: 14.04.2025). – Текст : электронный.
5. Kale, R. D., Bansal, P. S., Gorade, V. G. (2018) Extraction of Microcrystalline Cellulose from Cotton Sliver and Its Comparison with Commercial Microcrystalline Cellulose // J Polym Environ 26, 355–364. URL: <https://doi.org/10.1007/s10924-017-0936-2> (date accessed: 15.04.2025).
6. Li, J.-B, Zhang, M.-Y, Liu, Y.-S, Zhang, Y. (2011). Preparation and characterization of wheat straw MCC for synthetic leather // Advanced Materials Research. 42. 1606-1609.
7. Mohamad Haafiz, M. K., Eichhorn, S. J., Azman Hassan, Jawaid, M. (2013) Isolation and characterization of microcrystalline cellulose from oil palm biomass residue // Carbohydrate Polymers. Volume 93, Issue 2, 2013, 628-634. URL: <https://doi.org/10.1016/j.carbpol.2013.01.035> (date accessed: 16.04.2025).
8. Norazli, N., Mohammad Rawi, N. F., Abdulwahab Taiwo, O. F., Mohamad Kassim, M. H., and Jawaid, M. (2023). Delignification's effect on microcrystalline cellulose obtained from oil palm empty fruit bunch fibres // BioResources 18(1), 1901-1915.
9. Ramli, R., Junadi, N., Beg, H. & Yunus, R. (2015). Microcrystalline Cellulose (MCC) from oil palm empty fruit bunch (EFB) fiber via simultaneous ultrasonic and alkali treatment // International Journal of Chemical, Nuclear, Materials and Metallurgical Engineering. 9, 8-11.

10. Folahan Abdul-Wahab Taiwo, Owolabi, Ghazali, Arniza, H.P.S, Abdul Khalil & Hassan, Azman & Arjmandi, Reza & Fazita, M. & Haafiz, M.K. (2016). Isolation and Characterization of Microcrystalline Cellulose from Oil Palm Fronds using Chemomechanical Process // Wood and fiber science: journal of the Society of Wood Science and Technology. 48. 1-11.
11. Uesu, N. Y., Pineda, E.A., Hechenleitner, A. A. (2000) Microcrystalline cellulose from soybean husk: effects of solvent treatments on its properties as acetylsalicylic acid carrier // Int J Pharm. 2000 Sep 25; 206(1-2), 85-96.
12. Alamdari, N. E., Aksoy, B., Babu, R.J., Jiang, Z. (2024) Microcrystalline cellulose from soybean hull as an excipient in solid dosage forms: Preparation, powder characterization, and tableting properties // Int J Biol Macromol. 2024 Jun; 270(Pt 1):132298.
13. Preparation method of sweet potato diet microcrystal cellulose. URL: <https://patents.google.com/patent/CN1295250C/en> (date accessed: 14.04.2025).
14. Trache, D., Khimeche, K., Donnot, A., Benelmir, R. (2013) FTIR spectroscopy and X-ray powder diffraction characterization of microcrystalline cellulose obtained from alfa fibers // MATEC Web of Conferences. 3. 10, 1-2.
15. Battalova, A., Kabdrakhmanova, S., Akatan, K., Beisebekov, M., Kantay, N., Ibraeva, Z., Mausumbayeva, A. and Merck, L. (2023) Features of microcrystalline cellulose produced from sunflower seeds of different oil content // International Journal of Biology and Chemistry, 16(1), 78–86. doi: 10.26577/ijbch.2023.v16.i1.08.

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THE USE OF NEUROMORPHIC SYSTEMS IN THE CREATION OF ARTIFICIAL INTELLIGENCE

Abstract. The article discusses issues related to the development of artificial intelligence based on ideas taken from wildlife. Improving the efficiency of computing processes is one of the key tasks facing developers of neuromorphic systems that increase the speed of machine learning.

Keywords: neuromorphic systems, artificial intelligence, von Neumann computer architecture, training.

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ИСПОЛЬЗОВАНИЕ НЕЙРОМОРФНЫХ СИСТЕМ В СОЗДАНИИ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА

Аннотация. В статье рассматриваются вопросы, связанные с развитием искусственного интеллекта на основе идей, взятых из живой природы. Повышение эффективности вычислительных процессов – одна из ключевых задач, стоящих перед разработчиками нейроморфных систем, обеспечивающих повышение скорости машинного обучения.

Ключевые слова: нейроморфные системы, искусственный интеллект, фон Неймановская архитектура ЭВМ, обучение.

The term “neuromorphic” in relation to computing systems means an attempt to overcome technological problems associated with information processing, studied using approaches borrowed from biology, i.e. the principles of the brain. The neuromorphic system is an alternative to the classical von Neumann computer architecture in the creation of artificial intelligence (AI).

The fact is that in modern computers, the memory and processor are separated by a logical device and exchange via the data bus occurs by continuous transfer of data

from memory to a logical device and vice versa. Most of the processor power is spent on data transfer. For example, to add two numbers, one number is taken from memory, placed in the processor register, then another number is taken and placed in another processor register. The operation is performed, the result being placed in the third register of the processor, from where it is moved back to memory. A modern processor does this very quickly, but the efficiency of this operation is low. Most calculations in neural networks, as a basic idea in creating AI, are based on data flows and constant switching between processing units and memory units, which becomes a bottleneck that slows down system performance. Solving this problem requires new architectures and processor implementations that will meet the ever-increasing requirements of neural network algorithms.

In the human brain, information is processed in the same structures called neurons. Neurons are connected by synaptic connections. In sets of these synaptic connections, information is stored, and in neurons it is processed [1]. If the sum of the input signals on the neuron exceeds a certain threshold value, then it generates a pulse as a kind of short message, which transmits further to the network to other neurons (calculations). This is called calculations in a certain neural structure.

The convergence of storage and calculation is called a neuromorphic structure, which provides several orders of magnitude lower energy consumption for performing calculations. We put memory in some computing core and synchronization occurs at a high frequency inside the core – calculations next to memory. At the same time, energy consumption is reduced a thousand times.

Neuristors appear – the idea of a new component calculation base occurs where information is stored.

The discipline, known as “neuromorphic engineering”, has been tasked with reproducing, at least in part, the structure of the human brain in the form of electronic circuits for decades. The idea itself is quite old, developments (including quite successful ones) have been going on for a very long time (the classic model of a neural network – the perceptron – was developed back in the sixties of the last century). At one time, neuromorphic systems had a chance to become a mainstream trend in computational cybernetics, but then the classical “von Neumann” architecture won, and we have what we have. However, given the amount of data processing, the time has come for neuromorphism in computing systems, because it is better suited for AI tasks than the “classics”.

The limit of the development of computer systems, from their first steps to the present day, is the task of creating artificial intelligence – a machine that can not only solve individual problems, but also learn to set new ones. These are, first of all, machine learning systems and neural network algorithms. They are already solving such practical problems as the problem of recognizing letters, numbers, images and distinguishing objects. In the medical field, it can make a diagnosis better (or at least earlier) than an ordinary doctor, recognizing one with a characteristic sign of a tumor in a thousand X-rays. However, the multithreading required for “comparative” computing makes the traditional structure ineffective. The calculations required to implement neural network algorithms are simple, but they need to be done a lot and preferably at the same time. Ordinary processors with their sequential operation

scheme are poorly suited, you have to use video cards with their thousands and tens of thousands of weak, but specialized computing modules. However, they are specialized, in general, for other tasks, and the problem of “iron for neurocomputation” remains acute. Man, with his relatively small hardware computing power, still copes with the task of “recognition and comparison” three orders of magnitude better than the most powerful computer cluster.

The key difference between the architecture of neuromorphic processors and the traditional von Neumann architecture is that they combine memory and computing cores, so the data transfer distance is minimized. This minimizes delays and power consumption.

Neuromorphic processors, unlike classical ones, do not access memory (or registers) and do not extract data from there – all information is already stored in artificial neurons. Thus, it becomes possible to process large data on end devices without the need for additional computing power. For example, the domestic neuromorphic processor Altai consumes almost a thousand times less energy on comparable tasks than traditional graphics accelerators. Given that robotics, wearables or autonomous cars require increasingly sophisticated computing devices operating in real time with low latency and low power consumption, neuromorphic processors look like a very promising direction.

And one more important aspect: currently, new network algorithms that work, for example, in an unmanned vehicle, are not trained, they are updated, the weight parameters of the network are changing, there is no self-learning [2].

The following types of learning can be distinguished:

- Supervised learning involves providing explicit guidance by indicating what is correct and what is incorrect. For example, I point to specific classes or provide labeled vectors, thereby teaching neural networks to recognize patterns accurately.
- Self-supervised learning involves feeding data into the system and allowing it to discover the underlying structure within that data. The goal is to identify distinguishing features without explicit labels.
- Reinforcement learning, similar to a “hot or cold” game uses environmental feedback in the form of rewards or punishments – such as pain or emotional reinforcement (approval). This process associates the algorithm’s behavior with personal or emotional needs, guiding it toward desired outcomes.

Nevertheless, it should be said that today even large language models have no internal needs. Until we request a chat-bot to provide some information, it will not give anything itself, it operates strictly according to a question-answer framework and does not initiate actions on its own.

It is assumed that some neuromorphic devices will be able to remember these certain emotions, encode, remember their interaction with the outside world or virtual environment, or even some body, an agent that will interact with the environment. However, this is still far from achieving strong AI, as an agent with an internal structure of needs has yet to be created.

The direction of creating neuromorphic processors is of great interest all over the world, and such chips may gradually become available for scientific and industrial use. In parallel with the availability of chips, scientists in the field of artificial

intelligence are creating more and more effective mechanisms for training neuromorphic neural networks [3].

Thus, unlike traditional von Neumann computational architectures, the logic and structure of neuromorphic processors was originally specialized for the operation of neural networks. This will be a specialized class of microprocessors that are used for the hardware acceleration of computer vision algorithms, voice and image recognition, machine learning and artificial intelligence methods, we are unlikely to see them in home computers. However, the number of interesting tasks in a rapidly digitalizing world is so large that the development of neuromorphic systems is extremely promising.

Список литературы:

1. Иевлев, П. Нейроморфные вычисления – новое мышление ИИ. Что такое «нейроморфные процессоры» и что они считают? : [сайт] / П. Иевлев. – 2022. – URL: <https://digitalocean.ru/n/nejromorfnye-vychisleniya-novoe-myshlenie-ii> (дата обращения: 10.04.2025). – Текст : электронный.
2. Сидельников, В. И. Использование машинного обучения при разработке системы автоматизации процесса отбелки целлюлозы / В. И. Сидельников, А. В. Кокшаров, И. В. Анисимов. – Текст : непосредственный // Вестник Санкт-Петербургского государственного университета технологии и дизайна. Серия 1: Естественные и технические науки. – 2024. – № 1. – С. 168-171.
3. Кондрашкова, Г. А. Синергетический подход к развитию современного образования / Г. А. Кондрашкова, И. В. Бондаренкова, В. И. Сидельников. – Текст : непосредственный // IX Всероссийская научная конференция «Системный синтез и прикладная синергетика»: сборник научных трудов (п. Нижний Архыз, Россия 24–27 сентября 2019 г.); Южный федеральный университет. – Ростов-на-Дону ; Таганрог : Издательство Южного федерального университета, 2019. – 589 с. – С. 458-464.

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PROBLEMS AND CHALLENGES IN THE OPERATION OF TRACTION DRIVE CONTROL SYSTEMS IN URBAN ELECTRIC TRANSPORT

Abstract. Traction drive control systems play a crucial role in the operation of urban electric transport vehicles, ensuring high efficiency, reliability, and safety. However, the operation of such systems is associated with a number of problems and challenges, including equipment reliability, control complexity, external factors, and the need to adapt to changing operating conditions. This article examines the main problems and challenges encountered in the operation of traction drive control systems and proposes possible solutions.

Keywords: control systems, traction drive, electric transport, reliability.

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ПРОБЛЕМЫ И ВЫЗОВЫ В РАБОТЕ СИСТЕМ УПРАВЛЕНИЯ ТЯГОВЫМ ЭЛЕКТРОПРИВОДОМ ГОРОДСКОГО ЭЛЕКТРИЧЕСКОГО ТРАНСПОРТА

Аннотация. Системы управления тяговым электроприводом играют важнейшую роль в работе подвижного состава городского электротранспорта, обеспечивая высокую эффективность, надежность и безопасность передвижения. Однако эксплуатация таких систем сопряжена с рядом проблем, связанных с надежностью оборудования, сложностью управления, воздействием внешних факторов и необходимостью адаптации к меняющимся условиям работы. В данной статье рассматриваются основные проблемы и вызовы, возникающие при эксплуатации систем управления тяговым электроприводом, а также предлагаются возможные пути их решения.

Ключевые слова: системы управления, тяговый электропривод, электротранспорт, надежность.

Introduction

Currently, electric propulsion is increasingly being adopted in urban passenger transport. For a long time, the fleet of public transport in major cities primarily consisted of buses and minibuses powered by internal combustion engines. However, technological progress, economic growth, and environmental concerns have driven the development of urban electric transport (UET) – such as subways, trams, and trolleybuses – and the emergence of new transport types, such as electric buses.

Compared to internal combustion engines, the use of traction electric motors (TEMs) in trolleybuses, trams, and subway cars offers several advantages: no emissions of fuel combustion byproducts that pollute the atmosphere; passenger comfort due to lower floor height in trolleybuses and trams, reduced noise levels, modern ergonomics, and design; energy savings through regenerative braking; excellent traction and dynamic characteristics; and high reliability and durability [1]. Therefore, improving electric propulsion systems in general and traction drive control systems (TDCS) in particular can lead to significant energy savings, reduced material resource consumption, and improved environmental conditions.

The operation of TDCS presents various problems and new challenges that affect the performance of electric transport, energy efficiency, and maintenance and repair processes for rolling stock (RS).

1. Concepts and Classification

A *control system* is a combination of a *controlled object (CO)* and a *control device (CD)* that interact according to a given control law (algorithm).

Controlling the CO involves generating control actions to ensure that the regulated variable (coordinate) changes according to the required law.

Automatic control of electric drives is one of the key conditions for the productivity of mechanisms. Electric drive control involves **starting, speed regulation, braking, reversing, and maintaining** the drive's operating mode in accordance with the requirements of the technological process.

The choice of devices for building control systems and the type of control systems themselves depends on the requirements for the electric drive and the functions it must perform [2, 3, 4].

Based on the nature of voltage changes in the TEM, TDCS can be classified into:

- **Stepwise systems** (direct, rheostatic-contactor);
- **Smooth or continuous systems** (thyristor-pulse, transistor-based).

In a stepwise rheostatic-contactor control system (RCCS), voltage regulation in the TEM – and thus traction force – occurs in steps. During the starting phase, resistances from the main starting rheostat are gradually removed from the armature circuit of the TEM using a group rheostatic controller (GRC). This increases the armature currents, motor rotation speed, and accelerates the vehicle. This phase corresponds to the driver's controller positions M (maneuvering), X1, and X2.

In the second phase, once all starting rheostats are removed from the power circuit, the TEM rotation speed can be further increased by raising the voltage applied to the armature. This is achieved by regrouping the motors from series to series-parallel and parallel connections (primarily in trains and subway cars).

The third phase involves reducing the magnetic flux of the TEM poles by

disconnecting sections of the field weakening rheostat, which is connected in parallel to the series winding of the TEM (position X3).

During braking, the motors are disconnected from the contact network and switch to generator mode: the inductive current generated in the closed loop of the TEM armature windings is dissipated in the braking rheostats (heating them), which are sequentially removed from the circuit using the GRC. To increase braking force, the driver sets the controller to positions T1, T2, and T3 and disconnects sections of the shunt (adjustment) rheostat – this increases the excitation current of the TEM windings and, proportionally, the braking torque. At maximum shunt winding current, the braking rheostat is fully removed, and the inductive current is now used solely to create the braking torque of the TEM armature.

If voltage is lost in the power circuit, a voltage relay (VR) activates, notifying the driver that the shunt winding power is lost and further excitation of the TEM will be provided by series windings powered by the battery (emergency braking mode) (Figure 1).

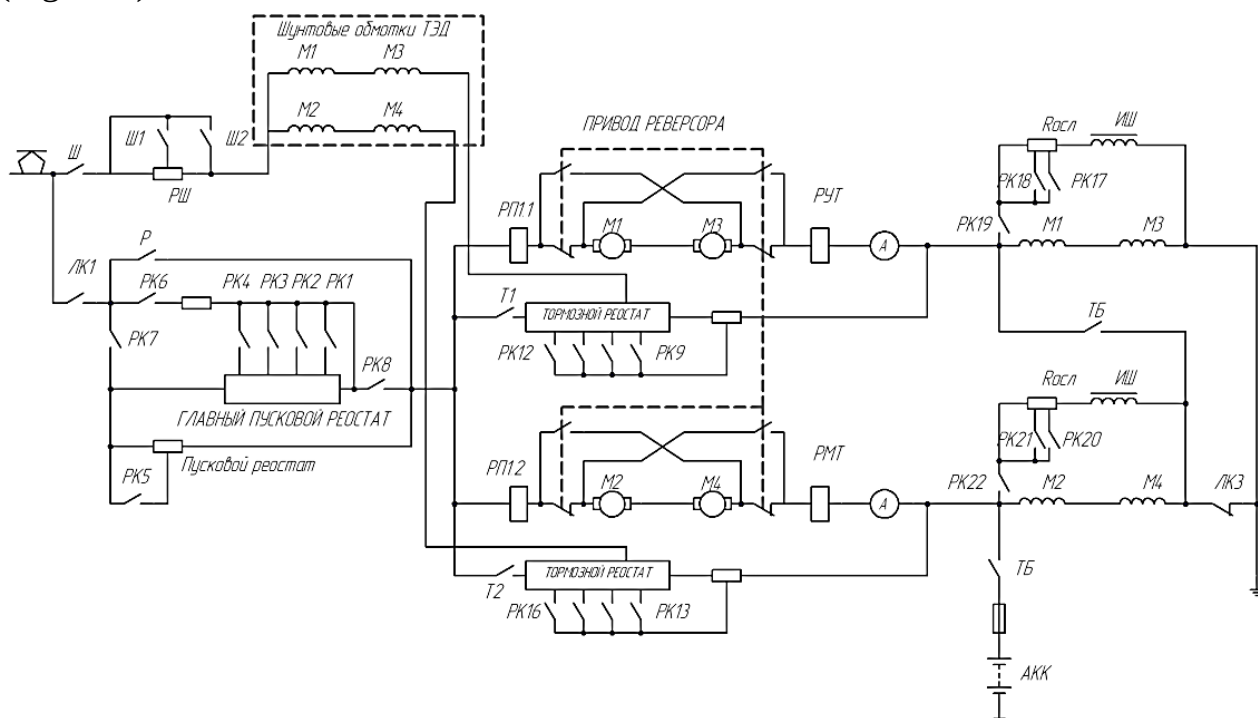


Figure 1 – Diagram of a rheostatic-contactor control system for tram cars KTM-5M3 / KTM-8 / LM-68M

Advantages of RCCS:

- Comparative simplicity of the device and repairs;
- Relatively high electrical and fire safety;
- High ease of control of the driver's controller compared to the direct control system.

Disadvantages of RCCS:

- High energy consumption during startup, as part of the energy is dissipated as heat in the starting rheostats.

- Regular maintenance of electromechanical power devices is required, such as cleaning contacts from carbon deposits and timely replacement of contact pairs.
- Numerous mechanical components require attention, such as the GRC and its drive, which must rotate freely without jamming.
- Possible variation in traction forces between traction machines and, consequently, differences in currents due to group power supply from a single source.
- Limitations on the maximum rotation speed of commutator traction machines due to commutation conditions in the brush-collector assembly, collector heating from friction, brush wear, and mechanical strength.
- Sensitivity of commutator traction machines to moisture, especially on the collector, which can cause inter-lamellar short circuits and circular fires on the collector, as well as reduced insulation strength.
- Poor ride smoothness due to stepwise changes in current in the traction motors during acceleration.

In continuous (smooth) control systems, pulse-width modulation (PWM) is used, which converts a continuous input signal into a discrete output signal [5]. The alternation of pulses and pauses in the output signal follows a specific pattern determined by the control system.

There are three main types of pulse regulation systems: amplitude, pulse-width, and frequency modulation. For electric rolling stock (ERS) with DC power, the latter two systems are preferred.

Pulse regulation of voltage in drive electric machines has been known for some time, but it only began to be applied in UET with the advent of high-power semiconductor devices. Due to their high speed (short switching times), thyristor regulators can apply voltage to the TEM in very short pulses. The average voltage on the motor is determined by the parameters of these pulses – shape, duration, and frequency.

Let us consider a more modern transistor-pulse control system (TPCS). Its key component is a three-level traction voltage converter, the schematic of which is shown in Figure 2.

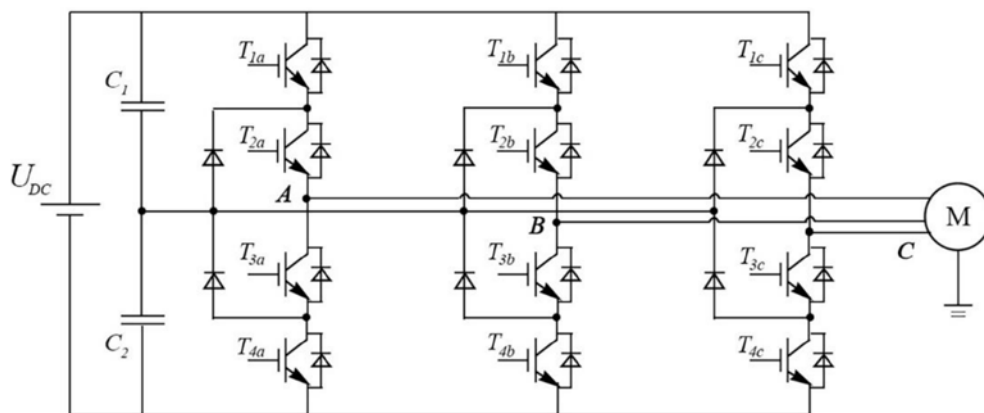


Figure 2 – Schematic of a three-level traction voltage converter:
 U_{DC} – contact network voltage; C_1 , C_2 – input filters; T1a-T4c – IGBT-transistors

When the train is in traction mode, the DC current collected by the pantograph from the contact network passes through the traction inverter, which powers the traction asynchronous motor (TAM) by supplying three-phase AC power. During braking, the traction converter is controlled to switch the TAM into power generation mode (regenerative braking), and the converter feeds the three-phase AC output from the TAM back into the contact network through a rectifier channel.

Replacing RCCS with contactless TPCS offers significant **advantages**, including:

- The use of rheostat-free starting and regenerative braking across the entire speed range of RS can reduce energy consumption by 25–40 %.
- Continuous current regulation in the TEM ensures exceptionally smooth starting and braking of RS.
- The absence of sharp current fluctuations in the TEM and the ability to use higher-power motors improve dynamic performance: acceleration, deceleration, and travel speed without increasing motor weight.
- Replacing contact-based equipment with more reliable contactless components reduces maintenance costs for electrical equipment.
- Reduced currents in the traction network during starts and the return of energy to the network during regenerative braking minimize voltage drops in the traction network, thereby increasing the average voltage level and further improving RS speed.

Disadvantages of pulse regulation in UET RS:

- Higher initial equipment costs.
- Slightly greater weight of electrical equipment.
- Relative complexity of control systems.
- Need for more qualified maintenance personnel.

2. Problems and Challenges in TDCS Operation

During the operation of RS with various TDCS – stepwise and continuous – the main problem is the efficient use of regenerative braking energy. Part of the mechanical braking energy, converted into electrical energy by the motors in generator mode, remains unused: it is dissipated in braking rheostats and released into the atmosphere.

In drives with *RCCS*, this portion is equivalent to the full energy of the motor's generator mode. In other words, a car with *RCCS*, which has the potential to return mechanical energy during braking for useful work, leaves this potential unrealized despite the TEM's conversion of mechanical energy into electrical energy [6].

For RS equipped with transistor-inverter control systems (TPCS), there is the possibility of converting energy from the TEM terminals into DC energy with the parameters required by the contact network (voltage not lower than the instantaneous contact network voltage). The efficiency of the traction converter is quite high, averaging around 0.95. If there is a load in the contact network comparable to the power of the regenerating TEM, the converted energy from the traction machine is fed into the contact network for this load, becoming useful regenerative energy. In the absence of such a load, the regenerative energy is dissipated in braking resistors, becoming excess.

Useful regenerative energy exchanged between trains through the contact

network is partially used by the regenerating car for its own non-traction needs and by other cars on isolated sections of the contact network for their traction and non-traction needs. Additionally, useful regenerative energy can power stationary electrical loads connected to the contact network (traffic lights, switch heating, passenger information systems, and lighting at stops, track monitoring systems, etc.). The excess portion of the converted regenerative energy in such cars remains unused – dissipated in balast resistors.

Long-term observations of energy consumption for tram traction equipped with frequency traction converters and bidirectional energy meters show that the share of useful regeneration is about 18 % of the rectified energy supplied by the traction substation, while the volume of excess regeneration is about 15%. The full potential of regenerative energy (useful and excess) in the power supply system of UET with cars equipped with TPCS amounts to up to one-third of the total output of the traction substation.

In recent years, with advancements in supercapacitor-based buffer energy storage systems, many rolling stock manufacturers have been testing cars equipped with such systems. *Onboard storage (OS)* includes a supercapacitor block with a parameter monitoring system and its own energy converter. The OS is integrated into the traction circuit so that during braking, it accumulates all the regenerative braking energy from the traction converter. In this case, feeding energy from the converter into the contact network for inter-train exchange of useful regeneration (ITE) – for other cars and for its own non-traction needs – is impossible. The OS inverter converts the energy from the DC link of the traction converter into the parameters required for charging the supercapacitors, and this energy is stored as voltage between the charged layers of the supercapacitors. When the car begins to accelerate, the OS inverter opens, converting the stored energy in the supercapacitors and feeding it to the DC link of the traction converter to power the TEM, thereby replacing part of the energy consumption from the contact network. In other words, if the supercapacitors have sufficient capacity to absorb all the regenerative energy, the latter is not divided into useful and excess from the perspective of the contact network but is fully returned by the car for its own traction needs after intermediate storage in the supercapacitors and double conversion – during charging and discharging (Figure 3).

According to supercapacitor-based onboard storage manufacturers [7], the actual efficiency of the storage/release cycle is approximately 0.684.

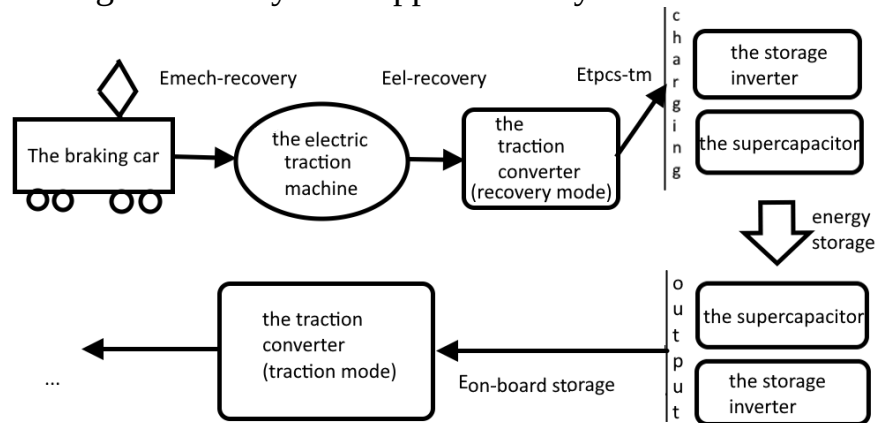


Figure 3 – Stages of regenerative energy conversion in a system equipped with onboard energy storage without inter-train exchange capability

Another solution to the regeneration problem is the use of *stationary energy storage (SES)* in contact network sections. The SES control system allows only excess regenerative braking energy to be absorbed, while useful regeneration remains outside the active operation zones of such storage devices, i.e., it is preserved in the form exchanged through inter-train regeneration flows in the power supply systems of ERS with TPCS without buffer storage.

If during the regeneration of one tram there is a comparable load in the network, the regenerative energy of this car is transferred via inter-train flows to the consuming car; in this case, the voltage in the contact network does not exceed the upper threshold of the stationary storage. In the absence of such a useful consumer in the contact network, the voltage at the terminals of the braking car's traction converter rises, increasing the voltage in the contact network. The presence of excess regeneration in the network is detected by the stationary storage when the instantaneous voltage exceeds the upper threshold, set relative to the average voltage of the traction substation at no-load at the point in the circuit where the stationary storage is connected. Upon reaching the upper threshold, the storage switches to energy absorption mode.

Controlled storage devices, such as the flywheel-based NKE-3G, equipped with a frequency converter and a motor-generator (MG), first convert the excess regenerative energy received from the braking car via the contact network into a form suitable for powering the MG, and then the electromechanical machine converts it into mechanical energy of the rotating shaft, spinning the flywheel. Conditions for releasing previously stored regenerative energy – which would otherwise remain excess – are determined by the SES control system when the instantaneous voltage in the network falls below the lower threshold, also set relative to the average no-load voltage of the traction substation at the connection point. The storage control system switches the motor-generator to generator mode, converting the mechanical energy of the flywheel rotation into electricity, which is fed to the stator winding terminals. The storage converter then converts this three-phase energy into DC energy and feeds it into the contact network for consumption by the emerging network load (Figure 4).

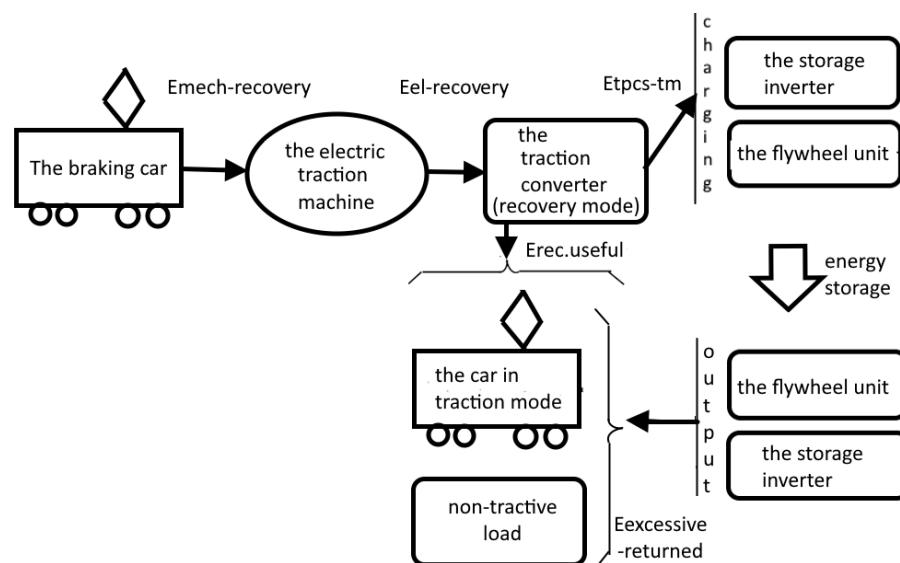


Figure 4 – Stages of regenerative energy conversion in a system with stationary controlled flywheel storage

Another variant of onboard energy storage based on *supercapacitor assemblies* was theoretically studied and practically tested on a tram [8]. A unique feature of this storage was its installation as a replacement for braking resistors, connection to the DC link, and allowance for inter-train exchange of useful regenerative energy when a load was present in the contact network, storing only excess regenerative braking energy. Its energy capacity was comparable to that of a supercapacitor storage without inter-train exchange capability. This was because it had to absorb all excess regenerative energy in a single braking cycle when no load was present in the network for the entire duration of the car's braking. In other words, the mass of this storage was practically identical to that of a supercapacitor storage without inter-train exchange capability, and the energy costs for transporting such a storage with inter-train exchange capability were equal to those of the former.

In such a system, part of the regenerative energy is directly exchanged via the contact network for the network load, while another part is indirectly stored in the onboard storage for the car's traction system after storage when the car begins to accelerate. The efficiency of such an onboard storage with inter-train exchange capability is equal to that of a supercapacitor storage without inter-train exchange. For full utilization of excess regenerative braking energy of cars operating on routes, onboard storage devices must be installed on all ERS units.

Conclusion

Control systems for electric drives are designed for starting, speed regulation, braking, reversing, and maintaining the operating mode in accordance with specified requirements.

Currently, the most common are continuous (stepless) control systems for drives, where the average voltage on the motors changes smoothly or in very small steps. These are primarily pulse-based control systems (thyristor or transistor-pulse).

Indirect – automated and automatic – control systems require the least effort from the driver. The driver remotely controls high-voltage switches via a controller and can manage the train in multiple-unit operation when low-voltage circuits are connected in parallel.

The operation of ERS with traction drives of various control systems presents numerous problems, the main one being the efficient use of regenerative energy. The return of regenerative energy during braking is maximized with stationary energy storage and minimized with onboard storage.

The total energy consumption of a car consists of power supplied by returned regenerative energy and the traction substation. To ensure full utilization of excess regenerative energy, onboard storage devices must be installed on all units of a UET enterprise's fleet. Stationary storage devices are required in numbers equal to the number of traction substations.

Список литературы:

1. Богдан, Н. В. Современные системы управления тяговыми электродвигателями городского электрического транспорта / Н. В. Богдан, А. И. Сафонов, К. И. Мазаник. – Текст : электронный // Энергетика: Известия высших учебных заведений и энергетических объединений СНГ. – 2001. – № 4.

- С. 22-30. – URL: <https://energy.bntu.by/jour/article/view/1509> (дата обращения: 01.04.2025).
2. Иванов, В. В. Электрический привод: учебно-методический комплекс / сост. В. В. Иванов. – СПб. : Изд-во СЗТУ, 2009. – 106 с. – URL: <https://m.eruditor.one/file/1045739/> (дата обращения: 02.04.2025). – Текст : электронный
3. Бирюков, В. В. Тяговый электрический привод : учебник для вузов / В. В. Бирюков, Е. Г. Порсев. – 2-е изд., испр. и доп. – Текст : электронный // Образовательная платформа Юрайт: [сайт]. – Москва : Издательство Юрайт, 2025. – 315 с. – URL: <https://urait.ru/bcode/562783> (дата обращения: 02.04.2025).
4. Zhang, K., Yang, J., Liu, C., Wang, J., & Yao, D. (2022). Dynamic Characteristics of a Traction Drive System in High-Speed Train Based on Electromechanical Coupling Modeling under Variable Conditions // *Energies*, 15(3), 1202. URL: <https://doi.org/10.3390/en15031202> (date accessed: 02.04.2025).
5. Маковский, А. Л. Силовые преобразователи электрической энергии в технических системах управления: учебное пособие. / А. Л. Маковский. – Минск: БГУИР, 2017. – 250 с. – Текст : непосредственный.
6. Кацай, А. В. Преобразование энергии рекуперации в городском электротранспорте / А. В. Кацай, М. В. Шевлюгин. – Пермь : Вестник ПНИПУ, 2022. – 25 с. – URL: https://www.researchgate.net/publication/366646127_PREOBRAZOVANIE_ENERGII_REKUPERACII_V_GORODSKOM_ELEKTROTRANSPORTE (дата обращения: 03.04.2025). – Текст : электронный.
7. Чернигов, В. М. Электрооборудование трамвайного вагона с ёмкостным накопителем. – URL: http://mapget.ru/wpcontent/uploads/2021/12/MAPGET_NTS_Chergos.pdf (дата обращения 03.04.2025). – Текст : электронный.
8. Шариков, В. А. Возможности рационального использования энергии торможения электрического подвижного состава / В. А. Шариков, О. Л. Шарикова, А. В. Агунов, А. В. Третьяков. – Текст : непосредственный // *Электротехника*, 2018. – № 10. – С. 55-59.

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STUDY ON THE OBTAINMENT OF NITROGEN AND PHOSPHORUS- CONTAINING CORROSION INHIBITORS

Abstract. This article provides information on corrosion in metal structures in the oil and gas industry, measures to prevent it, and analysis methods.

Keywords: corrosion, oil, gas, condensate, nitrogen, sulfur.

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ИССЛЕДОВАНИЕ ПО ПОЛУЧЕНИЮ АЗОТ- И ФОСФОРСОДЕРЖАЩИХ ИНГИБИТОРОВ КОРРОЗИИ

Аннотация. В статье приведены сведения о коррозии металлических конструкций в нефтегазовой отрасли, мерах по ее предотвращению и методах анализа.

Ключевые слова: коррозия, нефть, газ, конденсат, азот, сера.

Oil is the largest source of energy consumed by the world's population, surpassing other energy resources such as natural gas, coal, nuclear energy and

renewable energy. 90 % of the world's energy consumption comes from petroleum products [1].

The total consumption of motor fuels in the world is 1.75 billion tons per year, including the need for motor gasoline is more than 800 million tons per year [2].

After the 20th century, the demand for energy has increased dramatically due to the rapid industrialization of the world, accelerating economic growth, improving living standards, modern transportation system, technology and the energy sector, which depends only on limited oil reserves. By 2050, energy consumption will be completely replaced by biofuels. Oil is the world's most important source of life and chemicals, with consumption currently estimated at 12 million tonnes per day (84 million barrels per day) and projected to increase to 16 million tonnes per day (116 million barrels per day) by 2030 [3].

Motor gasoline is the main product of the petrochemical industry. About 25 % of the world's oil is refined into gasoline, the primary fuel for automobiles.

Research Method and Processes. There are currently over 1 billion cars in the world. Every year, their number exceeds 100 million. The world leader in automobile production is China, with a production share of 26.76 % (Figure 1). The total volume of automobile production in the United States, Germany, and Japan is equal to that of China.

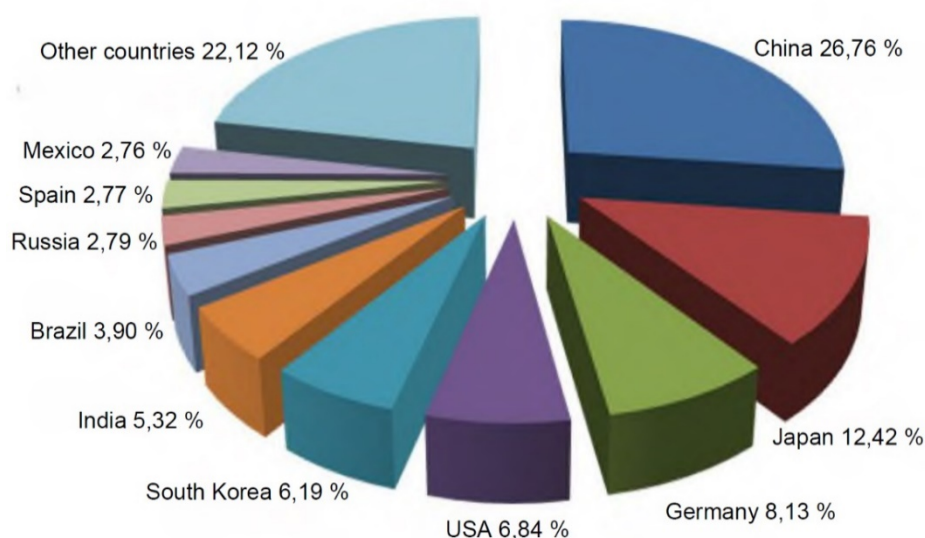


Figure 1 – Major car producing countries (share of total cars produced in the world)

Gasoline is a fuel intended for use in spark-ignition internal combustion engines. Gasoline is widely used in agriculture, aviation, as a solvent for paints and varnishes, and for other household purposes. The technological processes for obtaining gasoline fractions used as gasoline components include: primary oil refining, catalytic cracking, catalytic reforming, alkylation, isomerization, thermal cracking; visbreaking, pyrolysis, hydrocracking, hydrotreating. Automobile gasoline is a fuel that boils in the temperature range of 28-215 °C and is intended for combustion in internal combustion engines. According to its intended purpose, gasolines are divided into automobile and aviation. The main indicators of gasoline are explosion resistance (octane number), saturated vapor pressure, fractional composition, chemical stability, and the amount of

sulfur and aromatic compounds. In recent years, the tightening of environmental requirements for the quality of petroleum fuels has limited the amount of aromatic hydrocarbons and sulfur compounds in gasoline. Modern automobile gasolines, as petroleum products, are usually prepared by combining individual components in the form of fractions that can be obtained directly and by methods of catalytic cracking, reforming, hydrogenation processes – hydrotreatment, hydrocracking and petrochemical processes – alkylation. Gasoline is also obtained on the basis of polymerization, isomerization, as well as some other processes of thermal processing of oil and petroleum residues.

The IR spectrum of the PF-1 corrosion inhibitor we synthesized and used in the test was provided to investigate its composition and structure (Figure 2).

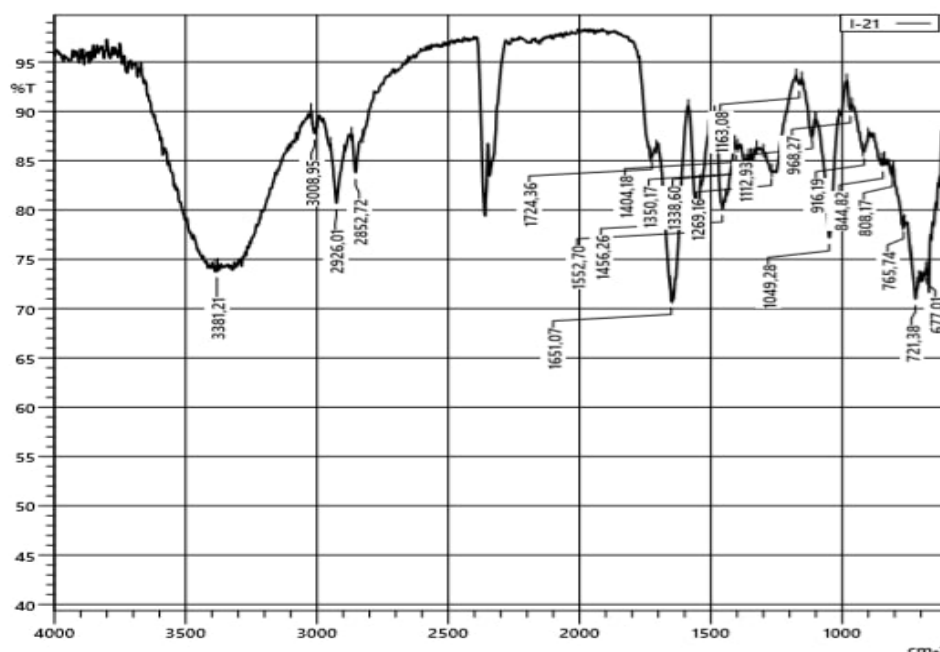


Figure 2 – IR spectrum of PF-1 brand corrosion inhibitor

The composition and structure of the PF-1 corrosion inhibitor were studied using IR spectrometer technology (IK-Fure, SHIMADZU, Japan) in the range up to 4000 cm^{-1} . In the IR spectroscopy of the inhibitor used for corrosion protection of the PF-1 brand, asymmetric and symmetric valence vibrations of CH_2 groups were observed in the regions $2926\text{--}2852\text{ cm}^{-1}$. In the region 1456 cm^{-1} , we can see asymmetric deformation vibrations of CH_2 groups. One of the most characteristic absorption regions for the product was the symmetric valence vibrations of (N-C) at 1112 cm^{-1} . Absorption lines corresponding to the valence vibrations of the C=O group are observed in the IR spectrum range $1650\text{--}1820\text{ cm}^{-1}$. The intensity of the absorption line corresponding to this vibration is greater than that of the other absorption lines in the IR spectrum. According to the results of this analysis, the corrosion inhibitor we tested contains nitrogen, which indicates that it has anti-corrosion properties [4].

Taking into account these problems in the oil and gas industry, we conducted testing processes of the PF-1 brand corrosion inhibitors containing nitrogen in our synthesis at different temperatures and in different proportions and selected the proportions and temperatures that were acceptable for us and provided high levels of protection.

The protection levels, corrosion rates and surface coverage coefficients of our PF-1 brand corrosion inhibitor, which we synthesized based on the processing of organochlorine waste and synthesized using fatty acids, were calculated based on the results of the test studies. The test results were carried out gravimetrically in accordance with the requirements of GOST 9.506-87.

The protection levels of the PF-1 brand corrosion inhibitor soluble in petroleum products were studied at different proportions. In this case, the inhibitor concentration was 3 %, and the test time was 72 hours.

Table – Corrosion rates, protection levels, and surface coverage coefficient values for various mass ratios of PF-1 brand corrosion inhibitor

Mass ratios P:F	Corrosion rate	Protection level	θ
1:1	0,065	72,31	0,7231
1:2	0,08	89	0,89
1:3	0,071	78,98	0,7898
2:1	0,058	64,5	0,645
3:1	0,051	56,7	0,567

As a result of the tests, we can see from Table 1 that the best mass ratio of the organochlorine mixture and fatty acid was found to be 1:2, and the protection level was 89 %.

PF-1 inhibitors obtained on the basis of the processing of these organochlorine wastes are widely used in oil, gas, gas condensate wells, in the process of drilling wells, and in the production of oil and fatty acids.

Список литературы:

1. Jamshid, K., Fayzulla, N., Abdulahat, D. Research And Properties Of AFMD-2 Brand Corrosion Inhibitor For Corrosion Protection Of Oil And Gas Wells // Universum: технические науки. – 2023. – № 5-8 (110). – Текст : непосредственный.
2. Халилов, Ж. А. У. Синтез и исследование ингибитора коррозии OS-1 для нефтегазовой промышленности / Ж. А. У. Халилов, Ф. Н. Нуркулов, А. Т. Джалилов. – Текст : непосредственный // Universum: технические науки. – 2023. – № 2-4 (107).
3. Khalilov, J. A. U. Extraction of corrosion inhibitors soluble in petroleum products and their analysis // Universum: технические науки. – 2024. – № 9 (126). – URL: <https://cyberleninka.ru/article/n/extraction-of-corrosion-inhibitors-soluble-in-petroleum-products-and-their-analysis> (дата обращения: 29.03.2025). – Текст : электронный.
4. Khalilov, J. A. U., Nazarbekova, D. K., Nurtoev, B. N. Technical and technological solutions to increase the productivity of oil and gas wells // European Journal of Emerging Technology and Discoveries ISSN (E): 2938-3617. Vol. 2. Issue 9, September – 2024.

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NEUE ÄSTHETIK IN DER RAUMTRANSFORMATION ZU BEGINN DES 21. JAHRHUNDERTS

Zusammenfassung. Die neue Ästhetik in der Raumtransformation zu Beginn des 21. Jahrhunderts zeigt, dass Architektur und Stadtplanung weit über die bloße Gestaltung von Gebäuden und Plätzen hinausgehen. Sie erfordert ein tiefes Verständnis für die Bedürfnisse der Menschen, die Dynamik urbaner Räume und die Herausforderungen, vor denen unsere Gesellschaft steht. In der vorliegenden Arbeit werden wir diese neue Ästhetik näher beleuchten und untersuchen, wie sie sich in verschiedenen Projekten manifestiert, die als Vorreiter für eine zukunftsorientierte Stadtentwicklung gelten.

Schlüsselwörter: Raum, Design, High Line, Low Line, Superkilen, „GES-2“, Park, Stadt, New York, U-Bahn, Transformation, Innovationen, Ästhetik, Zukunft.

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NEW AESTHETICS IN THE TRANSFORMATION OF SPACE AT THE BEGINNING OF THE 21ST CENTURY

Abstract. The new aesthetics of space transformation at the beginning of the 21st century demonstrate that architecture and urban planning go far beyond merely designing buildings and squares. This requires a deep understanding of people's needs, the dynamics of urban spaces, and the challenges faced by our society. In this work, we will examine this new aesthetic in more detail as well as the way it manifests itself in various projects considered pioneers in the field of prospective urban development.

Keywords: space, design, High Line, Low Line, Superkilen, GES-2, park, city, New York, metro, transformation, innovation, aesthetics, future.

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НОВАЯ ЭСТЕТИКА В ПРЕОБРАЗОВАНИИ ПРОСТРАНСТВА НАЧАЛА 21 ВЕКА

Аннотация. Новая эстетика трансформации пространства в начале 21-го века показывает, что архитектура и городское планирование выходят далеко за рамки простого проектирования зданий и площадей. Это требует глубокого понимания потребностей людей, динамики городских пространств и проблем, с которыми сталкивается наше общество. В настоящей работе мы более подробно рассмотрим эту новую эстетику и то, как она проявляется в различных проектах, которые считаются пионерами в области перспективного городского развития.

Ключевые слова: пространство, дизайн, Хай-Лайн, Лоу-Лайн, Суперкилен, ГЭС-2, парк, город, Нью-Йорк, метро, трансформация, инновации, эстетика, будущее.

Ein zentrales Merkmal dieser neuen Ästhetik ist die Rückkehr zur Natur und die Integration von grünen Elementen in städtische Umgebungen. Angesichts der wachsenden Besorgnis über den Klimawandel und die damit verbundenen ökologischen Herausforderungen wird die Schaffung von grünen Oasen in urbanen Räumen als essenziell erachtet. Diese grünen Räume fördern nicht nur die Biodiversität, sondern bieten auch den Stadtbewohnern Rückzugsorte und Möglichkeiten zur Erholung und sozialen Interaktion. Die Verbindung von Natur und Stadt wird somit zu einem zentralen Element der neuen Ästhetik, die darauf abzielt, das Lebensumfeld der Menschen zu verbessern.

Darüber hinaus spielt die kulturelle Diversität eine entscheidende Rolle in der Raumtransformation. In einer globalisierten Welt, in der Migration und kulturelle Vermischung alltäglich sind, müssen städtische Räume die Vielfalt der Gesellschaft widerspiegeln. Die neue Ästhetik fördert die Schaffung von Orten, die verschiedene kulturelle Ausdrucksformen integrieren und Raum für Begegnungen und Dialog schaffen. Diese Räume werden zu Plattformen, die den sozialen Zusammenhalt stärken und die Identität von Gemeinschaften fördern.

Hier sind einige Beispiele, wie sich diese Aufgaben lösen lassen.

High Line – ein vergleichsweise neuer, aber bereits von den Bewohnern New Yorks heiß geliebter Park, in dem alles – von der Entstehungsgeschichte bis zum Ergebnis – interessant und gelungen ist. Das Foto des Parks ist in der Abbildung 1 dargestellt:

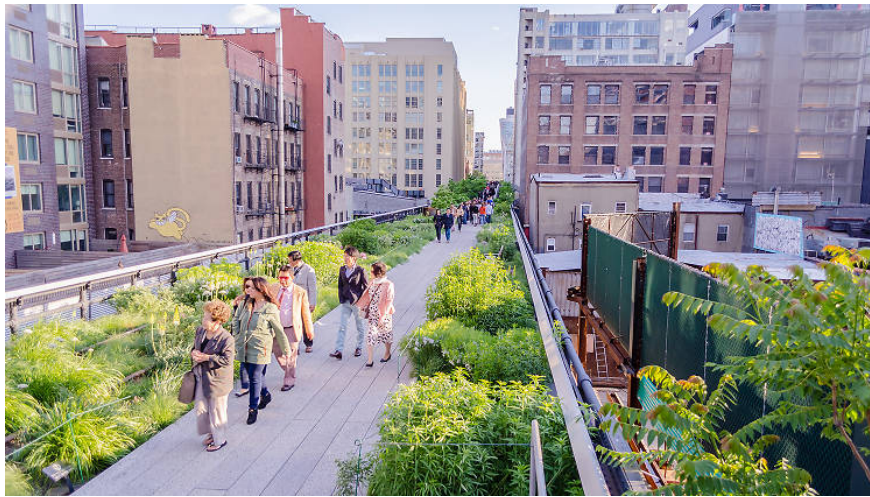


Abbildung 1 – Das Foto des Parks „High Line“

Ursprünglich war dies ein Abschnitt einer alten Eisenbahnlinie: Die Strecke verlief in einer Höhe von 10 Metern durch eine Reihe von Stadtvierteln und zwischen den Gebäuden. Bereits Mitte des 20. Jahrhunderts war die Linie vollständig erschöpft und wurde außer Betrieb genommen [1]. Fast ein Jahrzehnt nachdem der Bürgermeister von New York versucht hatte, die High Line abzureißen [2], wurde sie in einen der innovativsten und attraktivsten öffentlichen Orte der Stadt und möglicherweise des ganzen Landes verwandelt.

Um die vielen Liebhaber der verwilderten Eisenbahnstrecke zu unterstützen, wurde die Gemeinschaft „The Friends of High Line“ gegründet, die die Idee vorschlug, die Strecke in einen vollwertigen Park zu verwandeln. Ein großer internationaler Wettbewerb wurde ausgeschrieben, den das bekannte Architektentrio Elizabeth Diller, Ricardo Scofidio und Charles Renfro gewann. Als Landschaftsarchitekt trat Piet Oudolf auf, der thematische Bereiche im Park gestaltete und dabei eine Vielzahl von Pflanzen verwendete, um den einzigartigen halb-natürlichen und halb-industriellen Charakter dieses Raumes zu betonen [1].

Das von ihnen realisierte Projekt sieht tatsächlich beeindruckend aus – die Eisenbahnschienen wurden teilweise erhalten, und entlang der Strecke wurden über 200 Arten von Sträuchern und Bäumen gepflanzt [2]. Den Architekten gelang eine erstaunliche Kombination aus Natur und industriellen Motiven, die New York so nahe stehen. Im Park wurden zahlreiche Bänke, Liegen und Trinkbrunnen installiert.

Der erste Abschnitt des High Line Parks wurde im Sommer 2009 eröffnet. Der zweite Abschnitt folgte 2011, und der dritte Abschnitt wurde 2014 eröffnet. Der Park hat eine Länge von 2,33 km. Heute ist der High Line Park einer der meistbesuchten Orte in New York, der jährlich 4 Millionen Besucher anzieht [2].

Low Line ist noch ein beeindruckendes Beispiel einer unkonventionellen Lösung. Im Gegensatz zur High Line, die in die Höhe wächst, verfolgt die Low Line ein anderes Konzept: Sie soll in einem unterirdischen Raum entstehen. Seit einigen Jahren arbeiten Leute an dem Projekt Low Line (ähnlich wie die berühmte High Line). Dieser Park soll ein echtes Wunder in einem verlassenen Bahnhof werden. Früher war der Bahnhof Williamsburg Bridge Railway Terminal im Südosten von Manhattan ein

wichtiger Ort. Er verband die Eisenbahn und die U-Bahn und hatte acht unterirdische Bahnsteige. Im Jahr 1948 wurde er geschlossen, weil die Eisenbahn nicht mehr fuhr. So entstand ein großes unterirdisches Gebiet mitten in New York [3]. Hier soll der unterirdische Park entstehen. Die Visualisierung des Parks ist in der Abbildung 2 dargestellt:



Abbildung 2 – Die Visualisierung des Parks „Low Line“

Diese Idee wurde 2011 von dem Architekten James Ramsey (Architekturbüro RAAD) und dem Leiter des Netzwerks für soziale Innovationen, Dan Barasch, vorgeschlagen. Sie haben nicht nur die Idee vorgestellt, sondern auch ein Projekt entworfen, den verlassenen Bahnhof in einen unterirdischen Park zu verwandeln. Der Park wird sich unter der Erde über 2 Hektar erstrecken [3].

James Ramsey hat beschlossen, eine Konstruktion zu schaffen, die den Pflanzen genug Licht gibt. Er hat auf Elektrizität verzichtet und stattdessen eine Technologie entwickelt, die Sonnenlicht konzentrieren und im Garten verteilen kann [4].

Es sind Wege für Spaziergänge mit Bänken und Plätzen für aktive Freizeit geplant. Es werden Brunnen gebaut, grüne Wiesen angelegt, Sträucher gepflanzt und sogar Bäume, die nach oben zur Sonne wachsen.

Die innovative Methode benötigte Tests. Dafür haben die Architekten einen Mini-Garten namens Low Line Lab mit einer Fläche von 420 Quadratmetern geschaffen, in dem jetzt mehr als 40 Pflanzenarten wachsen [5]. Das Besondere an diesem Garten ist, dass diese Blumen, Bäume und Gräser in der Natur nicht in diesem geographischen Gebiet vorkommen [3]. Das Foto des Gartens ist in der Abbildung 3 dargestellt:



Abbildung 3 – Das Foto des Gartens „Low Line Lab“

Obwohl die Low Line noch in der Entwicklungsphase ist, hat das Projekt bereits viel Aufmerksamkeit auf sich gezogen und das Interesse an der Nutzung unterirdischer Räume in urbanen Umgebungen geweckt. Es steht die Frage, wie wir ungenutzte Flächen in Städten sinnvoll nutzen können, um die Lebensqualität zu verbessern und gleichzeitig die Umwelt zu schützen.

Die Architekten Kopenhagens verwandelten den ehemaligen Ort mit schlechtem Ruf in einen Park der Vielfalt, der Superkilen genannt wird.

Seit mehreren Jahrzehnten hatte der Ort, an dem Migranten aus verschiedenen Ländern lebten, einen schlechten Ruf wegen massiver Unruhen. Der „gigantische Keil“ befindet sich auf dem Gelände einer ehemaligen, verlassenen Eisenbahn, umgeben von Gebäuden, die von Squattern (Obdachlosen, die illegal in leerstehenden Häusern leben) besetzt waren [6].

Im Jahr 2007 wurde ein Wettbewerb zur Transformation dieses tristen Ortes in einen Park ausgeschrieben. Um das Projekt von den Anwohnern akzeptiert zu bekommen, wurden auch sie in die Arbeit einbezogen. Vertreter verschiedener Nationalitäten bildeten fünf Gruppen. Jede Gruppe begleitete Designer auf Expeditionen in die Länder, aus denen die Einwanderer einst kamen [6].

Während dieser Expeditionen wurden traditionelle Artefakte gesammelt. So verwandelte sich der Park in eine riesige Ausstellung von Objekten, die die Heimatländer von 60 Ethnien symbolisieren [6]. Hier entstanden kubanische und brasilianische Bänke, ein bulgarischer Schach-Tisch, argentinische Grillplätze, schaukelnde Kabuler und irakische Schaukeln, marokkanische Brunnen, eine Rutsche in Form eines schwarzen Oktopus aus Japan und vieles mehr [7]. Jedes Objekt erhielt ein Schild in Dänisch und in der Sprache der jeweiligen Ethnie. Das Foto des Parks ist der Abbildung 4 dargestellt:



Abbildung 4 – Das Foto des Parks „Superkilen“

Superkilen ist in drei Zonen unterteilt: die rote, die schwarze und die grüne Zone. Auf dem roten Platz mit einem bunten, weichen Belag befinden sich eine Skatezone, Basketball- und Fitnessplätze, Thai-Boxen und Spielbereiche sowie eine Medienbühne. Der schwarze Platz fungiert als Wohnzimmer: Hier wird Schach oder Backgammon gespielt. Im grünen Park finden Picknicks statt. Entlang des gesamten Parks verlaufen bequeme Radwege, und die skulpturalen Formen, künstlerischen Linien und die ungewöhnliche Farbpalette machen diesen Park zu einem hervorragenden Hintergrund für Beiträge in sozialen Medien [7]. Der Park-Plan ist in der Abbildung 5 dargestellt:



Abbildung 5 – Superkilen Park-Plan

Der Park Superkilen gilt zu Recht als eine der herausragendsten Sehenswürdigkeiten Kopenhagens. Dank des gelungenen Konzepts, das Menschen aus der ganzen Welt vereint, wurde er mit zahlreichen Preisen im Bereich Design und Architektur ausgezeichnet [7]. Das Experiment, das acht Millionen Euro kostete, war ein Erfolg: Der Ort, an dem es einst gefährlich war, nach Einbruch der Dunkelheit zu erscheinen, ist zu einem Anziehungspunkt für die Bewohner des Viertels geworden.

Die Raumtransformation zu Beginn des 21. Jahrhunderts ist ein faszinierendes und vielschichtiges Phänomen, das die Art und Weise, wie wir städtische Räume gestalten und erleben, grundlegend verändert hat. In einer Zeit, in der Urbanisierung,

Klimawandel und soziale Ungleichheit drängende Herausforderungen darstellen, zeigen innovative Projekte wie die High Line in New York, die Low Line, Superkilen in Kopenhagen und „GES-2“ in Moskau, wie durch kreative Ansätze und partizipative Planung neue, lebendige und nachhaltige urbane Räume entstehen können.

Die „GES-2“ wurde in den Jahren 1904 bis 1908 im neorussischen Stil erbaut und diente ursprünglich als städtisches Kraftwerk. Nach der Schließung im Jahr 2006 wurde das Gebäude zum Verkauf angeboten und von dem Milliardär Leonid Michelson für seine Stiftung V-A-C erworben. Das Rekonstruktionsprojekt, das darauf abzielte, das historische Erscheinungsbild des Gebäudes weitestgehend zu bewahren und es in einen neuen urbanen Raum zu verwandeln, war die erste Arbeit des Architekten Renzo Piano in Russland [8].

„Ein Ort des Lichts und der Freiheit“, so beschrieb der Architekt das Projekt in Moskau. Renzo Piano sieht es als „Fabrik der Kunst“ [9]. Während der Rekonstruktion wurden historische Elemente wie die gusseisernen Säulen und Stuckarbeiten erhalten, restauriert und in die neue Architektur integriert. Die Visualisierung des Gebäudes ist in der Abbildung 6 dargestellt:



Abbildung 6 – Die Visualisierung des Gebäudes „GES-2“

Die Fläche bringt ihre eigenen Herausforderungen mit sich: Es handelt sich um eine Insel mit beweglichem Boden, weshalb ein neues Fundament errichtet wurde, das den modernen Standards entspricht [10]. Es wurde beschlossen, die Rohre, wie im historischen Gebäude „GES-2“, zu belassen; ihre Höhe beträgt 70 Meter [9].

Die Mittel, durch die die Architektur mit den Menschen kommunizieren wird, sind Licht, Transparenz und Natur. Die Fassade, die zum Fluss ausgeht, ist vollständig transparent und kann in den warmen Monaten geöffnet werden, wodurch der Innenraum mit dem Außenraum verbunden wird [9].

Das zentrale „Nave“ des Gebäudes hat eine Höhe von 22 Metern und ist nicht für einen bestimmten Zweck vorgesehen. Auf der rechten Seite des Haupteingangs befinden sich Werkstätten, eine Bibliothek, multifunktionale Säle ohne feste Trennwände und ein Konzertsaal. Dieser öffnet sich zum Park und hat transparente Wände. So wurde die Verschmelzung von Architektur und Natur verstärkt. Vor dem Gebäude wurden 620 Birken gepflanzt. Das ist sowohl schön als auch funktional: Das

bloße Bewundern des Hains ist ein Akt der Kunst. Im linken Teil des Gebäudes befinden sich Räume, die nicht mit Bildung und Kreativität verbunden sind: Hier wird es eine Parkgarage geben, die bei Bedarf auch andere Funktionen erfüllen kann, sowie geschlossene Säle für Präsentationen und verschiedene Veranstaltungen [9]. Die Visualisierung des zentralen “Nave” ist in der Abbildung 7 dargestellt:



Abbildung 7 – Die Visualisierung des zentralen “Nave”

Das Gebäude strebt die Gold-Zertifizierung nach LEED (Leadership in Energy and Environmental Design) an. „GES-2“ nutzt aktiv erneuerbare Energiequellen.

- Auf dem Dach sind Solarmodule installiert, die bis zu 10 % des Stroms, den „GES-2“ verbraucht, erzeugen.
- Die 70 Meter hohen Rohre von „GES-2“ werden zur Luftfilterung verwendet.
- Die Parkgarage ist mit Ladestationen für Elektroautos ausgestattet.
- Im Gebäude gibt es ein System zur Sammlung und Reinigung von Regenwasser, das für technische Zwecke genutzt wird [8].

Dieses Projekt soll nicht nur ein statisches, in die Landschaft der Stadt integriertes Bauwerk sein, sondern ein aktives Element des städtischen Lebens, ein Agent zwischenmenschlicher Beziehungen, der das Erlebnis, in der Stadt zu sein, wirklich modern macht. Die Gründer des Projekts sind überzeugt, dass „GES-2“ zu einer kulturellen Institution neuen Typs wird, einem Anziehungspunkt für Menschen aus den unterschiedlichsten Städten und Ländern [10].

Diese Projekte verkörpern eine neue Ästhetik, die über die bloße Gestaltung von Flächen hinausgeht. Sie sind Ausdruck eines Wandels hin zu integrativen, nachhaltigen und gemeinschaftsorientierten Ansätzen, die die Lebensqualität in urbanen Räumen verbessern.

Insgesamt verdeutlichen diese Projekte, dass die neue Ästhetik in der Raumtransformation eine Antwort auf die komplexen Herausforderungen des 21. Jahrhunderts ist. Sie zeigen, wie durchdachte und kreative Raumgestaltungen nicht nur ästhetische Werte schaffen, sondern auch soziale und ökologische Verantwortung übernehmen. Diese Initiativen fördern die Interaktion zwischen den Menschen, die Verbindung zur Natur und die kulturelle Identität, was zu einer höheren Lebensqualität in urbanen Räumen führt.

Die neuen Ansätze in der Raumtransformation inspirieren uns dazu, die Möglichkeiten der Stadtgestaltung umzudenken. Sie fordern uns auf, Räume zu schaffen, die nicht nur funktional und nachhaltig sind, sondern auch die Menschen zusammenbringen und ein Gefühl der Gemeinschaft fördern. In einer Welt, die sich ständig verändert, ist es von entscheidender Bedeutung, dass wir Städte gestalten, die lebendig, dynamisch und inklusiv sind – Orte, an denen Menschen gerne leben, arbeiten und sich begegnen.

Zusammenfassend lässt sich sagen, dass die Projekte, die in dieser Arbeit behandelt wurden, nicht nur Beispiele für innovative Raumtransformationen sind, sondern auch Visionen für die Städte der Zukunft darstellen. Sie bieten wertvolle Impulse für die zukünftige Stadtentwicklung und zeigen, dass durch kreative Zusammenarbeit und visionäres Denken positive Veränderungen möglich sind. Die neue Ästhetik in der Raumtransformation ist somit nicht nur ein Trend, sondern ein notwendiger Schritt in Richtung einer nachhaltigeren und menschenfreundlicheren urbanen Zukunft.

Список литературы:

1. Парк Хай-Лайн: зеленая крыша Манхэттена. – URL: <https://www.liveinternet.ru/users/willynat/post411940527/> (дата обращения: 22.03.2025). – Текст : электронный.
2. Хай-Лайн парк. – URL: <https://travellan.ru/articles/khay-layn-park-v-nyu-yorke/> (дата обращения: 22.03.2025). – Текст : электронный.
3. Low Line – судьба подземного парка в Нью-Йорке. – URL: <https://afisha.life/low-line-sudba-podzemnogo-parka-v-nyu-jorke/> (дата обращения: 24.03.2025). – Текст : электронный.
4. In New York wird weltweit erster unterirdischer Park. – URL: Geplant <https://www.ingenieur.de/technik/fachbereiche/architektur/in-new-york-weltweit-erster-unterirdischer-park-geplant/> (Datum des Zugriffs: 24.03.2025).
5. Manhattan's subterranean Lowline park flatlines. – URL: <https://www.archpaper.com/2020/02/the-lowline-flatlines/> (date accessed: 24.03.2025).
6. Вид с неба: выйти из сумрака, Дания. – URL: <https://www.vokrugsveta.ru/article/307582/> (дата обращения: 26.03.2025). – Текст : электронный.
7. Парк Суперкилен. – URL: <https://guide.planetofhotels.com/ru/daniya/kopengagen/park-superkilen> (дата обращения: 26.03.2025). – Текст : электронный.
8. «ГЭС-2» в Москве. – URL: <https://www.architime.ru/news/ges2/2.htm#1.jpg> (дата обращения: 26.03.2025). – Текст : электронный.
9. Ренцо Пьяно рассказывает о реконструкции ГЭС-2 в Москве. – URL: <https://www.interior.ru/architecture/7444-rentso-pyano-rasskazyvaet-o-rekonstruktsii-ges-2-v-moskve.html> (дата обращения: 28.03.2025). – Текст : электронный.
10. Es ist kein Museum: Wie wird das neue Kulturzentrum von GES-2 aussehen? – URL: <https://design-mate.ru/read/objects/projects/new-cultural-center-ges2> (Datum des Zugriffs: 28.03.2025).

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ANALYSE DER EUROPÄISCHEN QUALITÄTSSTANDARDS FÜR BEKLEIDUNG

Zusammenfassung. Die Einhaltung und Weiterentwicklung von Qualitätsstandards spielen eine zentrale Rolle in der europäischen Bekleidungsindustrie, insbesondere im Hinblick auf die wachsenden Anforderungen an Nachhaltigkeit, Produktsicherheit und Verbrauchertransparenz. Diese Studie bietet eine systematische Analyse europäischer Normen und Richtlinien, die die Kleidungsqualität betreffen, einschließlich EN-, ISO- und OEKO-Standards. Das Ziel der Untersuchung ist, die wichtigsten Qualitätskriterien zu identifizieren, regulatorische Rahmenbedingungen zu vergleichen und deren Auswirkungen auf Design, Produktion, Materialwahl und Vertrieb zu bewerten. Die Analyse basiert auf einer Auswertung aktueller EU-Dokumenten sowie branchenspezifischen Regelwerken. Die Ergebnisse zeigen, dass hauptsächlich Zertifizierung zur Produktsicherheit, Umweltverträglichkeit und sozialen Verantwortung beiträgt und zunehmend einen Einfluss auf den Markterfolg und Wettbewerbsfähigkeit europäischer Modeunternehmen ausübt. Die Studie leistet einen Beitrag zur besseren Orientierung in der komplexen Regulierungslandschaft und bietet praktische Empfehlungen für Hersteller, Designer und Entscheidungsträger in der Bekleidungsbranche.

Schlüsselwörter: Bekleidungsindustrie, Qualität, Zertifizierung.

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ANALYSIS OF EUROPEAN APPAREL QUALITY STANDARDS

Abstract. Maintaining and updating quality standards is essential to the European apparel industry, especially amid increasing expectations for sustainability, product safety, and consumer transparency. This study presents a review of European

regulations and standards concerning clothing quality, including EN, ISO, and OEKO-TEX. The aim of the paper is to identify key quality indicators and compare regulatory frameworks to evaluate their influence on design, production, material selection, and product distribution. The analysis draws on current EU documents and industry-specific regulations. The findings show that quality certifications demonstrating product safety, environmental sustainability, and corporate social responsibility have a considerable impact on the competitiveness of European apparel companies. The paper contributes to a better understanding of the complex regulatory landscape and offers practical recommendations for manufacturers, designers, and managers involved in apparel production and quality management.

Keywords: apparel industry, quality, certification.

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АНАЛИЗ ЕВРОПЕЙСКИХ СТАНДАРТОВ КАЧЕСТВА ОДЕЖДЫ

Аннотация. Соблюдение и актуализация стандартов качества играют важную роль в европейской отрасли производства швейных изделий, особенно в контексте растущих требований к устойчивому развитию, безопасности продукции и прозрачности для потребителя. В данном исследовании проводится систематический анализ европейских норм и регламентов, связанных с качеством одежды, включая стандарты EN, ISO и OEKO-TEX. Целью исследования является определение ключевых показателей качества и сравнение нормативных рамок для оценки их влияния на дизайн, производство, выбор материалов и сбыт продукции. Анализ основан на изучении актуальных документов ЕС, а также отраслевых нормативных актов. Результаты показывают, что сертификаты качества, подтверждающие безопасность продукции, экологичность и социальную ответственность предприятия, оказывают значительное влияние на конкурентоспособность европейских предприятий швейной промышленности. Статья способствует лучшему пониманию сложной нормативной среды и содержит практические рекомендации для производителей, дизайнеров и специалистов, принимающих решения в сфере производства и управления качеством одежды.

Ключевые слова: швейная промышленность, качество, сертификация.

In der europäischen Bekleidungsindustrie spielen Qualität und Normenkonformität eine entscheidende Rolle. Oberbekleidung wie Jacken, Mäntel und Blazer unterliegt besonders hohen Anforderungen hinsichtlich Funktionalität, Langlebigkeit und Verbrauchersicherheit. Ästhetische Aspekte werden ergänzt durch

Anforderungen an nachhaltige und sozial verantwortungsvolle Herstellungsprozesse. Verschiedene nationale und internationale Standards gewährleisten die Einhaltung dieser Anforderungen, wobei deren Bedeutung durch zunehmende Globalisierung sowie wachsendes Umwelt- und Sozialbewusstsein der Konsumenten noch weiter verstärkt wird.

Qualitätsstandards in der Bekleidungsindustrie werden durch globale Wettbewerbsbedingungen, technologische Innovationen und internationale Kooperationen wesentlich beeinflusst. Von insgesamt 208 relevanten Veröffentlichungen, die in Dimensions recherchiert wurden, beleuchten ausgewählte Studien zentrale Themen wie strategische Kooperationen, Industrie 4.0 sowie die Auswirkungen neuer Technologien auf Arbeitsplätze und Produktionsqualität.

Yvonne Rückert et al. (2007) unterstreichen ebenfalls die Bedeutung von Kooperationen, insbesondere hinsichtlich der Verknüpfung von Beschäftigungsbedingungen und Qualitätsstandards bei Kooperationen deutscher KMU mit Partnern in Mittel- und Osteuropa [1]. Philip Marschall et al. (2020) befassen sich mit den Auswirkungen der Digitalisierung und Industrie 4.0 auf Qualität und Effizienz in der Textilindustrie [2]. Sie prognostizieren Chancen für die Rückverlagerung der Produktion nach Deutschland. Das „Handbuch für den Textilkaufmann“ (1964) bietet zudem grundlegende betriebswirtschaftliche und technologische Einsichten in Qualitätsprozesse, während Georg Erber (2013) wirtschaftspolitische Kontextfaktoren behandelt, die indirekt Qualitätsstandards beeinflussen [3, 4].

Standards fungieren dabei als grundlegende Orientierungshilfe für Hersteller, Händler und Verbraucher, indem sie verbindliche Vorgaben zu Materialqualität, Fertigungstechniken, chemischer Sicherheit und Produktkennzeichnung festlegen. Neben der Unterstützung bei rechtlicher Konformität fördern Standards die Verbrauchervertrauen und erleichtern Markteinführungen neuer Produkte. Darüber hinaus spielen normative Vorgaben eine immer größere Rolle im Kontext nachhaltiger Produktion und Kreislaufwirtschaft, indem sie den gesamten Lebenszyklus eines Produktes - von der Rohstoffauswahl bis hin zur Wiederverwertung - begleiten.

Die vorliegende Studie stützt sich auf eine interdisziplinäre Auswahl aktueller wissenschaftlicher und normativer Quellen aus den Bereichen Textiltechnik, Qualitätsmanagement, Nachhaltigkeit sowie europäisches Produktsicherheitsrecht. Insbesondere wurden Fachartikel aus peer-reviewed Journals, technische Normdokumente (EN-, ISO-, DIN-, GOST-Standards), Verordnungen der Europäischen Union (REACH) sowie Materialien von Zertifizierungsstellen (z. B. OEKO-TEX Association) ausgewertet [6-10].

Ein zentrales Dokument ist die REACH-Verordnung (EG Nr. 1907/2006), die als gesetzlicher Rahmen für die chemische Sicherheit von Textilien dient. Darüber hinaus geben die Normen EN ISO 13688:2013 und DIN EN ISO 5077 Aufschluss über technische Anforderungen an Bekleidung. Die ISO 9001:2015 wurde herangezogen, um die organisatorischen Aspekte des Qualitätsmanagements zu beleuchten.

Die Zertifizierungen von OEKO-TEX und die Positionierungen von nationalen Normungseinrichtungen wie AFNOR (Frankreich) und DIN (Deutschland) wurden hinsichtlich ihrer praktischen Bedeutung für Hersteller analysiert.

Ergänzt wurde die Untersuchung durch Fachliteratur zu Trends der Kreislaufwirtschaft, zur Digitalisierung in der Textilproduktion und zu Anforderungen an Lieferkettentransparenz. Die Integration russischer Standards - insbesondere GOST 25294-2003 - erlaubt einen transnationalen Vergleich. Diese Standards bilden die Grundlage für Produktqualität und Verbraucherschutz in der EU. Unternehmen integrieren häufig mehrere dieser Normen, um sowohl gesetzlichen Anforderungen gerecht zu werden als auch ihr Markenimage zu stärken. Die wichtigsten Regelwerke sind in Tabelle dargestellt.

Tabelle – Übersicht der wichtigsten europäischen Qualitätsstandards für Bekleidung

Standard	Land / Organisation	Bezeichnung	Wesentliche Kontrollparameter	Besonderheiten
GOST 25294-2003	Russland	Oberbekleidungsprodukte für Erwachsene. Allgemeine technische Bedingungen	- Qualität der Materialien (Stoff, Futter, Isolierung) - Maßgenauigkeit und Passform - Qualität der Nähte und Stiche - Farbechtheit gegenüber Waschen, Reibung, Schweiß - Atmungsaktivität, Feuchtigkeitsbeständigkeit	Obligatorischer Standard für inländische Produktion und Zertifizierung. Standardisiert Ergonomie, Haltbarkeit und Tragekomfort.
EN ISO 13688:2013	EU / ISO	Schutzbekleidung – Allgemeine Anforderungen	- Größen, Passform, Kennzeichnung - Sicherheit der Materialien - Reiß- und Zugfestigkeit - Beständigkeit gegen Abnutzung und Alterung	Basisnorm für zahlreiche weitere EU-Standards im Bereich Schutz- und Arbeitsbekleidung.
OEKO-TEX Standard 100	International	Zertifizierung der Textilsicherheit	- Ausschluss gesundheitsschädlicher - Chemikalien - Prüfung auf allergene oder krebserregende Substanzen - Einteilung in vier Produktklassen	Freiwilliger, aber global etablierter Standard mit hoher Verbraucherakzeptanz.

REACH (EG Nr. 1907/20 06)	EU	EU-Verordnung zur Registrierung, Bewertung, Zulassung und Beschränkung chemischer Stoffe	- Kontrolle gefährlicher Substanzen (SVHC) - Vorschriften zur Kennzeichnung und Dokumentation - Umwelt- und Verbraucherschutz	Gesetzlich verpflichtend für alle Textilerzeugnisse auf dem EU-Markt. Umfassend in der gesamten Lieferkette.
ISO 9001:2015	International	Qualitätsmanagementsysteme – Anforderungen	- Strukturelle und prozessuale Anforderungen an Unternehmen - Fehlervermeidung und kontinuierliche Verbesserung - Kundenorientierung und Risikomanagement	Betrifft nicht direkt die Produkte, sondern die Organisation des Produktionsprozesses.
DIN EN ISO 5077	Deutschland / ISO	Bestimmung der Maßänderung nach der Haushaltswäsche	- Maßhaltigkeit nach Waschen und Trocknen - Einfluss von Pflegezyklen auf Stoffeigenschaften	Besonders relevant für natürliche oder empfindliche Materialien.
AFNOR NF G07-122 / G07-131	Frankreich	Nationale Textilstandards	- Farbechtheit - Pilling-Beständigkeit - Mechanische Festigkeit und Wasseraufnahme	Ergänzen internationale Normen mit branchenspezifischen Parametern für die französische Textilindustrie.

Im Vergleich dazu fokussiert der russische Standard GOST 25294-2003 stärker auf technische und praktische Kriterien wie Materialqualität, Maßgenauigkeit, Farbechtheit, Luftdurchlässigkeit und chemische Belastung [5]. Diese klare, technisch orientierte Ausrichtung des GOST-Standards bietet den Herstellern eindeutige, überprüfbare und praxisnahe Vorgaben. Dadurch gewährleistet der russische Standard eine verlässliche und konstant hohe Produktqualität, die sich besonders gut für die Anforderungen des russischen Marktes und die dort herrschenden klimatischen Bedingungen eignet. Insbesondere die klar definierten technischen Parameter machen den GOST-Standard in der praktischen Anwendung oft effektiver und einfacher handhabbar als vergleichbare europäische Normen.

Europäische Normen hingegen betonen verstärkt Aspekte der Nachhaltigkeit, sozialen Verantwortung und des Umweltschutzes. Insbesondere Zertifizierungen wie OEKO-TEX und die Einhaltung der REACH-Verordnung verdeutlichen diesen Wandel hin zu einer umfassenderen Qualitätsdefinition.

Hersteller, die in Europa tätig sind, stehen angesichts dieser umfassenden und komplexen Normenlandschaft vor erheblichen Herausforderungen. Insbesondere kleine und mittlere Unternehmen (KMU) benötigen oft spezialisierte Unterstützung und Beratung, um die Anforderungen internationaler Standards erfolgreich zu implementieren. Jedoch bieten diese komplexen Anforderungen auch bedeutende Chancen: Unternehmen können ihre Position auf dem Markt durch nachhaltige und sozial verantwortliche Praktiken stärken und damit langfristig das Vertrauen und die Loyalität ihrer Kunden gewinnen.

Neue technologische Entwicklungen wie digitale Produktpässe, Blockchain-basierte Lieferkettenlösungen und automatisierte Qualitätssicherungssysteme eröffnen zusätzliche Möglichkeiten, die Transparenz und Nachvollziehbarkeit innerhalb der gesamten Wertschöpfungskette zu erhöhen. Diese Innovationen helfen Unternehmen, regulatorische Anforderungen effizienter umzusetzen und tragen gleichzeitig zur Verbesserung der Gesamtqualität bei.

Abschließend lässt sich festhalten, dass der GOST-Standard aufgrund seiner klaren und technisch fundierten Struktur im Hinblick auf die praktische Anwendung und Qualitätskontrolle oft überlegen ist. Europäische Qualitätsstandards bieten hingegen einen integrativen Ansatz, der ökologische und soziale Aspekte stärker berücksichtigt. Für Unternehmen, die einen einfachen, transparenten und unmittelbar anwendbaren Qualitätsrahmen bevorzugen, stellt der GOST-Standard daher eine besonders attraktive Option dar. Um dennoch international wettbewerbsfähig zu bleiben, empfiehlt es sich, Elemente beider Ansätze gezielt miteinander zu kombinieren. Dazu sollten Unternehmen verstärkt in Schulungen und Weiterbildung ihrer Mitarbeiter investieren, technologische Innovationen proaktiv einsetzen und kontinuierlich interne Qualitätsprozesse optimieren. Eine enge Zusammenarbeit mit Forschungseinrichtungen, Zertifizierungsstellen und Branchennetzwerken kann diese Bemühungen zusätzlich unterstützen und fördern. Die Analyse kann als Grundlage für betriebliche Qualitätsstrategien im Bekleidungssektor dienen.

Список литературы:

1. Rückert, Y., Wannöffel, M., & Lungwitz, R.-E. (2007) Kooperationsbeziehungen deutscher Klein- und Mittelunternehmen in Mittel- und Osteuropa. WSI-Mitteilungen.
2. Marschall, P., Peters, R., Jordan, J., Fromhold-Eisebith, M., Thomes, P., & Kemper, M. (2020) IWiSoTex4.0: Wirtschaftsräumliche Implikationen von Industrie 4.0 in relationaler Perspektive // SSRN Electronic Journal. DOI: 10.2139/ssrn.3548419.
3. Springer Nature. Handbuch für den Textilkaufmann. Berlin : Springer, 1964.
4. Erber, G. (2013) Economic Relations between China and the EU, the Euro Area and Germany // SSRN Electronic Journal. DOI: 10.2139/ssrn.2345401.
5. ГОСТ 25294–2003. Одежда верхняя платьево-блузочного ассортимента. Общие технические условия = Outerwear of dress-blouse assortment. General specifications : национальный стандарт Российской Федерации. – Введ. 2006-01-01. – М. : Стандартинформ, 2003. – 10 с. – (Код ОКС: 61.020).
6. EN ISO 13688:2013. Protective clothing – General requirements. Brüssel : CEN, 2013.

7. DIN EN ISO 5077:2008. Textilien – Bestimmung der Maßänderung nach Haushaltswäschen. Berlin : Beuth Verlag, 2008.
8. ISO 9001:2015. Системы менеджмента качества – Требования. – Женева : ISO, 2015.
9. Регламент (ЕС) № 1907/2006 Европейского парламента и Совета от 18 декабря 2006 г. о регистрации, оценке, разрешении и ограничении химических веществ (REACH). – Текст : электронный. – URL: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32006R1907> (дата обращения: 10.04.2025).
10. OEKO-TEX® Standard 100. Критерии сертификации текстильной продукции. Цюрих : OEKO-TEX International, 2023.

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EFFET D'UNE AIGUILLE À COUDRE AVEC UNE POINTE DE COUPE À ANGLE GAUCHE SUR LES DÉFAUTS DE COUTURE

Annotation. L'article présente les résultats d'une étude sur l'effet d'une aiguille à coudre avec une pointe coupante gauche №80 sur un défaut de couture (trou après une piqûre d'aiguille). Il a été établi que la capacité de récupération dépend de l'épaisseur et de la porosité du revêtement en polyuréthane. Une étude des propriétés de cicatrisation d'un revêtement en polyuréthane poreux a montré une relation directe entre l'épaisseur du polymère et le taux de cicatrisation des perforations. Ceci est démontré par la réduction du temps nécessaire à la restauration complète du revêtement.

Mots clés: tissu enduit, polyuréthane poreux, trou, aiguille machine, restauration, vêtement, couture.

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EFFECT OF A SEWING NEEDLE WITH A LEFT-ANGLED CUTTING POINT ON SEWING DEFECTS

Abstract. The article reflects the results of the study of the effect of a sewing needle with a cutting point with a left slope of № 80 on a sewing defect (a hole after a puncture with a needle). It was found that the ability to restore depends on the thickness and porosity of the polyurethane coating. The study of the property of restoring a porous polyurethane coating showed a direct relationship between the thickness of the

polymer and the rate of healing of punctures. This is evidenced by the reduction in the time required for complete restoration of the coating.

Keywords: coated fabric, porous polyurethane, hole, machine needle, restoration, clothing, sewing.

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ВЛИЯНИЕ ШВЕЙНОЙ ИГЛЫ С РЕЖУЩИМ ОСТРИЕМ С ЛЕВЫМ НАКЛОНОМ НА ДЕФЕКТЫ ШИТЬЯ

Аннотация. В статье отражены результаты исследования влияния швейной иглы с режущим острием с левым наклоном № 80 на дефект шитья (отверстие после прокола иглой). Установлено, что способность к восстановлению зависит от толщины и пористости полиуретанового покрытия. Исследование свойства восстановления пористого полиуретанового покрытия показало прямую зависимость между толщиной полимера и скоростью заживления проколов. Об этом свидетельствует сокращение времени, необходимого для полного восстановления покрытия.

Ключевые слова: ткань с покрытием, пористый полиуретан, отверстие, машинная игла, восстановление, одежда, пошив.

L'analyse des défauts de couture est essentielle pour garantir la qualité et la durabilité des produits textiles. Ces défauts peuvent compromettre l'esthétique, la fonctionnalité et la résistance des articles. On distingue plusieurs types de défauts, notamment les points sautés, les fronces, les plis, les tensions incorrectes du fil, les coutures déformées et les cassures de fil, trou après crevaisson. Les causes sont variées et peuvent être liées à la machine à coudre (réglages incorrects, aiguilles émoussées), au fil (mauvaise qualité, tension inadéquate), au tissu (épaisseur, texture) ou à l'opérateur (manque d'expérience, erreurs de manipulation) [1].

Les défauts de couture peuvent entraîner une usure prématurée du vêtement, des déchirures, des problèmes d'ajustement et une insatisfaction du client. Ce travail examinera un défaut – un trou indésirable dans un matériau textile après avoir été percé par une aiguille.

Ce défaut a été bien étudié dans les tissus et les tricotés, mais n'a pas été étudié dans le cuir artificiel et dans les tissus avec une couche de polymère. La popularité des tissus avec un revêtement en polyuréthane poreux ("éco-cuir") ne cesse de croître,

devenant un classique dans le monde de la mode. Ils ont une grande élasticité et de bonnes propriétés hygiéniques. Cependant, les matériaux en polyuréthane peuvent également être sensibles à divers défauts de couture, ce qui rend l'étude de l'influence de l'aiguille à coudre particulièrement pertinente. En théorie, la structure poreuse du polyuréthane permet de restaurer le revêtement après avoir été perforé par une aiguille à coudre. Les auteurs ont mené une série d'études pour étudier la capacité à restaurer l'intégrité de la structure après une perforation à l'aiguille de tissus biélorusses avec un revêtement en polyuréthane [2]. Il est cependant nécessaire d'étudier tous les affûtages d'aiguilles utilisés et leur effet sur la restauration de l'intégrité.

Lorsqu'une aiguille non adaptée aux tissus en polyuréthane est utilisée, des problèmes tels que le perçage du matériau peuvent survenir [3]. Cela est souvent dû au fait que la pointe de l'aiguille n'est pas assez solide ou qu'elle a une forme inadaptée. Le poinçonnage peut entraîner des accrocs et des coutures désordonnées, ce qui affecte négativement l'esthétique du produit [4].

L'objectif de ce travail est d'étudier l'influence d'une aiguille à coudre à pointe coupante gauche sur les défauts de couture des tissus enduits de polyuréthane. Ces études apporteront de nouvelles informations sur le comportement de ces matériaux lors du processus de couture.

Les matériaux biélorusses ont été choisis comme objet d'étude. Le tableau 1 présente les caractéristiques des tissus étudiés avec un revêtement en polyuréthane poreux de production biélorusse. Le matériau est utilisé pour coudre des vêtements de deuxième et troisième couche.

Tableau 1 – Caractéristiques des échantillons étudiés

Exemple de code	Épaisseur du PU, μm	Épaisseur de l'ensemble du matériau, μm	Densité de surface, g/m ²
№2r	350	650	350
№3s	450	850	310
№4g	530	900	340
№5h	720	910	385

L'essentiel de l'étude était le suivant. Les points de suture ont été réalisés à la machine sans fil sur les échantillons, avec une fréquence de 7 points par cm. Pour mesurer la forme et la surface du trou après les perforations, un microscope Altami MET5 5X/0,12 BD ∞/- (distance de travail 9,7 mm), grossissement 50X a été utilisé. Des mesures des changements dans la zone de ponction ont été prises à intervalles réguliers.

D'après l'ouvrage de référence "Assortiment de fils à coudre et d'aiguilles. Normes de consommation de fils à coudre pour vêtements d'extérieur" [5] pour la couture du cuir et des tissus avec un revêtement polymère, il existe un certain nombre d'aiguilles à affûter avec une pointe coupante, qui à leur tour sont divisées en six groupes par application (D, DI, LL, LR, PCL, S). Le numéro d'aiguille (taille) est sélectionné en tenant compte de la structure et du type de tissu, ainsi que du nombre de couches à coudre. Dans cette étude, des aiguilles Schmetz à pointe LL, №80 ont été

utilisées (Figure).

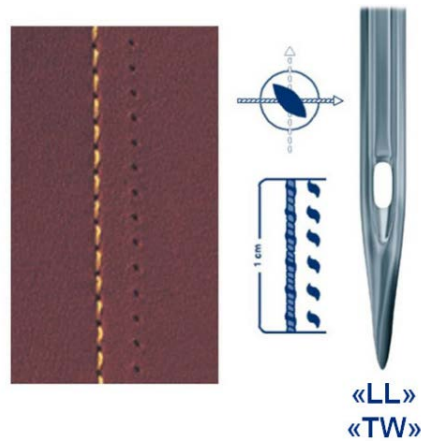


Figure – Aiguille à coudre avec affûtage à pointe LL

Le choix de l'aiguille est une décision importante qui affecte considérablement la qualité du point.

L'aiguille à coudre avec pointe coupante à gauche “LL“ est utilisée pour:

- tous types de cuir utilisés dans la fabrication de vêtements, chaussures, sacs, valises en cuir ;
- tissus avec revêtement polymère ;
- faire des coutures droites.

Le tableau 2 présente les résultats des études sur la capacité des tissus biélorusses avec un revêtement en polyuréthane poreux à auto-restaurer l'intégrité de la structure après avoir été perforés avec une aiguille à pointe acérée LL №80.

Tableau 2 – Capacité des tissus avec revêtement PU à restaurer l'intégrité structurelle après perforation avec l'aiguille LL №80

Exemple de code	Temps après la ponction, min					
	0	5	10	60	360	1440
№2r						
№3s						
№4g						
№5h						

Sur la base des résultats de la recherche menée, des dépendances mathématiques du temps de récupération après une perforation sur l'épaisseur de la couche de polyuréthane ont été obtenues (tableau 3).

Tableau 3 – Dépendance mathématique du temps de récupération après une perforation sur l'épaisseur de la couche de polyuréthane

Exemple de code	Épaisseur du PU, μm	Dépendance mathématique
№2s	350	$y = 13022x^{-0,671}$ $R^2 = 0,9445$
№3r	450	$y = 179492x^{-1,547}$ $R^2 = 0,947$
№4g	530	$y = 1051,8x^2 - 14161x + 45498$ $R^2 = 0,9234$
№5h	720	$y = -343,62x^2 - 5424,5x + 44861$ $R^2 = 0,9977$

Pour les échantillons №2s et №3r, la dépendance est décrite par une fonction puissance, et pour les échantillons №4g et №5h, elle est polynomial ($R^2 > 0,92$).

En analysant les données présentées dans le tableau 2, nous pouvons conclure que l'échantillon №2p, qui présente la plus petite épaisseur du revêtement poreux en polyuréthane (350 μm), présente la plus grande surface de perforation. Cet échantillon restaure également l'intégrité structurelle plus lentement sans influence externe.

Les perforations des échantillons forment un trou de forme irrégulière, presque ronde.

À mesure que l'épaisseur du revêtement en polyuréthane poreux augmente, la capacité d'auto-guérison s'améliore. L'échantillon №2r présente encore une petite perforation après 1440 heures. Ce type d'échantillon nécessite une exposition supplémentaire à la vapeur chaude. Pour les échantillons №3s, №4g, №5h, la récupération complète de la ponction se produit respectivement en 6 heures, 1 heure et 5 minutes. Cela confirme la théorie selon laquelle le temps de récupération diminue avec l'augmentation de l'épaisseur de la couche de polymère.

Pour tous les échantillons, la restauration de l'intégrité de la structure du revêtement en polyuréthane est caractérisée par deux étapes. Durant les premières minutes, la ponction est intensément "resserrée". Ensuite, ce processus ralentit. Par la suite, le processus d'auto-guérison atteint un état d'équilibre.

Les échantillons №3h présentent la plus grande épaisseur du revêtement en polyuréthane et, par conséquent, une plus grande porosité, ce qui permet un "resserrement" plus rapide de la perforation à une taille minimale. Après avoir été percée avec une aiguille, la piqûre guérit en 2 à 3 secondes.

Lors de la couture de vêtements, l'état de l'aiguille est d'une grande importance. Pour éviter tout dommage, les aiguilles doivent être remplacées rapidement. Pour

restauration l'intégrité de la structure des échantillons avec une faible épaisseur de revêtement en polyuréthane, une action supplémentaire est nécessaire, vraisemblablement un traitement thermique humide, qui contribuera à accélérer le processus de "resserrement" des perforations et à améliorer l'aspect esthétique des échantillons.

Ce matériau textile est capable de retrouver son intégrité après avoir été perforé par une aiguille à coudre. Cette propriété remarquable ouvre des perspectives inédites dans de nombreux domaines. Ces polymères réagissent à la chaleur, se contractant pour refermer les micro-trous causés par l'aiguille. Cette technologie promet une durabilité accrue des textiles, réduisant ainsi les déchets et favorisant une consommation plus responsable. L'impact environnemental pourrait être significatif, ouvrant la voie à une industrie textile plus durable.

Le choix de la bonne aiguille à coudre joue un rôle clé dans le processus de couture des tissus en polyuréthane. Cela est nécessaire non seulement pour éviter les défauts, mais également pour garantir la durabilité et l'attrait esthétique des produits finis. Connaître les caractéristiques des aiguilles et leur impact sur les défauts de couture aidera les couturiers à gérer plus efficacement les complexités associées au travail avec un revêtement en polyuréthane.

La réalisation d'études expérimentales avec différentes tailles d'aiguilles constitue une étape obligatoire dans le développement d'une technologie de couture efficace.

Список литературы:

1. Бузов, Б. А. Практикум по материаловедению швейного производства / Б. А. Бузов, Н. Д. Алыменкова, Д. Г. Петропавловский. – М. : Издательский центр «Академия», 2004. – 416 с. – Текст : непосредственный.
2. Марущак, Ю. И. Исследование способности тканей с полиуретановым покрытием к самовосстановлению целостности структуры после прокола иглой microtex / Ю. И. Марущак. – Текст : непосредственный // Материалы Всероссийской науч.-практ. конференции Легкая промышленность: проблемы и перспективы. – ОмГТУ, Омск, 2024. – С. 136-142.
3. Гаврилова, О. В. Особенности проектирования и изготовления изделий легкой промышленности из современных комплексных полимерных материалов / О. В. Гаврилова, Л. Л. Никитина. – Текст : непосредственный // Вестник Казанского технологического университета. – 2013. – С. 136-140.
4. Stjepanović, Z. (1998) Selection of suitable sewing needle using machine learning technique // International Journal of Clothing Science and Technology 10(3/4): 209-218.
5. Бодяло, Н. Н. Ассортимент швейных ниток и игл. Нормы расхода швейных ниток для верхней одежды: справочник / сост. Н. Н. Бодяло. – Витебск, УО«ВГТУ». – 2009. – 82 с. – Текст : непосредственный.

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УДК 677.467

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THERMOCHROMIC DYES BASED ON CRYSTAL VIOLET LACTONE

Abstract. Thermochromic dyes are promising for their use in various fields. Studies examining thermochromic dye compositions based on crystal violet lactone of various content and proposing a replacement for the classic developer bisphenol A and studies on encapsulation of such compositions were reviewed.

Keywords: thermochromic dyes, microencapsulated thermochromic dyes, proton donor developers, crystal violet lactone, microencapsulation.

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ТЕРМОХРОМНЫЕ КРАСИТЕЛИ НА ОСНОВЕ КРИСТАЛЛИЧЕСКОГО ФИОЛЕТОВОГО ЛАКТОНА

Аннотация. Термохромные красители являются перспективными для использования в различных областях. Рассмотрены исследования, изучающие термохромные красящие композиции на основе кристаллического фиолетового лактона различного состава и предлагающие замену классического проявителя бисфенола А и исследования по инкапсулированию таких композиций.

Ключевые слова: термохромные красители, микрокапсулированные термохромные красители, протонно-донорные проявители, кристаллический фиолетовый лактон, микрокапсулирование.

Introduction

Thermochromic dyes are dyes that can change their color under the influence of changing environmental conditions. Today, thermochromic materials are a promising area for study and are of great interest in various areas of human life. They are used as temperature markers and for decorative purposes. Of particular interest are fibrous materials that have the effect of thermochromism.

Thermochromism is the property of substances to change color with temperature changes [1]. Thermochromic textiles can be used in the household sphere when creating design solutions, as well as in any special-purpose textile materials where constant temperature control is required. For example, thermochromic textiles can be used in hospital clothing for continuous monitoring of the patient's body temperature; in the manufacture of firefighter suits to control the temperature and prevent overheating of the rescuer's body; in the manufacture of clothing for workers who are in false working conditions (Arctic workers), and so on.

However, the mechanisms of thermochromic behavior have not yet been fully studied, attempts to replace the classic developer bisphenol A are faced with insufficient elaboration of this topic, as well as the high cost of alternative options. This article will discuss the prospects and features of using thermochromic dyes based on crystal violet lactone.

Developers for thermochromic compositions based on crystal violet lactone

Thermochromic dye composition consists of a dye, a developer and a medium (solvent).

The color change in these systems is the result of a reversible proton transfer reaction between the dye (crystal violet lactone) and the developer. This reaction results in a change in the structure of the chromophore in the dye molecule responsible for the color (Figure 1).

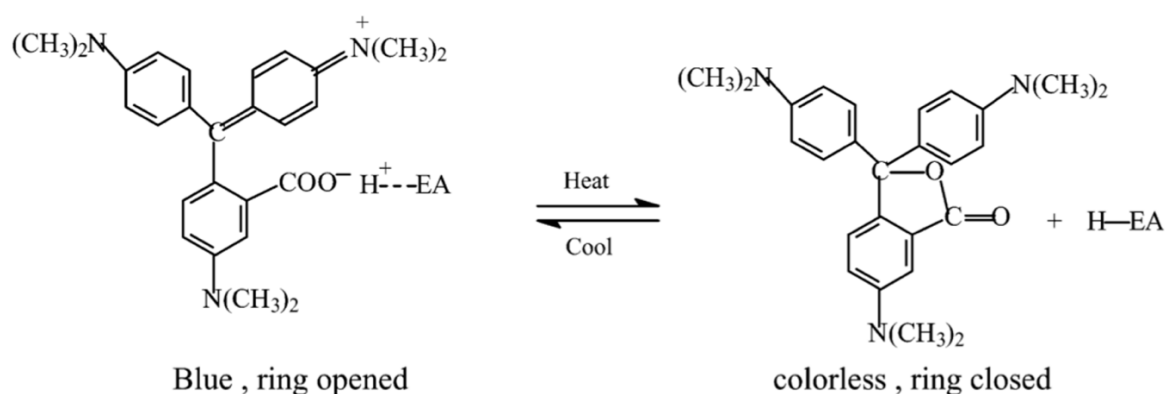


Figure 1 – Dependence of crystal violet lactone on pH [2]

Fatty alcohols and hydrocarbons are used as solvents. It is selected taking into account the required temperature of the color transition of the dye. The solvent at this temperature should change from crystalline form to liquid.

The most commonly used industrial developer is bisphenol A, as it is effective and has a low cost. However, bisphenol A is highly toxic and is prohibited for use in many areas, such as the production of food plastic, children's toys, etc. It has been established that this substance affects the development of cancer, diabetes and metabolic syndrome [3]. The search for new, less toxic, developers for thermochromic compositions based on crystal violet lactone and the study of the mechanisms of interactions in thermochromic systems is still an urgent task.

In 2022, scientists proposed using macrocyclic compounds as a developer [4]. According to the data presented in the study, the macrocyclic compound resorcinol [4] arene (RC4) gives a result similar to bisphenol A, the color change reaction is reversible. Color reaction tests confirm that RC4 is capable of complex formation and opening of the lactone ring of leuco dyes by releasing protons from phenolic groups. It is worth noting that this is the first study to show that macrocyclic compounds can replace bisphenol A.

Studies on finding a replacement for the toxic developer bisphenol A have been conducted previously. The article by Zhu C. F. and Wu A. B. [2] presents various compositions of thermochromic compositions based on crystal violet lactone. The following were used as electron acceptors in the study: cresol red, p-dihydroxybenzene, tannic acid, methylpropylphenol, phenolpropenoic acid, p-methylphenol, phenolphthalein, m-nitrobenzoic acid, propyl gallate, calcium chloride, m-aminobenzoic acid, $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, magnesium sulfate, $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$. The following compounds were used as solvents in the study: octadecanol, hexadecanol, stearic acid. According to the study data, 17 new complexes were synthesized, 15 of which had a thermochromic effect (Figure 2).

SB	Composition ^a		Property	Color change ^b
	Electron acceptor	Solvent compound		
(I)	Cresol red	Octadecanol	Thermochromic	Earthyellow $\rightleftharpoons$ red brown
(II)	<i>p</i> -Dihydroxybenzene	Hexadecanol	Thermochromic	Pale blue $\rightarrow$ colorless $\leftarrow$ deep blue $\leftarrow$ pale blue
(III)	Tannic acid	Octadecanol	Thermochromic	Blue $\rightleftharpoons$ colorless
(IV)	Methyl propyl phenol	Octadecanol	Thermochromic	Blue purple $\rightleftharpoons$ colorless
(V)	Methyl propyl phenol	Hexadecanol	Thermochromic	Blue $\rightleftharpoons$ colorless
(VI)	Phenolpropenoic acid	Octadecanol	Thermochromic	Blue green $\rightleftharpoons$ colorless
(VII)	<i>p</i> -Methylphenol	Hexadecanol	Thermochromic	Deep blue $\rightleftharpoons$ colorless
(VIII)	<i>p</i> -Methylphenol	Octadecanol	Thermochromic	Deep blue $\rightleftharpoons$ colorless
(IX)	Phenolphthalein	Hexadecanol	Thermochromic	Blue purple $\rightleftharpoons$ colorless
(X)	<i>m</i> -Nitrobenzoic acid	Octadecanol	Thermochromic	Blue $\rightleftharpoons$ colorless
(XI)	Propyl gallate	Octadecanol	Thermochromic	Blue $\rightleftharpoons$ colorless
(XII)	Calcium chloride	Octadecanol	Thermochromic	Pale blue $\rightarrow$ colorless $\leftarrow$ blue purple $\leftarrow$ pale blue
(XIII)	Calcium chloride	Stearic acid	Thermochromic	Pale blue $\rightleftharpoons$ colorless
(XIV)	<i>m</i> -Aminobenzoic acid	Octadecanol	Thermochromic	Pale blue $\rightleftharpoons$ colorless
(XV)	MgCl ₂ ·6H ₂ O	Stearic acid	Thermochromic	Blue green $\rightleftharpoons$ colorless
(XVI)	Magnesium sulfate	Octadecanol	Nonthermochromic	White
(XVII)	NiCl ₂ ·6H ₂ O	Octadecanol	Nonthermochromic	Blue

^a The mass ratio of CVL, electron acceptor, and solvent is 1:20:40.

^b $\rightarrow$, heating; $\leftarrow$, cooling.

Figure 2 – Compositions and thermal behavior of the studied complexes [2]

The results described in the study show that the new complexes can potentially be used as developers for thermochromic dye compositions based on crystal violet lactone.

Currently, research is also underway in Russia to find a replacement for the toxic developer bisphenol A. In 2023, a patent was obtained [5], according to which a tetrazole derivative can be used as a developer (Figure 3). The proposed developer is non-toxic and is used in the treatment of bacterial infections [6].

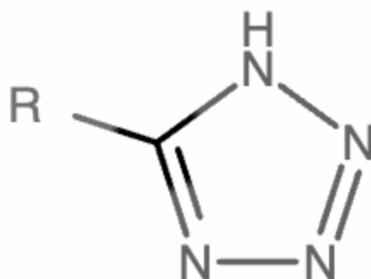


Figure 3 –Tetrazole derivative where R is selected from methyl, butyl, n-butyl and 3-methoxy-4-oxyphenyl

Microencapsulation of thermochromic dyes

For ease of use, thermochromic dyes must be encapsulated in a polymer shell. Microencapsulation is necessary to obtain an isolated system. The polymer coating imparts hydrophobic properties to the microcapsules and makes them insoluble in water, and the capsule shell protects the thermochromic composition from external influences that may affect the thermochromic properties of the dye. The following requirements are imposed on the microcapsule shell: transparency, insolubility in water, and inertness with respect to the substances of the core material. The following are used as the shell material for microcapsules:

- urea-formaldehyde [7-8];

- polymethyl methacrylate [9-10];
- melamine formaldehyde [11];
- polyurethane [12].

Thermochromic compositions in the form of microcapsules can be used in the production of fibrous textiles and polymeric materials. On textile materials, they are fixed to the surface of the fabric at the final finishing stage, using methods such as spraying, impregnation or printing. The dye is fixed to the fiber using thermosetting acrylic, polyurethane, silicone resins, as well as starch-based compositions.

Thermochromic dyes are introduced into polymeric materials in solutions or melts; after molding, the finished product has a thermochromic effect.

Conclusion

Thus, microencapsulated thermochromic dyes are a promising direction for study. They can be used in various areas of human life, including the production of smart textiles.

Список литературы:

1. Термохромные полимеры, волокна и материалы: получение и свойства / Е. С. Сашина, А. П. Михайловская, М. А. Бакаева, А. Ю. Кулешова. – Текст : электронный // Известия высших учебных заведений. Серия «Технология текстильной промышленности». – 2023. – № 5(407). – С. 20-29. – URL: https://tp.ivgpu.com/wp-content/uploads//2023/12//407_2.pdf (дата обращения: 30.03.2025).
2. Zhu, C. F., Wu, A. B. (2005) Studies on the synthesis and thermochromic properties of crystal violet lactone and its reversible thermochromic complexes // *Thermochimica Acta*. 425(1-2). 7-12.
3. Aklujkar, P. S., Kandasubramanian B. (2021) A review of microencapsulated thermochromic coatings for sustainable building applications // *J. Coat. Technol. Res.* 18. 19-37.
4. Sriphalang, S. (2022) Reversible Coloring/Decoloring Reactions of Thermochromic Leuco Dyes Controlled by a Macrocyclic Compound Developer // *Research Square*, 1-19.
5. Патент № 2813709 Российская Федерация, МПК C09D 5/26 (2006.01), C09K 9/02 (2006.01). Термохромная пигментная композиция : № 2023112699 : заявл. 16.05.2023 : опубл. 15.02.2024 / Мызников Л. В, Волкова Д. Д., Сашина Е. С. – 3 с. – Текст : непосредственный.
6. Aklujkar, P. S., Kandasubramanian, B. (2020) A review of microencapsulated thermochromic coatings for sustainable building applications. Department of Polymer and Surface Engineering. Institute of Chemical Technology, Mumbai, Maharashtra 400019, India. DOI: 10.1007/s11998-020-00396-3.
7. Zhang, Y., Naseer Mustapha A., Zhang, X., Baiocco, D., Wellio, G., Davies, T., Zhang, Z., Li, Y. (2020) Improved volatile cargo retention and mechanical properties

- of capsules via sediment-free in situ polymerization with cross-linked poly(vinyl alcohol) as an emulsifier // *Journal of Colloid and Interface Science*. 568, 155-164.
8. Zhao, W., Yan, X. (2022) Preparation of Thermochromic Microcapsules of Bisphenol A and Crystal Violet Lactone and Their Effect on Coating Properties // *Polymers*. 14, 1393.
9. Han, Y., Yan, X., Zhao, W. (2022) Effect of Thermochromic and Photochromic Microcapsules on the Surface Coating Properties for Metal Substrates // *Coatings*. 12, 1642.
10. Iqbal, A., Iqbal, G., Muhammad Naveed, U., Haroon R Sher Wali Kh. (2022) Synthesis of novel silica encapsulated spiropyran-based thermochromic materials // *Royal Society Open Science*. 9 (3).
11. León, G. (2018) Formaldehyde-free melamine microcapsules as core/shell delivery systems for encapsulation of volatile active ingredients // *RSC Advances*. 7, 18962-18975.
12. Kardar, P. (2015) Preparation of polyurethane microcapsules with different polyols component for encapsulation of isophorone diisocyanate healing agent // *Progress in Organic Coatings*. 89, 271-276.

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WOUND COATINGS AND THEIR ANTIMICROBIAL COMPONENTS

Abstract. This article provides examples of wound coatings for accelerated and safe regeneration of human tissues. Components acting as carriers for various wound coatings, as well as plants with antimicrobial activity, are presented. Components contained in plant extracts potentially attractive for inclusion in wound dressings are described. The deficiencies of five plant extracts were identified, and the antimicrobial performance of these extracts obtained on test cultures of six human pathogens was described.

Keywords: components, extracts, wound coatings, regeneration, antimicrobial activity.

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РАНЕВЫЕ ПОКРЫТИЯ И АНТИМИКРОБНЫЕ КОМПОНЕНТЫ В ИХ СОСТАВЕ

Аннотация. В статье приведены примеры раневых покрытий для ускоренной и безопасной регенерации тканей человека. Представлены компоненты, выступающие носителями для различных раневых покрытий, а также растения, обладающие антимикробной активностью. Приведены компоненты, содержащиеся в растительных экстрактах, потенциально привлекательных для включения в состав раневых покрытий. Выявлены недостатки пяти растительных экстрактов и отражены антимикробные показатели данных экстрактов, полученные на тестовых культурах шести возбудителей болезней человека.

Ключевые слова: компоненты, экстракты, раневые покрытия, регенерация, антимикробная активность.

The rate of healing of wounds of different natures is of great importance for practical medicine. Wound healing involves the following stages: inflammatory, proliferative, and skin remodeling.

The main types of wounds are conventionally considered to be acute and chronic wounds. The first type includes wounds in which healing occurs in stages according to a standardized pathway and with a predictable end to the recovery process. The second differs from the first in that the healing process does not follow a standardized path and can produce functional and anatomical altered structures upon completion [1].

To facilitate the healing of wounds of different genesis, a variety of wound coatings are now actively used.

Wound coatings currently play a key role in tissue regeneration by providing optimal protection from external factors and pathogens, creating optimal conditions within the system, and accelerating the healing of skin lesions.

Wound coatings are complex multi-component systems that include both synthetic and natural compounds. They may contain polymer matrices, gel-forming agents, metal nanoparticles, and natural antiseptics that promote accelerated healing and prevent wound surface infection [2].

Modern dressings are characterized by complex compositions that include biopolymers, antimicrobial components, and regenerative factors that promote quality tissue repair. The cosmetic results that can be achieved through physiological processes and the timing of tissue regeneration are becoming increasingly important in the development of wound coatings.

It is important to remember that in addition to the standard requirements for a wound dressing, there are a number of requirements, such as ease of application and removal, lack of toxicity to the human body, and, where appropriate, not interfering with wound drainage. According to these criteria, materials are divided into standard dressings, artificial coatings, and biomaterial-based (natural) coatings.

Materials of both artificial (derivatives of polyurethane, polyethylene glycol, Teflon, polycaprolactam, silicone, etc.) and natural origin can be used for wound coatings, which are selected depending on the type of wound. For example, artificial

polymers (films, foams, hydrogels, and hydrocolloids) used for vascular grafts, cartilage, superficial wound dressings, and scaffolds for internal organs have advantages such as elasticity, ease of manufacture and application, and biodegradability; these materials have disadvantages such as localized lowering of pH when dissolved and susceptibility to damage.

The most popular coatings are polymer coatings, which can be made from biological and synthetic materials. The most commonly used synthetic polymers for the production and manufacture of film-type wound coatings are polyurethane and its derivatives, polyethylene glycol, and polycaprolactam. The most common natural materials for polymeric wound coatings are hyaluronic acid and chitosan, which are used for hydrogel coatings, and cellulose, collagen, or gelatin, which are used for both hydrogel and hydrocolloid coatings. The ideal wound dressing is one that is as similar in structure and properties to human skin as possible. A major disadvantage of natural structural components for wound coatings is that they have little or no antimicrobial activity [3].

As a result, more attention is being paid to the inclusion of additional antimicrobial agents in the composition of dressings to reduce the risk of potential complications associated with infection.

There are three categories of antimicrobial substances: antiseptics, disinfectants, and chemotherapeutic agents. Depending on the purpose, all antimicrobial drugs are divided into three groups: antibiotics – affect bacteria; antifungal – effective against fungi; and antiprotozoal – act on protozoa. The most common antimicrobial agents are silver, copper, chlorhexidine, and various antibiotics. Natural antimicrobial substances such as honey and plant extracts with high biocompatibility and antiseptic properties are also being actively researched.

Innovative coatings with controlled-release antimicrobial agents that provide long-lasting protection without toxic effects on tissues are important in this context. The prospect of bioengineered materials that combine antimicrobial and healing properties is also being considered.

Infectious complications of wounds remain one of the key problems in modern medicine, especially in the context of increasing resistance of microorganisms to antibiotics. The development of effective wound dressings with antimicrobial properties is critical to improving the effectiveness of patient care. Modern dressings not only create optimal conditions for healing but also actively prevent the development of infection, making them indispensable in clinical practice.

This study examines wound dressings and the antimicrobial components included in their composition. The objects of the study were modern biomaterials used for wound coating, as well as active substances providing their antimicrobial action. Special attention is paid to natural ingredients that can have a complex effect on wound healing, including antibacterial, anti-inflammatory, and regenerative properties.

Plant extracts and their bioactive compounds, such as xanthenes (*Garcinia mangostana*), flavonoids (*Eupatorium cannabinum*), sesquiterpene lactones (*Eupatorium cannabinum*), hypericin and hyperforin (*Hypericum perforatum*), alkaloids (*Chelidonium majus*), and essential oils (*Melissa officinalis* L.), have been studied as antimicrobial components. These substances contribute to the prevention of

wound infection through various mechanisms: destruction of bacterial membranes, inhibition of enzyme systems of pathogens, and inhibition of protein and nucleic acid synthesis.

Mangosteen (*Garcinia mangostana*) is a tropical plant containing xanthones, which are powerful natural antioxidants. Xanthones have anti-inflammatory, anticonvulsant, anti-allergic, anti-tumor, and antiplatelet properties.

Hemp-agrimony (*Eupatorium cannabinum*) is a plant quite widespread in the Russian Federation, rich in flavonoids and sesquiterpene lactones. It has pronounced antiseptic activity, especially against Gram-positive bacteria such as *Streptococcus* and *Staphylococcus*. The advantage of this component lies in its ability to inhibit oxidative processes and reduce inflammation. It can be toxic in high doses, but its mechanism of action is still poorly understood [4].

Perforate St. John's wort (*Hypericum perforatum*) contains hyperforin and hypericin, a compound with pronounced antimicrobial and antiviral activity. Hypericin is activated by light, causing photodynamic inactivation of bacteria, while hyperforin inhibits the function of their membrane proteins. St. John's wort has pronounced antitumor, antiviral, antimicrobial, and styptic properties due to the flavonoids hyperforin and hypericin. These properties make St. John's wort a promising remedy for the treatment of infected wounds, but it can cause phototoxicity, which limits its use [5].

Greater celandine (*Chelidonium majus*) contains such alkaloids as chelidone and sanguinarine, which have powerful bactericidal and fungicidal action. They inhibit the synthesis of nucleic acids and proteins in microorganisms, leading to their death. Celandine is effective against various bacteria and fungi, including *S. aureus*, *E. coli*, *P. aeruginosa*, *B. subtilis*, and *P. vulgaris*. However, its high toxicity in large doses requires cautious use.

Lemon balm (*Melissa officinalis* L.) contains rosmarinic, caffeic, and chlorogenic acids that protect cells from the oxidative process. It also contains citral, geraniol, and linalool, which inhibit the growth of *S. aureus* and *E. coli*, thus exhibiting antimicrobial activity. Lemon balm contains terpenoids and flavonoids that promote tissue regeneration [6].

If we consider these plants as extracts that contain the main active substances xanthones, flavonoids, sesquiterpene lactones, hypericin and hyperforin, alkaloids, and essential oils, it is worth identifying the main properties of the extracts and the risks of their use as components of wound coatings; a comparison of characteristics is presented in Table 1.

Table 1 shows that mangosteen has the same antibacterial and antiviral effect as St. John's wort, but it does not grow on the territory of the Russian Federation, which complicates its use in the composition of wound dressings and makes it more expensive in comparison with other extracts presented in the table that grow on the territory of the country [7].

Table 1 – Comparative characterization of extracts with antimicrobial activity.

Plant extracts	Main properties	Disadvantages
<i>Garcinia mangostana</i>	Antibacterial, anti-inflammatory, antiviral.	Availability in Russia
<i>Eupatorium cannabinum</i>	Antiseptic, anti-inflammatory	Toxic in large doses
<i>Hypericum perforatum</i>	Antibacterial, hemostatic, antiviral	Phototoxic
<i>Chelidonium majus</i>	Bactericidal, fungicidal	Toxic in large doses
<i>Melissa officinalis</i> L.	Antimicrobial, antioxidant, anti-inflammatory	Thyroid disorders

Collection strains of microorganisms were used for the determination of antimicrobial activity by the disk diffusion method; the results obtained in the assays are presented in Table 2.

Table 2 – Comparison of antimicrobial activity of selected plant extracts

Plant extracts	<i>S. Aureus</i>	<i>E. coli</i>	<i>P. aeruginosa</i>	<i>C. albicans</i>	<i>P. vulgaris</i>	<i>E. faecalis</i>
<i>Garcinia mangostana</i>	+++	++	++	+	++	++
<i>Eupatorium cannabinum</i>	++	+	-	-	-	+
<i>Hypericum perforatum</i>	+++	+	-	++	-	+
<i>Chelidonium majus</i>	++	++	+	+++	++	++
<i>Melissa officinalis</i> L.	++	++	+	++	+	++

(+++)⁺ – high activity, (++) – moderate activity, (+) – weak activity, (-) – no activity detected.

When comparing the antimicrobial activity of plant extracts, it was found that hemp-agrimony has moderate activity against *S. aureus* and weak activity against *E. coli* and *E. faecalis*; no activity was detected against the other test strains; therefore, it has a narrow focus and can be included in the composition of wound coatings only in combination with other antimicrobial components as an agent against *S. aureus*. Extract of St. John's wort also showed no antimicrobial activity against cultures of microorganisms *P. aeruginosa* and *P. vulgaris* but showed high efficacy against *S. aureus* and moderate efficacy against *C. albicans*. St. John's wort extract and hemp-agrimony extract can be used as adjunct ingredients in wound coating formulations, but not as the primary ingredient due to a narrower spectrum of activity than mangosteen, celandine, and *Melissa officinalis*, which showed variable activity against all types of microorganisms tested. Celandine has pronounced activity against *C.*

albicans and medium activity against *S. aureus*, *E. coli*, *E. faecalis*, and *P. vulgaris*, while mangosteen has high suppressive ability against *S. aureus* and medium activity against *P. aeruginosa* compared to celandine, but weak activity against *C. albicans*. Lemon balm does not have a pronounced high antimicrobial activity but shows medium activity to 4 out of 6 cultures tested, with weak activity against the rest [8].

The comparative analysis showed that the most suitable plants for further research on the development of wound coatings as components are mangosteen, celandine, and lemon balm. Due to the broad-spectrum antimicrobial activity, however, it is worthwhile to conduct more research on the antimicrobial activity of the pure components of each plant, such as xanthenes (mangosteen), flavonoids (hemp-agrimony), sesquiterpene lactones (hemp-agrimony), hypericin and hyperforin (St. John's wort), alkaloids (celandine), and essential oils (lemon balm), rather than extracts containing a complex of additional substances. In this regard, further studies will be aimed at selecting optimal conditions for purification and separation of components for each extract and testing them in pure form for antimicrobial activity.

Список литературы:

1. Кудряшова, И. С. Разработка раневых покрытий для регенеративной медицины / И. С. Кудряшова, П. А. Марков, Е. Ю. Костромина, П. С. Еремин [и др.]. – Текст : электронный // Вестник восстановительной медицины – 2021. – Том 20, № 6. – URL: <https://doi.org/10.38025/2078-1962-2021-20-6-84-95> (дата обращения: 10.04.2025).
2. Куринова, М. А. Современные раневые покрытия / М. А. Куринова, Л. С. Гальбрайт, Д. Э. Скибина. – Текст : электронный // Современная медицина: актуальные вопросы – 2015. – № 10-11 (43). – URL: <https://cyberleninka.ru/article/n/sovremennyye-ranevye-pokrytiya-obzor> (дата обращения: 10.04.2025).
3. Каштанов, А. Д. Обзор современных материалов, применяемых для покрытия раневых поверхностей / А. Д. Каштанов, Ю. Л. Васильев, А. В. Байрашевская. – Текст : электронный // Оперативная хирургия и клиническая анатомия – 2020. – № 4 (2). – С. 49-56. – URL: <https://doi.org/10.17116/operhirurg2020402149> (дата обращения: 10.04.2025).
4. Береговых, Г. В. Исследование флавоноидов травы *Eupatorium Cannabinum* L. / Г. В. Береговых, С. В. Денисова, И. М. Баркин, Е. А. Мазур. – Текст : электронный // Фармацевтическая ботаника: современность и перспективы – Самара, 2019. – С. 71-75. – URL: <https://www.elibrary.ru/item.asp?id=42940538> (дата обращения: 08.04.2025).
5. Постраш, И. Ю. Трава зверобоя продырявленного: химический состав, свойства, применение / И. Ю. Постраш. – Текст : электронный // Вестник АПК Верхневолжья – Ярославль, – 2021. – № 1 (53). – С. 57-63. – URL: <https://www.elibrary.ru/item.asp?id=46173672> (дата обращения: 08.04.2025).
6. Гребенникова, О. А. Биологически активные вещества Melissa лекарственной / О. А. Гребенникова, А. Е. Палий, Л. А. Логвиненко. – Текст : электронный // Ученые записки Таврического национального университета им. В. И. Вернадского – Крым, 2013. – Том 26 (65), № 1. – С. 43-50. –

URL: <https://cyberleninka.ru/article/n/biologicheski-aktivnye-veschestva-melissy-lekarstvennoy> (дата обращения: 08.04.2025).

7. Кармалиев, Р. С. Оценка антимикробных свойств лекарственных растений для разработки комплексного растительного препарата / Р. С. Кармалиев, Ф. Х. Нуржанова, Б. О. Ертлеуова, Б. М. Сидихов. – Текст : электронный // Ғылым және білім – 2024. – Том 1, № 1 (74). – URL: <https://ojs.wkau.kz/index.php/gbj/article/view/1882> (дата обращения: 08.04.2025).

8. Фролова, А. В. Сравнительный анализ антимикробной активности лекарственных растений / А. В. Фролова, А. Н. Косинец, Г. Н. Бузук. – Текст : электронный // Вестник фармации. – 2006. – № 4 (34). – URL: <https://cyberleninka.ru/article/n/sravnitelnyy-analiz-antimikrobnoy-aktivnosti-lekarstvennyh-rasteniy> (дата обращения: 08.04.2025).

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THE PROBLEM OF IRON DEFICIENCY IN THE POPULATION'S DIET AND AGRONOMIC WAYS TO SOLVE IT

Abstract. The problem of iron deficiency in the diet of the population is a global problem and has been called "hidden hunger". If there is a lack of this element in the daily diet, the likelihood of many serious diseases increases. The article discusses the methods of biofortification of plants. Agronomic bio-enrichment of plants with iron during their cultivation is an inexpensive and effective way to significantly increase the concentration of this element in products. It is necessary to take into account the biological characteristics of plant species and varieties, the shape, concentration and method of iron application.

Keywords: iron deficiency, diet, biofortification of plants.

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ПРОБЛЕМА ДЕФИЦИТА ЖЕЛЕЗА В РАЦИОНЕ ПИТАНИЯ НАСЕЛЕНИЯ И АГРОНОМИЧЕСКИЕ ПУТИ ЕЕ РЕШЕНИЯ

Аннотация. Проблема дефицита железа в питании населения является общемировой проблемой и получила название «скрытого голода». При недостатке этого элемента в ежедневном рационе увеличивается вероятность множества тяжелых заболеваний. В статье рассматриваются способы биофортификации растений. Агрономическое биообогащение растений железом во время их выращивания является недорогим и эффективным способом, позволяющим существенно увеличить концентрацию этого элемента в продукции. При этом необходимо учитывать биологические особенности видов и сортов растений, форму, концентрацию и способ внесения железа.

Ключевые слова: дефицит азота, питание, биофортификация растений.

Micronutrient deficiency, also known as “hidden hunger”, is a condition in which the body lacks essential vitamins and minerals, which are required in small amounts for proper growth, development, and overall health. More than 2 billion people worldwide suffer from micronutrient deficiencies, which negatively affect their health and socio-economic status.

Deficiency of iron (Fe), zinc (Zn), iodine (I) and selenium (Se) in humans is a serious nutritional problem worldwide. Iron, zinc, iodine, and selenium deficiencies are the most common, accounting for about 60 % of cases of iron deficiency, 30 % of cases of zinc and iodine deficiency, and 15 % of cases of selenium deficiency [1].

Bio-enrichment is a sustainable strategy designed to eliminate micronutrient deficiencies by increasing the levels of essential vitamins and minerals in staple crops that are widely consumed by humans [2, 3].

There are a number of agricultural methods of bio-enrichment:

- breeding crops with a higher content of certain nutrients;
- an agronomic approach using fertilizers and other means to increase the digestibility of nutrients by agricultural crops;
- a transgenic approach.

Each of them has its pros and cons.

For example, traditional breeding can be a slow and time-consuming process, and it can take many years to produce a variety with a high nutrient content.

Agronomic bio-enrichment is the process of increasing the nutritional value of crops using fertilizers. This is an effective and timely solution, which is the fastest and most affordable way to produce high-nutrient products, although it provides only a short-term result (Figure).

The concentration of trace elements in a plant depends on the type and form of the fertilizer used, the method and rate of its application, the phase of plant development and the nature of the movement of nutrients inside the plant. Due to differences in the mobility of minerals, their accumulation in different plant species and soil composition in a particular geographical region where a particular crop is grown, the success of agronomic bio-enrichment varies greatly [4]. The effectiveness of this method has increased with the advent of specialized fertilizers with higher

nutrient absorption and better transfer of nutrients to the consumed parts of crops. These include water-soluble fertilizers, chelated fertilizers, and nano fertilizers. Due to the significant increase in the surface area and the small size of fertilizer nanoparticles, plants can easily absorb them [5, 6].

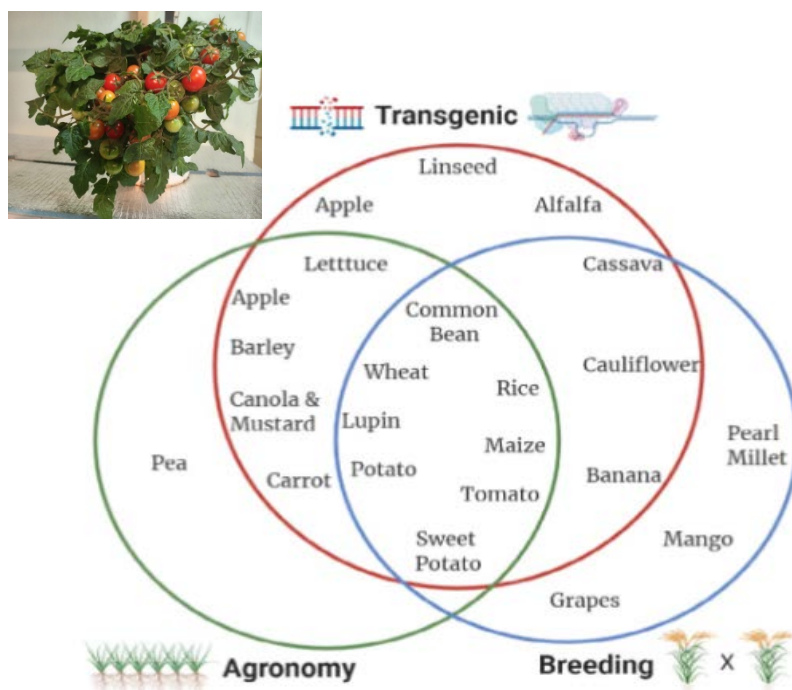


Figure – Crops in which different biofortification approaches were applied

Leaf treatments with solutions, seed hydro-priming, and hydroponics are also used as methods of agronomic biofortification.

Iron is a vital nutrient for humans, it is necessary for the normal functioning of the body, but it is not produced by the body and must be supplied with food. It is necessary for the production of red blood cells and the transport of oxygen in the human body, it also supports the immune system, provides processes with energy and supports the health of skin, hair and nails. It is especially important for pregnant women, infants, and young children, as they have higher iron requirements. Anemia, fatigue, and a weakened immune system are just some of the health problems that iron deficiency can cause, especially in countries where plant-based foods are the main source of iron.

The recommended daily intake of Fe for humans is between 8 and 18 mg per day, depending on age and gender, and about 30 mg per day for pregnant women. However, a large number of people in the world do not have the opportunity to enrich their diets enough to ensure this recommended intake.

Comparing vegans with meat eaters, the former should consume 1,8 times more iron from the recommended daily allowance (RDA) than the latter. Despite the sufficient iron content in the soil, most of it is not available for assimilation by plant roots due to its low solubility. Therefore, biofortification can be an effective way to enrich plants with iron. Active research in this area is underway all over the world and some progress has already been achieved. It has been found that bio-enrichment with iron of the main food crops (beans, cassava, corn, chumiz, rice, sweet potatoes and

wheat) can increase the level of iron (serum ferritin concentration and total iron content in the body), zinc and carotenoids. This is a promising and economically beneficial way for at-risk populations that can reach the majority of the population, regardless of their place of residence and social status. Bio-enriched millet increased iron levels in Indian schoolchildren, eliminating iron deficiency, and bio-enriched beans increased iron levels in women in Rwanda. However, the focus of nutrient fortification is currently on staple crops such as rice, wheat, and corn, but there is potential for nutrient fortification of other crops such as fruits, vegetables, and legumes.

Currently, more than 20 million people worldwide include bio-enriched food crops in their diets, and the popularity of such products is increasing [7]. According to expert estimates, the global biofortification market was estimated at 117,6 million US dollars in 2023 and is projected to reach 220,92 million US dollars by 2031, with an average annual growth rate of 8.2 % in the forecast period from 2024 to 2031.

Thus, bio-enrichment of plants with iron can be an inexpensive, economically affordable way to eliminate the problem of deficiency of this element in the diet of various population groups, however, continued scientific research is required to find the most effective ways to solve the problem.

Список литературы:

1. Yang Q. et al. (2016) Biofortification of rice with the essential amino acid lysine: molecular characterization, nutritional evaluation, and field performance // *Journal of experimental botany*. 67 (14), 4285-4296.
2. Pérez-Massot E. et al. (2013) The contribution of transgenic plants to better health through improved nutrition: opportunities and constraints // *Genes & nutrition*. 2013 (8), 29-41.
3. Jahan, T. A., & Tar'an, B. (2023). Agronomic approach to iron biofortification in chickpea // *Agronomy*, 13(12), 2894.
4. Ismail, A. M. et al. (2007) Genetic and genomic approaches to develop rice germplasm for problem soils // *Plant molecular biology*. 65, 547-570.
5. Волкова, Е. Н. Фолиарное биообогащение железом редиса с использованием органической и неорганической форм в условиях светокультуры / Е. Н. Волкова, М. В. Спиридонова, О. А. Шилова [и др.]. – Текст: непосредственный // *Journal of Agriculture and Environment*. – 2023. – № 12(40).
6. Спиридонова, М. В. Биообогащение железом растений с использованием водных суспензий магнетита и маггемита / М. В. Спиридонова, Е. Н. Волкова, О. А. Шилова [и др.]. – Текст : непосредственный // *Химия для биологии, медицины, экологии и сельского хозяйства: сборник тезисов докладов Третьего международного симпозиума, Санкт-Петербург, 05–07 июня 2024 года*. – Санкт-Петербург: ООО «Издательство "ЛЕМА"», 2024. – С. 213-214.
7. Bouis H.E., Saltzman A. (2003) Improving nutrition through biofortification: a review of evidence from HarvestPlus, 2003 through 2016 // *Global food security* (12), 49-58.

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PROPERTIES AND APPLICATIONS OF AZAMACROCYCLIC COMPOUNDS

Abstract. Azamacrocycles are potential agents in the field of biomedicine and organic chemistry. Due to their unique structure, similar to natural biologically active substances, they have found application in the field of coordination and organometallic chemistry, where they are used as ligands for the formation of complexes. In addition, azamacrocycles are used as active substances in pharmacology, as they are capable of exhibiting antibacterial, antifungal, antitumor, and antiviral activity.

Keywords: macrocycles, azamacrocyclic compounds.

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СВОЙСТВА И ПРИМЕНЕНИЕ АЗАМАКРОЦИКЛИЧЕСКИХ СОЕДИНЕНИЙ

Аннотация. Азамacroциклы являются потенциальными агентами в области биомедицины и органической химии. Благодаря своему уникальному строению, аналогичному природным биологически активным веществам, они нашли применение в сфере координационной и металлорганической химии, где используются в качестве лигандов для образования комплексов. Кроме того, азамacroциклы используются в качестве активных веществ в фармакологии, так как способны проявлять антибактериальную, антифунгицидную,

противоопухолевую, противовирусную активности.

Ключевые слова: макроциклы, азамacroциклические соединения.

Macrocyclic compounds are compounds that contain a cyclic fragment consisting of nine or more atoms, of which at least three act as donors. Donor atoms can be nitrogen, oxygen, sulfur, phosphorus, etc.

The interest in studying azamacrocyclic compounds is due to their distribution in nature, where they perform vital functions. For example, hemoglobin (the precursor of which is heme **1**), chlorophyll, vitamin B12 **2**, telomestatin **3** (Figure 1) [1-2]. The most common in nature, and therefore more studied, are nitrogen-containing macrocycles which are therefore called azamacrocyclic compounds.

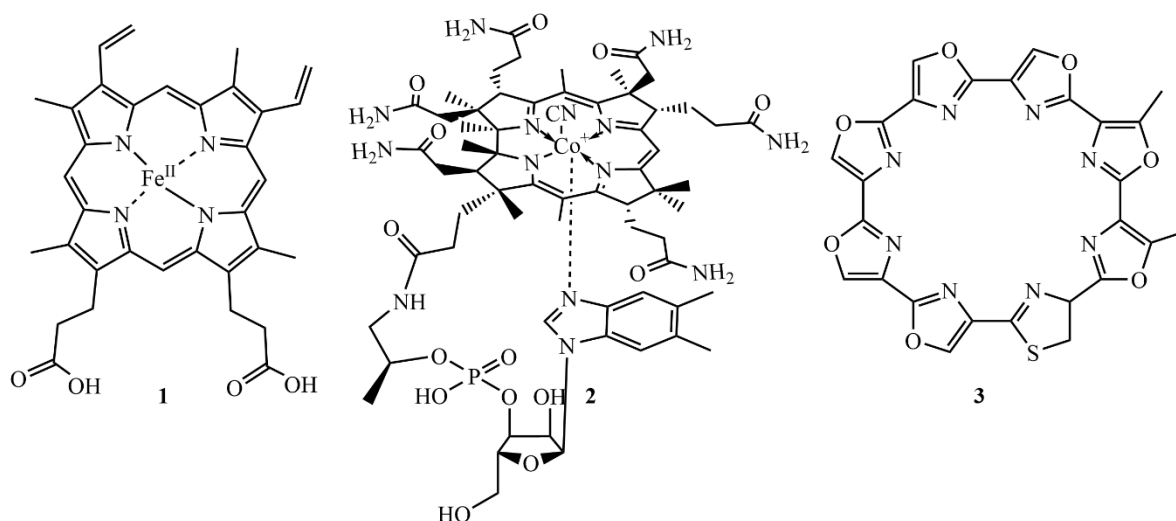


Figure 1 – Natural azamacrocyclic compounds

Synthetic derivatives of azamacrocycles have a wide range of practical applications. Thus, among them, substances with various types of biological activity have been found. For example, antifungal **4**, antiparasitic **5** and antibacterial (Figure 2) [3].

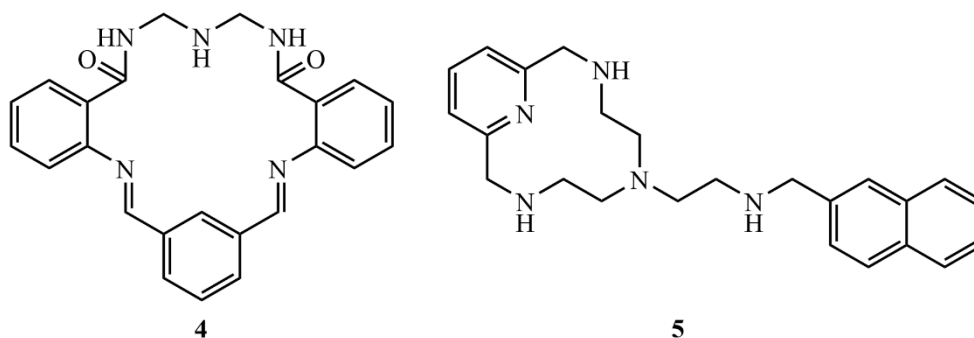


Figure 2 – Synthetic azamacrocyclic compounds

A special place among them is occupied by C- and N-derivatives of azamacrocyclic compounds. For example, the drug Plerixafor **6**, obtained by the alkylation reaction of cyclam, is used as an anticancer agent [4].

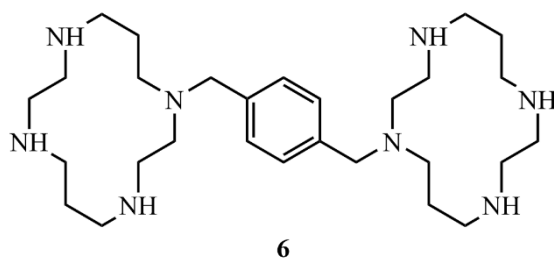


Figure 3 – The drug Plerixafor

It is worth noting that azamacrocycles have a cavity, which is a closed region with reduced electron density, limited by donor atoms of the macrocycle. The cavity size is determined based on X-ray structural analysis data or by performing quantum-chemical calculations and comparing the electron density. Due to the presence of this region and various heteroatoms, azamacrocycles can act as a “host” for binding metal “guests”. Due to this, azamacrocycles have found application as optical-chemical sensors **7** using the MRI method [5].

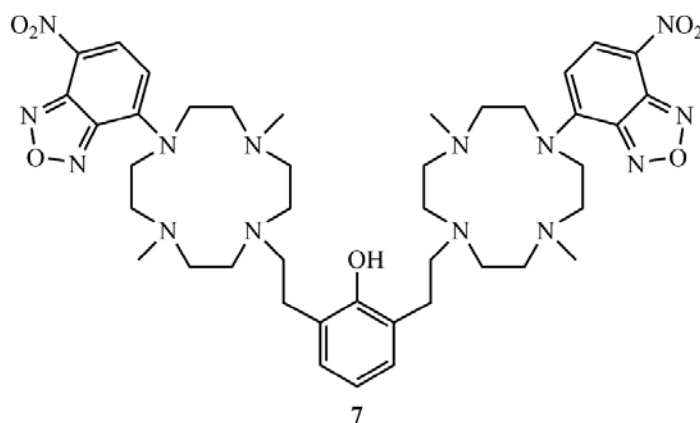


Figure 4 – Azaacrocyclic structure of a chemosensor **7**

The first representative of azamacrocyclic compounds, cyclam **8**, was obtained in 1936 by Van Alphen, later in the 1960s Curtis synthesized 14-membered azamacrocyclic compounds in the form of metal complexes **9**. However, free azamacrocycles, analogs of compounds **9**, remained unknown. They were first obtained at our department in 2013 by the interaction of acetone with the corresponding amines. In this way, free 14,16,18,22-membered azamacrocycles **10-13** were synthesized (Figure 6) [6].

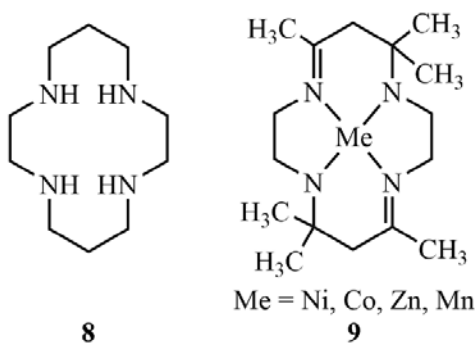


Figure 5 – Cyclam and Curtis metal complexes

Despite the fact that 14-membered azamacrocyclic compounds were discovered at the beginning of the last century, their chemical properties have been practically not studied. In the literature there are only scattered data on some reactions involving close structural analogues of 14-membered azamacrocycles (saturated representative of cyclam and substituted metal complexes). Among the obtained free azamacrocycles, the compound **10** one is the most accessible and stable compound.

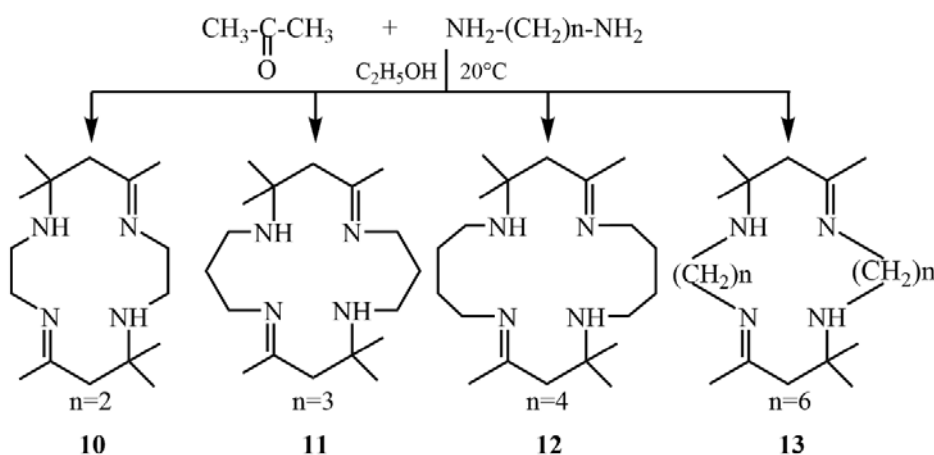


Figure 6 – General method for the preparation of 14,16,18,22-membered azamacrocycles

Thus, the 14-membered azamacrocyclic compound can be considered a promising little-studied compound, and the presence of three reaction centers in its composition makes it a convenient precursor for obtaining practically significant compounds.

Список литературы:

1. Яцимирский, К. Б. Синтез макроциклических соединений / К. Б. Яцимирский, В. В. Павлищук, Г. Г. Таланова. – Киев : Изд-во «Наук. Думка», 1987. – 280 с. – Текст : непосредственный.
2. Shin-ya, K., Wierzba, K., Matsuo, K., Ohtani, T., Yamada, Y., Furihata, K., Hayakawa, Y., Seto, H. (2001) Telomestatin, a Novel Telomerase Inhibitor from *Streptomyces anulatus* // J. Am.Chem. Soc. 123 (6), 1262-1263.
3. Gull, P., Hashmi, A. A. (2015) Biological Activity Studies on Metal Complexes of Macrocyclic Schiff Base Ligand: Synthesis and Spectroscopic Characterization // J. Braz. Chem. Soc. 26 (7), 1331-1337.
4. Ратманова, Н. К. Методы синтеза иммуностимулирующего препарата плериксафор / Н. К. Ратманова, И. А. Андреев, И. В. Трушков. – Текст : непосредственный // Химия гетероцикл. соединений. – 2020. – Том 56, № 4. – С. 30-35.
5. Amatori, S., Ambrosi, G., Borgogelli, E., Fanelli, M., Formica, M., Fusi, V., Giorgi, L., Macedi, E., Micheloni, M., Paoli, P., Rossi, P., Tassoni, A. (2014) Modulating the Sensor Response to Halide Using NBD-Based Azamacrocycles // Inorg. Chem. 53 (9), 4560-4569.
6. Anisimova, N. A., Khristoforova, E. I., Trishin, Yu. G. (2015) Cyclocondensation of Ethylenediamine with Acetone and Methyl Ethyl Ketone as a Synthetic Route to 14-Membered Azamacrocyclic // Rus. J. Gen. Chem. 85 (9), 1499-1505.

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THE IMPORTANCE OF ANTIHYPERTENSIVE DRUGS FOR THE PREVENTION AND TREATMENT OF CARDIOVASCULAR DISEASES

Abstract. The article explains the concept of arterial hypertension, the causes of occurrence, as well as the prevalence of arterial hypertension in the Russian Federation among various groups of patients. It also considers the medicinal methods of use for the treatment of this disease.

Keywords: arterial hypertension, drug treatment of cardiovascular diseases, cardiovascular diseases.

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ЗНАЧЕНИЕ АНТИГИПЕРТЕНЗИВНЫХ ПРЕПАРАТОВ ДЛЯ ПРОФИЛАКТИКИ И ЛЕЧЕНИЯ СЕРДЕЧНО-СОСУДИСТЫХ ЗАБОЛЕВАНИЙ

Аннотация. В статье раскрывается понятие артериальной гипертензии и причины ее возникновения, а также обстоятельства распространения артериальной гипертензии в Российской Федерации среди различных групп пациентов. Рассматриваются лекарственные методы, применяемые для лечения этого заболевания.

Ключевые слова: артериальная гипертензия, медикаментозное лечение сердечно-сосудистых заболеваний, сердечно-сосудистые заболевания.

Arterial hypertension is a chronic disease characterized by a steady increase in blood pressure. This condition is a key factor that increases the likelihood of developing diseases of the cardiovascular system, including stroke, myocardial infarction, cardiac insufficiency and other life-threatening pathologies.

In the context of the increasing incidence of hypertension and its severe consequences, the segment of antihypertensive drugs is one of the most active sections in the pharmaceutical industry. There is a constant appearance of new drugs with improved pharmacological characteristics, expansion, as well as the development of

new dosage forms, in particular, generics.

To make such a diagnosis, it is necessary that the systolic pressure exceeds 140 mmHg, and the diastolic pressure is 90 mmHg or higher. This state is recorded during multiple measurements, at different times of the day and under different conditions (rest, physical activity, awakening). Arterial hypertension is also called hypertension or hypertension disease. The term “hypertension” was introduced by the Soviet scientist G. F. Lang in 1948 [1].

Hypertension is one of the most common forms of arterial hypertension. According to statistics, approximately 30 % of the adult population suffers from it, while the likelihood of developing the pathology increases with age. With a rapid and significant increase in blood pressure, an attack called a “hypertensive crisis” may occur. This is a dangerous condition that requires immediate medical attention, such as intravenous therapy.

The cause of the disease has not yet been identified, but there are a number of factors that are associated with increased blood pressure:

- 1) Obesity and overweight;
- 2) Age-related changes – over time, people often experience an increase in blood pressure, especially systolic;
- 3) Excessive salt intake;
- 4) Hereditary predisposition – the risk of hypertension doubles if one or both parents had high blood pressure;
- 5) Alcohol abuse;
- 6) Regular emotional stress;
- 7) Low-activity lifestyle;
- 8) Hormonal imbalance (for example, it is common in women during pregnancy or menopause).

The prevalence of arterial hypertension in the Russian Federation among men is 39.2 %, and among women – 41.1 %. At the same time, 58 % of women and 37.1 % of men know about their illness. 45.7 % of women and 21.6 % of men receive medical treatment. The effectiveness of therapy was noted only in 17.5 % of women and 5.7 % of men [2].

With the age of patients, the incidence of arterial hypertension progresses. In Russia, elevated blood pressure is diagnosed in approximately 80 % of people over 65 years of age. Globally, this figure reaches 60 %. In the United States of America, approximately 65 million people suffer from arterial hypertension, while only 79 % of them are informed about their condition. 59 % of patients undergo treatment.

The presence of a family history of hypertension is found in 20-40 % of patients [3]. There is a significant concordance in blood pressure levels among identical twins. The risk of arterial hypertension increases in women during pregnancy and menopause, as well as in patients with sleep apnea and diabetes mellitus. For example, the risk of arterial hypertension over the next 3-8 years increases in patients with a glycemic level of 10-13 mmol/l at the 90th minute of the test. In patients with type I diabetes, arterial hypertension is diagnosed in 5 % of cases with diabetes duration up to 10 years and in 70 % with disease duration over 40 years.

Like most chronic diseases, hypertension requires lifelong treatment. In order to

control blood pressure and avoid the development of dangerous complications such as myocardial infarction or stroke, it is necessary not only to follow all recommendations on nutrition, physical activity and lifestyle, but also to regularly take antihypertensive medications prescribed by a doctor.

Optimal treatment of arterial hypertension implies a smooth decrease in blood pressure and stable maintenance of blood pressure at the target level, patient compliance, regression of target organ damage, an increase in life expectancy and an improvement in its quality.

For patients who have no specific indications, the main classes of hypotensive agents will be ACE inhibitors or ARBs, dihydropyridine AK.

Angiotensin converting enzyme inhibitors block the process of formation of the hormone angiotensin, responsible for the narrowing of blood vessels and arterial walls. As a result of a decrease in the production of this hormone, the vessels, on the contrary, relax and expand, which leads to a decrease in blood pressure.

Diuretics promote kidney function by removing excess sodium from the body. When sodium leaves the body, excess fluid in the bloodstream is also removed in the urine, which leads to a decrease in blood pressure.

Alpha-2 adrenoreceptor agonists affect nerve signals that stimulate blood vessel constriction. As a result, the vessels relax, which leads to a decrease in blood pressure.

Calcium channel blockers prevent calcium from entering the muscle cells of the heart muscle and the walls of blood vessels. As a result, the vessels relax, which leads to a decrease in blood pressure.

Each drug from a separate class is selected individually.

When selecting medications from the same group, it is better to choose those that last a long time – they provide a steady reduction in blood pressure throughout the day. This is extremely important: drugs with a short effect cause “fluctuations” in blood concentration between doses. Such jumps provoke activation of the nervous and hormonal systems, and this, in turn, increases the risk of heart attacks, strokes, and other heart and vascular problems.

To assess how long a medicine has been working, doctors use the “dip/peak” indicator. It shows how much the effect of the drug weakens 24 hours after ingestion compared to its maximum strength. Ideally, if this difference is minimal: after a day, at least half of the initial hypotensive effect should remain.

Non-drug treatment of hypertension can also be used.

Drug-free methods are not just an addition to therapy, but the basis for combating high blood pressure. They help not only to lower blood pressure, but also to reduce dependence on pills, enhance their effect, and most importantly, to prevent the development of hypertension and related problems (for example, strokes or heart disease). And this is not a temporary measure: such approaches are useful even for those who are already taking medications, regardless of the stage of the disease [4].

Lifestyle changes work at all levels: they support the effects of medications, slow down the progression of the disease, and reduce risks, even if the pressure is still low. Therefore, doctors insist that these recommendations should become a part of the life of every patient with hypertension.

Quitting cigarettes is perhaps the most powerful solution to protect not only

blood vessels and the heart, but also the entire body from diseases. Even if it seems that the damage has already been done, stopping now reduces the risks significantly.

Extra pounds are like a load on blood vessels: they directly raise blood pressure and provoke a chain reaction – diabetes, high cholesterol, heart disease. If you lose even 5-10 % of your weight, you will see how the numbers on the blood pressure monitor will become lower [5]. And if you combine this with walking and avoiding salty and strong drinks, the effect will double.

Salt, alcohol, and fatty foods are the main “enemies” of hypertension. Reducing their consumption helps to increase the effectiveness of antihypertensive therapy.

In terms of increasing the level of physical activity, it is useful to engage in moderate-intensity aerobic exercises. For example, vigorous walks or swimming, lasting 30-40 minutes, three to four times a week, are suitable. More intensive training may be of less benefit in terms of lowering blood pressure. Isometric exercises, including weight lifting, can provoke blood pressure spikes.

Summing up, we can say that antihypertensive drugs play a key role in reducing cardiovascular risks, providing effective management of hypertension. Their use significantly improves the prognosis for patients suffering from high blood pressure by preventing the development of dangerous complications such as myocardial infarction, stroke and heart failure.

It is important to note that the effectiveness of antihypertensive therapy largely depends on patients' adherence to treatment and compliance with recommendations for lifestyle changes. Doctors should individually approach the choice of drugs, taking into account the concomitant diseases and the characteristics of each patient

Список литературы:

1. Рекомендации ESH и ESC по лечению артериальной гипертензии. Рабочая группа по лечению артериальной гипертензии Европейского общества гипертензии (ESH) и Европейского общества кардиологов. – Текст : электронный // Российский кардиологический журнал. – № 1 (105). – 2014 – С. 7-94. – URL: <http://www.scardio.ru/content/Guidelines/ESChypertension2013.pdf> (дата обращения: 29.03.2025).
2. Клинические рекомендации. Артериальная гипертензия у взрослых. РКО. 2020. – URL: https://scardio.ru/content/Guidelines/Clinic_rek_AG_2020.pdf (дата обращения 31.03.2025). – Текст : электронный.
3. Российское медицинское общество по артериальной гипертензии. Всероссийское научное общество кардиологов. Диагностика и лечение артериальной гипертензии. Российские рекомендации (4-й пересмотр) // Системные гипертензии. – 2010. – № 3. – С. 5–26. – Текст : непосредственный.
4. Артериальные гипертензии : лит. на рус. яз. по библиогр. источникам 1990-1995 гг. / сост. Е. А. Аверьянова ; ред. О. Н. Гурбанова ; РНБ, Информ.-библиогр. отдел. – СПб., 1999. – 42 с. – Текст: непосредственный.
5. Профилактика сердечно-сосудистых заболеваний в клинической практике // Российский кардиологический журнал. – 2012. – № 4 (96). – Приложение, 84 с. – Текст: непосредственный.

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INVESTIGATION OF THE RUSSIAN MARKET OF IL-6 INHIBITORS FOR THE TREATMENT OF RHEUMATOID ARTHRITIS AND EVALUATION OF ITS DEVELOPMENT PROSPECTS

Abstract. Rheumatoid arthritis (RA) is a chronic autoimmune disease characterized by inflammation and joint destruction. Anti-inflammatory drugs are the mainstay of therapy, but their effectiveness is limited, prompting the search for more efficient treatments. Interleukin-6 (IL-6) inhibitors provide targeted action on inflammation, reducing joint damage and improving patients' quality of life. The IL-6 inhibitor market in Russia is expanding, including both original drugs and biosimilar forms. Increased availability of these medications is expected, contributing to improved RA treatment and reducing the financial burden on the healthcare system. Further development of domestic production and support from government programs will ensure wider access to therapy for patients, leading to better clinical outcomes.

Keywords: rheumatoid arthritis, interleukin-6, IL-6 inhibitors, biological therapy, pharmaceutical market, forecast.

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ИССЛЕДОВАНИЕ РОССИЙСКОГО РЫНКА ПРЕПАРАТОВ ИНГИБИТОРОВ ИЛ-6 ДЛЯ ЛЕЧЕНИЯ РЕВМАТОИДНОГО АРТРИТА И ОЦЕНКА ПЕРСПЕКТИВ ЕГО РАЗВИТИЯ

Аннотация. Ревматоидный артрит (РА) – хроническое аутоиммунное заболевание, характеризующееся воспалением и разрушением суставов. Основной терапией являются противовоспалительные препараты, но их эффективность ограничена, что приводит к поиску более эффективных средств. Ингибиторы интерлейкина-6 (ИЛ-6) оказывают целенаправленное воздействие на воспаление, уменьшая разрушение суставов и улучшая качество жизни пациентов. В России рынок ингибиторов ИЛ-6 развивается, включая как оригинальные препараты, так и биоаналоговые формы. Прогнозируется рост доступности этих препаратов, что будет способствовать улучшению лечения ревматоидного артрита и снижению финансовой нагрузки на здравоохранение.

Дальнейшее развитие отечественного производства и поддержка государственных программ обеспечат доступность терапии для пациентов, улучшив клинические исходы и повысив качество жизни людей с ревматоидным артритом.

Ключевые слова: ревматоидный артрит, интерлейкин-6, ингибиторы ИЛ-6, биологическая терапия, фармацевтический рынок, прогноз.

Rheumatoid arthritis (RA) is a chronic autoimmune disease [1] in which the body's immune system mistakenly attacks its own tissues, primarily the joints. This condition is characterized by prolonged joint inflammation, which over time leads to joint destruction, deformity, and reduced functional activity. Without appropriate treatment, rheumatoid arthritis can result in disability and a significant decline in a person's quality of life.

One of the key factors sustaining inflammation in RA is cytokines – molecules that regulate immune responses and inflammation. Among these cytokines, interleukin-6 (IL-6) plays a crucial role in the development of inflammation and the destruction of joint tissues. IL-6 activates various immune cells, stimulates the production of other inflammatory molecules, and contributes to joint tissue degradation.

IL-6 inhibitors are a crucial element in the treatment of rheumatoid arthritis (RA), especially when conventional disease-modifying anti-rheumatic drugs (DMARDs) are ineffective [2]. These drugs block the action of interleukin-6 (IL-6), thereby reducing inflammation and preventing further joint destruction. Medications such as tocilizumab, sarilumab, olokizumab, and levilimab are essential components of RA therapy, particularly when traditional anti-inflammatory treatments fail. These drugs help reduce pain symptoms, improve patients' condition, and enhance their quality of life.

The treatment of rheumatoid arthritis aims to reduce inflammation, improve the quality of life for patients, and prevent joint destruction. Currently, the main treatment methods include nonsteroidal anti-inflammatory drugs (NSAIDs), glucocorticoids, analgesics, and disease-modifying anti-rheumatic drugs (DMARDs). However, the effectiveness of these medications is limited, and side effects, such as gastrointestinal disorders and increased infection risk, require the search for new and safer therapeutic approaches. In recent years, biological drugs, particularly interleukin-6 (IL-6) inhibitors, have received special attention for their more targeted action and significantly improved treatment efficacy.

IL-6 inhibitors are a class of biological drugs designed to block the action of interleukin-6, one of the key cytokines that plays an important role in inflammation in rheumatoid arthritis (RA). IL-6 promotes the activation of immune cells and the destruction of joint tissues, which leads to disease progression. One of the most well-known drugs in this group is tocilizumab, which was the first to be introduced into practice and approved for the treatment of RA, as well as other autoimmune diseases [3].

IL-6 inhibitors, due to their targeted action, block inflammatory processes and significantly reduce joint destruction, improving patients' condition.

IL-6 inhibitors block the IL-6 receptor, preventing its activation and suppressing inflammation. This results in reduced disease symptoms, improved joint condition, and slowed disease progression. This approach helps to alleviate pain, improve joint mobility, and prevent further damage. In the Russian market, IL-6 inhibitors have already established themselves as effective treatments for RA [4].

Despite their high cost, IL-6 inhibitors are increasingly gaining a significant share in the treatment of RA in the Russian market. These drugs are successfully used for patients who do not respond positively to traditional treatments.

In recent decades, medicine has made significant progress in the development of new treatment methods for RA, among which IL-6 inhibitors hold an important place. These drugs have high therapeutic potential, significantly improving the prognosis for patients with RA.

Leading international pharmaceutical companies and domestic manufacturers are actively offering medications, which creates competition and stimulates the improvement of treatment accessibility. The Russian market features both original domestic drugs and biosimilars from foreign pharmaceutical companies. For instance, Tocilizumab (Actemra®) by the Swiss pharmaceutical company Roche is available in the Russian Federation, as well as its first Russian biosimilar, Complatrate by the pharmaceutical company Generium, and Sarilumab (Kevzara®) by the French pharmaceutical company, with no analogs of this drug available in Russia. Levilimab (Ilsira®) is an original drug by the Russian biotechnology company BIOCAD, while Olokizumab (Arthlegia®) is a new original drug from the Russian pharmaceutical company R-Pharm.

It is forecasted that in the next 10 years, the Russian market for IL-6 inhibitors will continue to develop, driven by the growing number of rheumatoid arthritis (RA) patients, improvements in diagnostics, and expanding indications for the use of biological drugs. In the future, new domestic innovative drugs with enhanced effectiveness and safety are expected to emerge, further increasing the treatment options for RA [5].

The Russian RA treatment market is developing rapidly. Biological drugs, including IL-6 inhibitors, account for a significant share of the pharmaceutical market. According to 2023 data, the sales volume of RA treatment medications reached several billion rubles, with projected growth in the coming years [6].

The market for IL-6 inhibitors is expected to continue growing due to the increasing number of patients, the introduction of new biological drugs, and advancements in diagnostic methods.

Government policy in the healthcare sector plays a significant role in market development. In recent years, there has been an increase in funding for RA treatment programs, which contributes to greater accessibility of medications. Stimulating domestic production and developing new drugs can reduce dependence on imported goods and improve treatment accessibility for a broader range of patients [7].

The Russian IL-6 inhibitor market has significant potential for further growth and development. Increased government support, local production development, and the introduction of new therapeutic solutions contribute to improved accessibility to effective treatment for RA patients. One of the key factors determining the positive

prospects of the market is the growing awareness of biological drugs and improvements in diagnostic methods, which lead to timely initiation of treatment and better therapeutic outcomes [8].

IL-6 inhibitors play a crucial role in the treatment of rheumatoid arthritis (RA), not only reducing inflammation but also significantly improving patients' quality of life. These drugs help slow disease progression and prevent joint destruction, allowing patients to maintain activity and independence for many years. The use of IL-6 inhibitors in RA therapy in Russia is growing, reflecting the increasing interest in innovative treatment methods.

Despite the high cost of these medications, their high clinical effectiveness and ability to provide prolonged periods of remission make them an integral part of the modern approach to treating RA. IL-6 inhibitors are especially important for patients who do not achieve adequate results from traditional treatments.

The prospects for the development of the IL-6 inhibitor market in Russia appear promising. It is expected that the market will continue to grow in the coming years due to the increasing availability of these drugs. The introduction of new molecules with improved effectiveness and safety will also open new horizons in RA treatment. Furthermore, the development of domestic production, support for state subsidy programs, and preferential drug coverage will make treatment more accessible for various patient groups [9].

The further development of the Russian IL-6 inhibitor market will be a key factor in improving the quality of treatment for RA patients. Enhancing accessibility, the emergence of new drugs, and support for domestic manufacturers will significantly contribute to improving the health of the population and increasing the quality of life for RA patients. Additionally, the active development of the biotechnology and pharmaceutical industries in Russia helps reduce dependence on imported drugs, strengthening national security in healthcare [10]. With ongoing research and innovative developments, significant progress in the treatment of RA can be expected, leading to long-term improvements in clinical outcomes and a reduction in the financial burden on the healthcare system.

Список литературы:

1. Smolen, J. S., Aletaha, D., McInnes, I. B. (2016) Rheumatoid arthritis // *The Lancet*. Vol. 388, No. 10055, 2023-2038.
2. Rubbert-Roth, A., Furst, D. E., Nebesky, J. M., Jin, A., & Berber, E. (2018). A Review of Recent Advances Using Tocilizumab in the Treatment of Rheumatic Diseases // *Rheumatology and therapy*, 5(1), 21–42. URL: <https://doi.org/10.1007/s40744-018-0102-x>
3. De Benedetti, F., Brunner, H. I., Ruperto, N., et al. (2012) Randomized trial of tocilizumab in systemic juvenile idiopathic arthritis // *New England Journal of Medicine*. 2012. Vol. 367, No. 25, 2385-2395.
4. Клинические рекомендации «Ревматоидный артрит» (утв. Министерством здравоохранения Российской Федерации, 2024 г.) : [сайт]. – 2025. – URL: <https://base.garant.ru/411241813/> (дата обращения: 16.03.2025). – Текст : электронный.

5. Clinical Trials Databases. URL: <https://clinicaltrials.gov/> (date accessed: 14.03.2025).
6. IQVIA. Reports and Analytical Studies of the Pharmaceutical Market. URL: <https://www.iqvia.com/locations/russia> (date accessed: 12.03.2025).
7. Приказ Министерства здравоохранения РФ от 24 ноября 2021 г. N 1094н "Об утверждении Порядка назначения лекарственных препаратов, форм рецептурных бланков на лекарственные препараты, Порядка оформления указанных бланков, их учета и хранения, форм бланков рецептов, содержащих назначение наркотических средств или психотропных веществ, Порядка их изготовления, распределения, регистрации, учета и хранения, а также Правил оформления бланков рецептов, в том числе в форме электронных документов" – URL: <https://base.garant.ru/403137145/> (дата обращения: 15.03.2025). – Текст : электронный.
8. Федеральная служба государственной статистики. Данные о здравоохранении и фармацевтическом рынке : [сайт]. – 2025. – URL: <https://rosstat.gov.ru/> (дата обращения: 16.03.2025). – Текст : электронный.
9. Государственный реестр лекарственных средств : [сайт]. – 2025. – URL: <https://grls.rosminzdrav.ru/> (дата обращения: 05.03.2025). – Текст : электронный.
10. DSM Group. Исследования фармацевтического рынка : [сайт]. – 2025. – URL: <https://www.dsm.ru/> (дата обращения: 18.03.2025). – Текст : электронный.

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EFFICIENCY AND AVAILABILITY OF MODERN METHODS OF GLAUCOMA TREATMENT

Abstract. The article discusses current trends in drug and surgical treatment of glaucoma, as well as their effectiveness and availability for patients. Current methods include both traditional drugs aimed at reducing intraocular pressure and innovative approaches such as minimally invasive surgery and laser technologies.

Keywords: glaucoma, drugs, treatment, latanoprost, travoprost, ophthalmology.

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ЭФФЕКТИВНОСТЬ И ДОСТУПНОСТЬ СОВРЕМЕННЫХ МЕТОДОВ ЛЕЧЕНИЯ ГЛАУКОМЫ

Аннотация. В статье рассматриваются современные тенденции в медикаментозном и хирургическом лечении глаукомы, а также их эффективность и доступность для пациентов. Актуальные методы включают как традиционные лекарственные препараты, направленные на снижение внутриглазного давления, так и инновационные подходы, такие как миниинвазивная хирургия и лазерные технологии.

Ключевые слова: глаукома, лекарственные средства, лечение, латанопрост, травопрост, офтальмология.

Today, a large number of people suffer from diseases of the visual organs. Chronic diseases are a pressing problem in ophthalmology. Among them, glaucoma occupies a leading position. Glaucoma is characterized by a chronic increase in intraocular pressure, which can manifest itself both in a constant and periodic form. This is a serious disease with a progressive course, capable of leading to irreversible loss of vision in the absence of adequate treatment [1].

Glaucoma is the most common cause of blindness. Currently, the incidence of glaucoma is rapidly growing throughout the world. In Russia alone, over the past 20 years, due to this disease, the number of visually impaired people has increased by 2.3

million people, and of those who have lost their sight – by 0.8 million people [2].

In the modern world, treatment of this disease begins with drug therapy and only in case of ineffectiveness or to increase effectiveness other methods of treatment are used.

Existing medications for the treatment of glaucoma that reduce intraocular pressure (IOP) can be classified into two categories depending on their effect on the hydrodynamics of the eye. The first category includes drugs that stimulate the outflow of intraocular fluid from the eye. The second category includes drugs that suppress its production.

It should be borne in mind that drug treatment of glaucoma is divided into two categories:

- First line therapy: this includes drugs that have proven themselves to be highly effective and have proven efficacy. These include prostaglandins and β -blockers.

- Second line therapy: the prescription of these drugs is determined by the individual characteristics of the patient, the form of glaucoma, as well as the presence of concomitant diseases [3].

Next, we will consider the drugs presented on the Russian market with the active ingredients latanoprost and travoprost. They belong to the pharmacological group of prostolongs.

Latanoprost is an artificially created derivative of prostaglandin F₂ α with a phenyl group. This substance selectively activates FP receptors.

The decrease in IOP begins approximately 3-4 hours after instillation of the drug, the maximum effect is noted after 8-12 hours. The effect of the drug lasts for at least 24 hours. On average, a decrease in intraocular pressure by 35 % is observed compared to the initial values.

Travoprost is a selective FP receptor agonist. Its use leads to a decrease in intraocular pressure (IOP). The minimum effect is observed two hours after instillation, the maximum decrease in IOP is achieved after 12 hours and averages 7-8 mm Hg. Travoprost is equivalent in its effectiveness to latanoprost. The recommended regimen is once a day, preferably in the evening.

Since 2020, there has been a tendency to reduce supplies of foreign-made antiglaucoma drugs to the Russian market, while the share of Russian manufacturers has increased slightly [4]. An example is the rapid growth in sales of latanoprost eye drops from Pharmstandard. Over the past four years, the company's market share has shown significant growth, increasing from 1 % in 2019 to 16 % based on the results of the first eight months of 2022. Such dynamic growth allowed the company to take a place among the five largest sellers in terms of sales volume.

In accordance with the Moscow Government Resolution of August 3, 2021 No. 540-RP, prostaglandins are included in the list of drugs provided free of charge on prescription to Moscow residents diagnosed with glaucoma. At present, this Resolution is valid exclusively in the city of Moscow [5].

During the monitoring of prices for latanoprost, conducted in the Russian Federation, it was revealed that the drug "Latanoprost-Optic" is characterized by a stable presence on the market and an attractive pricing policy [6].

The ophthalmological drug "Latanoprost-Optic" contains the same

concentration of the active substance latanoprost (0.05 mg) as the original drug and a similar composition of auxiliary components.

The average market price for Latanoprost-Optik 0.005 % is 324 rubles. One bottle contains 2.5 milliliters of the drug. It is applied one drop in the affected eye once a day. Therefore, this drug is available to patients with this disease.

Based on this, we can conclude that “Latanoprost-Optic” has therapeutic efficacy, safety level and availability.

The next drug under consideration is “Travoprost-Optic” by the pharmaceutical company Pharmstandard. The active ingredient is travoprost. The average cost of one bottle of “Travoprost-Optic 0.004 %” is 397 rubles. The volume of the drug is 5 milliliters. The method of application is similar to the previous drug [7].

A similar drug is “Travaxal” from the manufacturer OOO “Grotex”. These are eye drops in a dropper bottle with the active ingredient travoprost 0.04 mg. The cost of this drug is already 528 rubles. The volume of one bottle is 2.5 milliliters [8].

Also, on the Russian market there are drugs with active ingredients travoprost and lanoprost from foreign manufacturers. Their cost, naturally, is higher than the cost of domestic generics.

Therefore, we can conclude that the Russian market is provided with drugs for the treatment of glaucoma. Domestic generics are more affordable, while foreign manufacturers are less so.

Each drug has unique application characteristics, contraindications and potential side effects. For this reason, treatment should be carried out exclusively under the strict control and supervision of a qualified ophthalmologist.

Drug treatment can be integrated with other treatment approaches.

In the initial and advanced stages of primary open-angle glaucoma, with a moderate increase in intraocular pressure, laser trabeculoplasty is recommended. This procedure involves the action of a laser beam on the cells of the drainage zone of the eye, which helps to reduce intraocular pressure. Laser trabeculoplasty can be considered as an alternative treatment option in situations where the use of local drug therapy is difficult for various reasons: intolerance to the drugs used, physical limitations for instillation of eye drops, or limited access to the necessary drugs [9].

In case of primary open-angle glaucoma in the initial and advanced stages, laser trabeculoplasty is recommended – the effect of laser energy on the cells of the drainage zone. This procedure makes it possible to reduce intraocular pressure at its moderately elevated level. It can also act as an alternative option for starting treatment when it is impossible to prescribe local drug therapy: poor drug tolerance, physical difficulties associated with instillation of drops, and unavailability of specific drugs.

Surgical treatment is the most effective way to normalize intraocular pressure and preserve visual functions. The goal of all types of glaucoma surgery is one: to create additional pathways for the outflow of intraocular fluid, reduce and stabilize the pressure inside the eye.

In search of methods to increase the effectiveness of non-penetrating interventions and minimize complications after fistulizing operations, a study of procedures with minimal surgical impact was initiated. The abbreviation MIGS (minimally invasive glaucoma surgery) was proposed to designate such

procedures [10].

There is currently a debate about the criteria that determine whether a procedure is considered MIGC. However, the main requirement is considered to be “ab interno” access through a corneal incision. This minimally invasive approach has a number of advantages, including preservation of the conjunctiva, which is important for subsequent surgical interventions [11].

The main approaches to non-drug treatment of glaucoma include:

- microsurgical procedures, such as the placement of special drainage devices that help drain the eye fluid;
- using lasers to reduce the production or improve the outflow of fluid;
- mixed methods, which combine lasers and microinvasive technologies.

The advantages of these methods are:

- reduced risk of complications;
- faster recovery;
- less need for long-term use of drugs.

Minimally invasive surgery is suitable for various stages of glaucoma and can be used as a primary treatment or after unsuccessful attempts with traditional methods.

In summary, we can conclude that glaucoma treatment methods are rapidly developing, providing a wide variety of drugs for patients and various non-drug treatment methods. Availability of glaucoma treatment varies depending on the region of Russia. In cities, there are often specialized clinics offering a full range of services. At the same time, in remote areas, access to modern methods may be limited. Active prevention and early diagnosis programs will help improve the effectiveness of glaucoma treatment. The Russian drug market is replenished with domestically produced drugs every year, providing generics as well as original products, which contributes to the effective development of treatment in this area.

Список литературы:

1. Энциклопедия заболеваний «Про болезни». Глаукома – симптомы и лечение.. – URL: <https://probolezny.ru/glaukoma/> (дата обращения: 16.03.2025). – Текст : электронный
2. Еричев, В. П. Объективизация критериев оценки эффективности нейроретинопротекторной терапии глаукомы / В. П. Еричев, А. А. Антонов, И. В. Козлова. – Текст : электронный // Национальный журнал глаукома. – 2018. – Т. 17, № 3. – URL: <https://www.glaucomajournal.ru/jour/article/view/220> (дата обращения: 18.03.2025).
3. Регистр лекарственных средств России (РЛС). – Текст : электронный. – URL: <https://www.rlsnet.ru/library/articles/oftalmologiya/farmakoterapiya-glaukomy-94?ysclid=m21tsw2k2400894700> (дата обращения: 11.03.2025).
4. Гришина, М. Г. Рынок фармацевтической продукции России: призма развития в разрезе существующих проблем современности / М. Г. Гришина, Е. А. Кабачевская, А. В. Коваленко, А. А. Халимова. – Текст : непосредственный // Modern Economy Success. – 2023. – № 2. – С. 129-134.

5. Распоряжение Правительства Москвы № 540-ПП от 03.08.2021 «О внесении изменений в распоряжение Правительства Москвы от 10 августа 2005 г. № 1506-ПП». – URL: <https://www.mos.ru/authority/documents/doc/46860220/> (дата обращения: 21.03.2025). – Текст : электронный.
6. Современные тренды терапии глаукомы с учетом импортозамещения и лекарственной доступности препаратов // XV Российский общенациональный офтальмологический форум. – URL: https://umedp.ru/articles/sovremennye_trendy_terapii_glaukomy_s_uchetom_importozameshcheniya_i_lekarsvennoy_dostupnosti_prepa.html?forgot_password=yes (дата обращения: 20.03.2025). – Текст : электронный.
7. Официальный сайт фармацевтической компании Фармстандарт. – 2025. – URL: <https://pharmstd.ru/?ysclid=m6pjqm3l3583926450> (дата обращения: 22.03.2025). – Текст : электронный.
8. Фармацевтическая компания Solopharm: [Официальный сайт]. – 2025. – URL: <https://solopharm.com/> (дата обращения: 22.03.2025). – Текст : электронный.
9. Аветисов, С. Э. Современные достижения в диагностике и лечении глаукомы / С. Э. Аветисов, В. П. Еричев, А. А. Антонов, Р. П. Полева, И. В. Козлова, А. С. Макарова. – Текст : электронный // Вестник офтальмологии. – 2023. – URL: <https://www.mediasphera.ru/issues/vestnik-oftalmologii/2023/3/10042465X2023032096> (дата обращения: 05.02.2025).
10. Российская офтальмология онлайн. Новые устройства в лечении глаукомы. – URL: <https://eyepress.ru/article/novye-ustroystva-v-lechenii-glaukomy> (дата обращения: 28.03.2024). – Текст : электронный.
11. Петров, С. Ю. Современная микроинвазивная хирургия глаукомы / С. Ю. Петров, С. В. Вострухин, А. Э. Асламазова, Л. В. Шерстнева. – URL: <https://www.mediasphera.ru/issues/vestnik-oftalmologii/2016/3/10042465X2016031096> (дата обращения: 28.03.2025). – Текст : электронный.

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ALPHA-HYDROXY PHOSPHORYL COMPOUNDS

Abstract. α -Hydroxy phosphoryl compounds are phosphorylated alcohols containing the $R_2(O)PC-OH$ moiety. These compounds are used in medicine as an active moiety of drugs prescribed for the treatment of bone tissue diseases. Zoledronic acid salts help to relieve the general condition of patients with bone metastases in breast cancer. Compounds of this class have also found application in nuclear medicine. Etidronate and medronate effectively chelate radioactive isotopes of rhenium and technetium, which are used in MRI examination of bones, allowing safe and high-quality tomographic images to be obtained.

Keywords: α -hydroxy phosphoryl compounds, bisphosphonates, Abramov reaction, complexation, biological activity.

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АЛЬФА-ГИДРОКСИФОСФОРИЛЬНЫЕ СОЕДИНЕНИЯ

Аннотация. α -Гидроксифосфорильные соединения – фосфорилированные спирты, содержащие фрагмент $R_2(O)PCN(OH)$. Эти соединения применяются в медицине в качестве активных субстанций препаратов, назначаемых при лечении заболеваний костной ткани, благодаря комплексообразующим свойствам. Соли золедроновой кислоты способствуют облегчению общего состояния пациентов с костными метастазами при раке молочной железы.

Соединения данного класса также нашли применение и в ядерной медицине. Этидронат и медронат эффективно хелатируют радиоактивные изотопы рения и технеция соответственно, которые используются в современных МРТ-исследованиях костей, что позволяет безопасно получать высококачественные томографические изображения.

Ключевые слова: α -гидроксифосфорильные соединения, бисфосфонаты, реакция Абрамова, комплексообразование, биологическая активность.

α -Hydroxy phosphoryl compounds (α -HP) have been actively studied since the middle of the last century when V. S. Abramov discovered the aldehydes and ketones hydrophosphorylation reaction by hydrophosphoryl compounds in the presence of bases (Figure 1) [1].

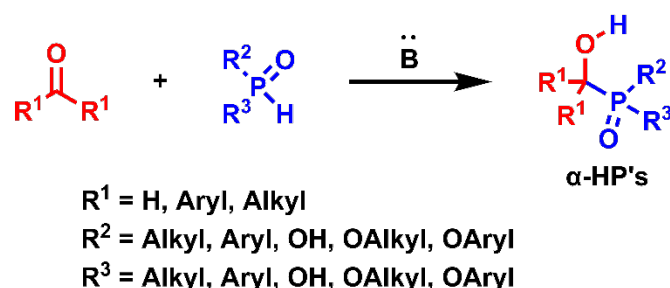


Figure 1 – Abramov reaction

The Abramov reaction remains the most popular method for obtaining α -HFS up to the present day, but other routes to obtaining α -HP are also known (Figure 2). For example, path A involves the interaction of tertiary phosphites with aldehydes or ketones under acid catalysis. The interaction of α -ketophosphoryl compounds with Grignard reagents and other organometallic reagents followed by hydrolysis of the intermediate compound (path B) also leads to α -HP. α -Hydroxyphosphonates ($R_2, R_3 = \text{OAlk}$) can be obtained by oxidation of the corresponding alkylphosphonates (path C).

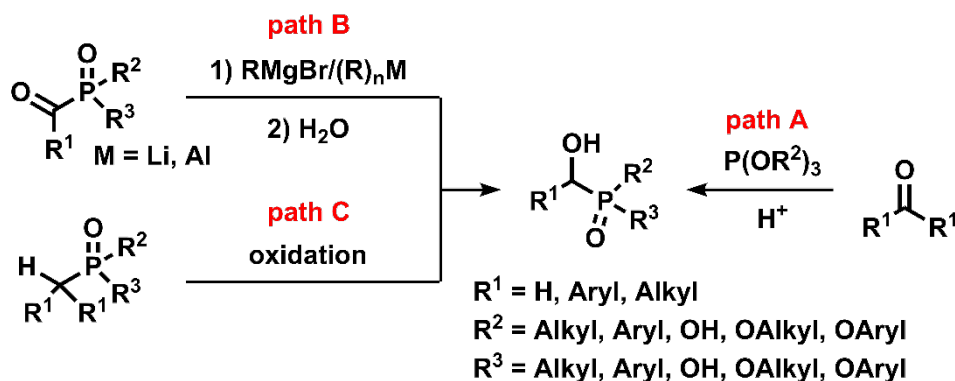


Figure 2 – Alternative synthesis paths of α -HPs

It is considered that the Abramov reaction follows the mechanism of

nucleophilic addition, but by now, how the reaction proceeds has not been established.

During the investigation [3] of the reaction between aromatic aldehyde **1a** or aromatic ketone **1b** and diethyl phosphite (Figure 3), several interpretations of the mechanism (Figure 4) were proposed in compliance with quantum chemical calculations.

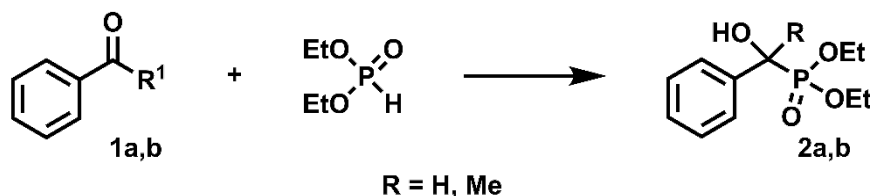


Figure 3 – Hydrophosphorylation of acetophenone or benzaldehyde by diethylphosphite

Based on the calculations, it has been established that without a basic catalyst the reaction can proceed in two ways. Path A assumes a one-stage process via the transition state **TS1** to product **2**. According to calculations, it has been shown that the energy of **TS** formation is slightly higher for **1b** (101.4 kJ/mol) than for **1a** (85.9 kJ/mol). The formation of **2a** is an exothermic process (-17.2 kJ/mol) meaning the equilibrium is shifted towards the formation of the adduct. Nevertheless, the combining heat of product **2b** tends toward zero (-0.4 kJ/mol), which indicates an equilibrium reaction.

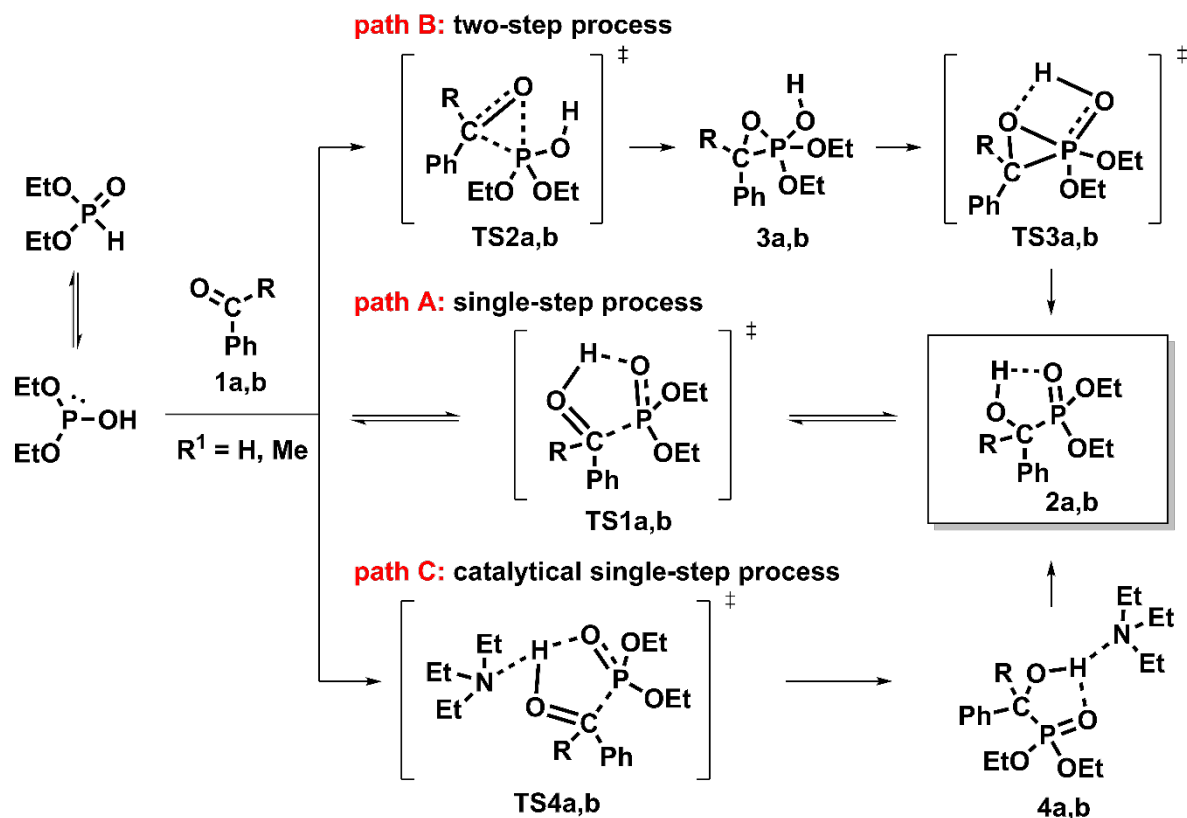


Figure 4 – Calculated Abramov reaction mechanisms

In path B, the energy of intermediate **3** is approximately equal to the energy of the preceding transition state **TS2**. Structure **3** contains a three-membered cycle with a C–O–P motif, including a pentavalent phosphorus atom. In two cases, these intermediates **3a** and **3b** have higher combining heat values (94.0 and 109.3 kJ/mol, respectively) compared to the corresponding transition states of path A (85.9 and 101.4 kJ/mol, respectively).

Path C has taken into consideration the addition of triethylamine as the main catalyst. In this case, triethylamine doesn't deprotonate the starting diethyl phosphite due to the endothermic deprotonation equilibrium between (EtO)₂P(O)H and triethylamine but promotes the transfer of a dialkyl phosphite proton to the transition complex by weakening the PO–H bond. Compared with the base-free reaction path A (**TS1**), the energy of the transition state decreases from 85.9 to 68.8 kJ/mol and from 101.4 to 82.2 kJ/mol for **1a** and **1b**, respectively. At the final stage, the amine forms a hydrogen bond with the hydroxyl group of α-hydroxyphosphonate **4**, which leads to an even more exothermic reaction. Thus, triethylamine can increase the reaction rate by reducing the activation energy of **TS4** by about 18 kJ/mol.

The addition of tertiary phosphites, as mentioned previously, requires acid catalysts, which should seem to activate carbonyl compounds. Although tertiary phosphites have lone-pair electrons on the phosphorus atom, which makes them nucleophiles, they do not react with aldehydes and ketones in the absence of any catalyst under mild conditions. V. S. Abramov in 1950, when reacting tertiary phosphites with aldehydes at 160 °C and high pressure, obtained a mixture of difficult-to-determine reaction products in addition to a small amount of the target α-HP [4].

In 2006 research, V. Goldman and M. Soroka [5] proposed a possible mechanism for the addition of trialkyl phosphite to carbonyl compounds with the participation of gaseous HCl. At the first stage, electrophilic activation of the carbonyl compound with hydrogen chloride takes place with the formation of the onium salt **5**, which then reacts with trialkylphosphite. Then, like the Arbuzov reaction, alkyl chloride is cleaved from the phosphonium salt **6** and α-HP **7** is formed (Figure 5).

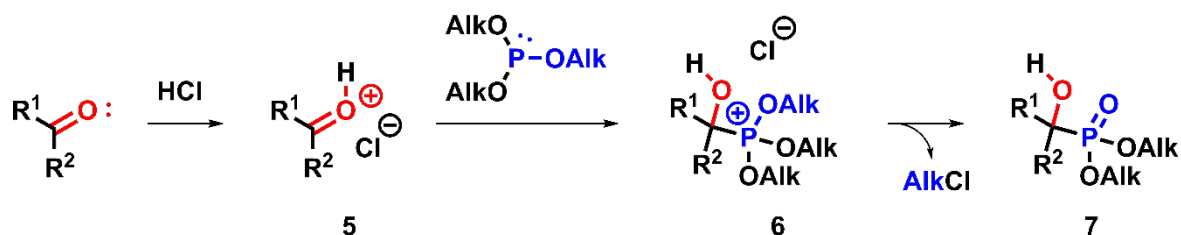


Figure 5 – Possible mechanism of phosphorylation of carbonyl compound by trialkyl phosphite

An important property exhibited by α-HP is complexing. Currently, complex compounds of geminal bisphosphonates (BP) containing the P–C–P bond are being actively studied [6]. Since the discovery of these compounds in 1865 by the Russian chemist N. I. Menshutkin [7], BPs have been used mainly in the textile, oil, and fertilizer industries to prevent scale deposition [8], which is apparently associated with

the formation of water-soluble complexes.

Nowadays, BPs are widely used in medicine as drugs or bone imaging agents [9]. The use of simple bisphosphonates like HMBPs (Figure 6) as bone scanning agents is due to their ability to accumulate in bone, especially at sites of increased bone metabolism in disease states, and their ability to bind to the γ -emitting technetium isotope ^{99m}Tc [10], which is used in medical diagnostic procedures.

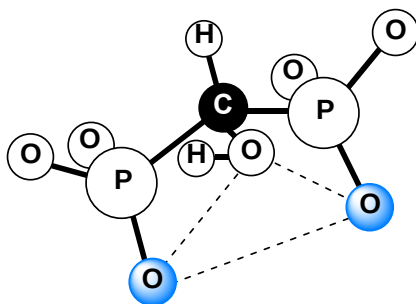


Figure 6 – Structural formula of hydromethylenediphosphonate (HMDP)

Using X-ray structural analysis of the metal complexes of HMBPs, it was established that the oxygen atoms of phosphorus and the hydroxyl group participate in the binding of the organic ligand to the calcium cation of bone mineral and technetium, and the binding modes with technetium and hydroxyapatite is realized according to the bidentate-tridentate (Figure 7, a) and tridentate-bidentate (Figure 7, b) types [11].

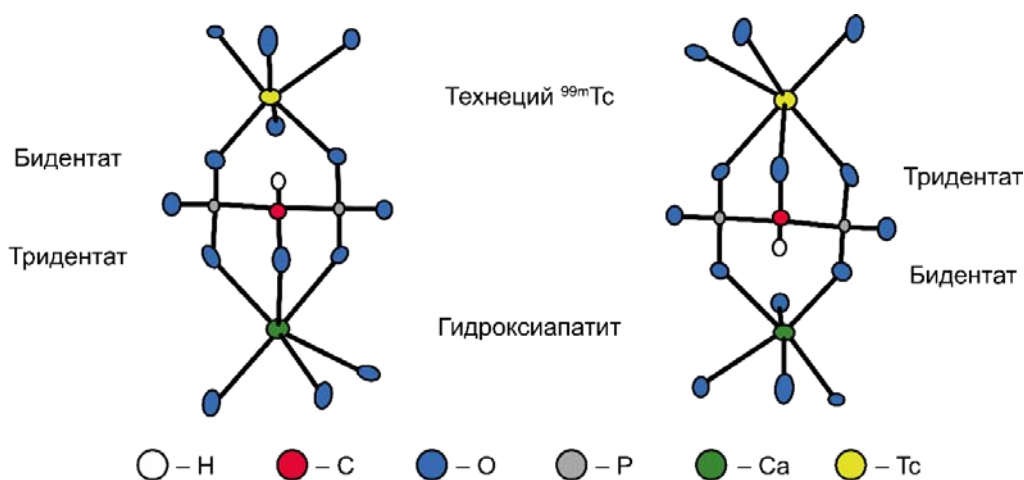


Figure 7 – Types of binding of HMDP-hydroxyapatite

Tertiary mono- α -HPs produce complexes with tin(IV) chloride. It was found that when the phosphonate reacts with SnCl_4 , coordination compounds **8** are formed in terms of *cis*- and *trans*-isomers (Figure 8), which are interesting as potential biologically active substances [12].

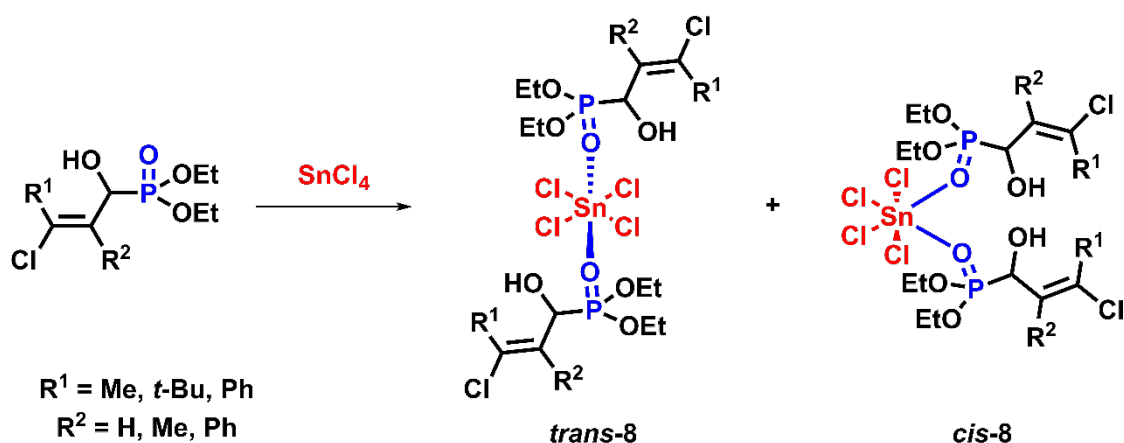


Figure 8 – Synthesis of tin(IV) complexes with α -HPs

The manifestation of biologically active properties of α -hydroxyphosphonates is due to the structure of the phosphonate group and the stability of compounds of this class at a physiological pH value. This provides unique binding interactions with biological targets. The most well-known examples are enzyme inhibitors, potent antibacterial, antiviral, antitumor agents, herbicides and insecticides [13, 14].

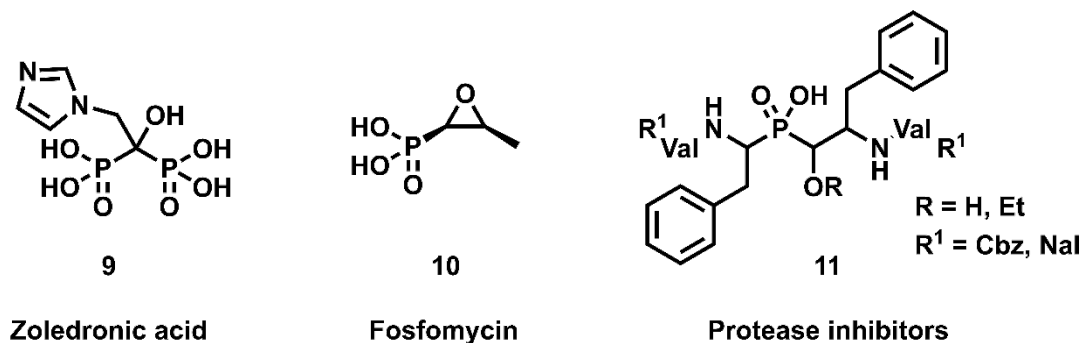


Figure 9 – Structural formulas of biologically active α -HPs

The antitumor and inhibitory drug includes zoledronic acid **9**, which is highly selective for osteoclast cells responsible for bone resorption. Acid **9** is also effective in the treatment of breast cancer and gynecomastia [15]. Phosphomycin **10** having a hidden hydroxyl group exhibits excellent antibiotic activity [14]. Preparations based on fosfomycin have found application in the treatment of diseases and infections of the genitourinary system (Figure 9).

For the present, the problem of HIV infection is relevant in the world [16]. The work [17] presents the results of a study of protease inhibitors. Compound **11** having a free or hidden OH group has proven to be an effective agent for possible use as an active substance in antiretroviral therapy.

Thus, this brief review summarizes the methods for producing α -HPs, provides possible mechanisms of the Abramov reaction, and gives examples of coordination compounds of hydroxyphosphonates. The biologically active properties of α -HPs and currently used drugs based on them are also reported.

Список литературы:

1. Абрамов, В. С. О взаимодействии диалкилфосфористых кислот с альдегидами и кетонами. Новый метод получения эфиров α -оксифосфоновых кислот / В. С. Абрамов. – Текст : непосредственный // ЖОХ. – 1952. – Том 22, № 4. – С. 647-652.
2. Zuo, Na., Hongwu, He (2008) Synthesis and Biological Activity of α -Hydroxyphosphonates // Phosphorus, Sulfur Silicon Relat. Elem. 183, 621-622.
3. Kiss, N. Z., Radai, Z.; Mucsi, Z., Keglevich, G. (2008) Synthesis of α -aminophosphonates from α -hydroxyphosphonates; a theoretical study // Heteroat. Chem. 27 (5), 260-268.
4. Абрамов, В. С. Докл. АН СССР / В. С. Абрамов. – 1950. – Том 73, № 4. – С. 487-489. – Текст : непосредственный.
5. Goldeman, W., Soroka, M. (2006) The Preparation of Dialkyl 1-Hydroxyalkylphosphonates in the Reaction of Trialkyl Phosphites with Oxonium Salts Derived from Aldehydes or Ketones // Synthesis. 18, 3019-3024.
6. Житлова, Е. А. Действие нового бисфосфоната на основе этидроната ионов лантаноидов и кальция на восстановление костных дефектов у животных в эксперименте / Е. А. Житлова, Ф. В. Шакирова, Д. А. Коробейникова. – Текст : непосредственный // Ученые записки КГАВМ им. Н. Э. Баумана. – 2017. – Том 232, № 4. – С. 57-63.
7. Menschutkin, N. (1865) Ueber die Einwirkung des Chloracetyls auf phosphorige Säure // Justus Liebigs Ann. Chem. 133 (3), 317-320.
8. Fleisch, H., Reszka, A., Rodan, G., Rogers, M. (2002) Chapter 78 – Bisphosphonates: Mechanisms of Action // Principles of Bone Biology (Second Edition). 1361-1385.
9. Popov, K., Oshchepkov, M., Tkachenko, S., Sergienko, V., Oshchepkov, A. (2022) Bisphosphonates: Synthesis, structures, properties, medical and industrial applications // J. Mol. Liq. 351, 118619.
10. Russell, R. G. G. (2011) Bisphosphonates: The first 40 years. Bone. 49 (1), 2-19.
11. Francis, M. D. (1984) ^{99m}Tc Diphosphonate Uptake Mechanism on Bone // Bone Scanning in Clinical Practice. London: Springer London. 7-17.
12. Baccari, Z., Sanhoury, M. A. K., Dejean, C., Crousse, B., Barhoumi-Slimi, T. (2018) Preparation, characterization and solution behavior of α -hydroxyphosphonate complexes with tin tetrachloride // J. Mol. Struct. 1167, 248-254.
13. Olszewski, T. K. (2014) Environmentally benign syntheses of α -substituted phosphonates: Preparation of α -amino- and α -hydroxyphosphonates in water, in ionic liquids, and under solvent-free conditions // Synthesis. 46 (4), 403-429.
14. Koszelewski, D., Ostaszewski, R. (2019) Biocatalytic promiscuity of lipases in carbon-phosphorus bond formation // Polish Journal of Chemistry. 1-4.
15. Wardley, A. [et al.] (2005) Zoledronic acid significantly improves pain scores and quality of life in breast cancer patients with bone metastases: a randomised, crossover study of community vs hospital bisphosphonate administration // British journal of cancer. 92 (10), 1869-1876.
16. Переверзева, Э. В. Актуальные вопросы культуры здоровья: ВИЧ-инфекции и СПИД / Э. В. Переверзева, С. Н. Филиппова. – Текст : непосредственный // Вестник РМАТ. – 2014. – № 1. – С. 21-37.
17. Stowasser, B., Budt, K. H., Jian-Qi, L. (1992) New hybrid transition state analog inhibitors of HIV protease with peripheric C2-symmetry // Tetrahedron lett. 33 (44), 6625-6628.

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CURRENT ENVIRONMENTAL EDUCATION IN THE WORLD

Abstract. The issue of environmental education and awareness has long been established in the world community as one of the most important and topical issues. In this paper the analysis of a social survey on the importance of environmental education in different countries of the world is conducted. The survey participants were schoolchildren, college and university students, lecturers, kindergarten teachers and business representatives from Russia, Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, Azerbaijan, India, Congo and Syria.

Keywords: environmental education in the world, sustainable development, ecology, social survey.

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СОВРЕМЕННОЕ ЭКОЛОГИЧЕСКОЕ ОБРАЗОВАНИЕ В МИРЕ

Аннотация. Вопросы экологического образования и просвещения уже давно закрепились в мировом сообществе как одни из самых важных и актуальных. В данной работе проведен анализ социального опроса, посвященного важности экологического образования в разных странах мира. Участниками опроса стали школьники, студенты колледжей и университетов, преподаватели, воспитатели детских садов и представители бизнеса из России, Казахстана, Кыргызстана, Узбекистана, Таджикистана, Азербайджана, Индии, Конго и Сирии.

Ключевые слова: экологическое образование в мире, устойчивое развитие, экология, социальный опрос.

Introduction

Current environmental education in the world is becoming increasingly relevant in the context of global environmental challenges, taking into account climate change, loss of biodiversity, environmental pollution and depletion of natural resources. The issues of environmental education can be solved through 17 goals of Sustainable Development [1].

Ecology and sustainable development are included in school and university curricula at all levels. A practice-oriented approach is increasingly being used, where students are involved in real environmental projects [2]:

- eco-clubs are created at schools;
- students of colleges and universities participate in waste sorting and energy saving programs.

There are several steps suggested for achieving sustainable development of regions:

- ecological culture starting since childhood;
- new knowledge about environment situation at every stage of our growing-up;
- sustainable lifestyle for the population of different countries;
- actions aimed at the protection of nature and life.

Methods

The social survey method in environmental education is an effective tool for collecting data on environmental literacy, values, behavior, and attitudes of various population groups to environmental issues. It allows for the involvement of students and the public in research activities, the development of critical thinking, and the formation of environmental culture [3].

In this article the method of a social survey was used. A social survey refers to the method of collecting information about a nation's population using probability sampling and rigorous question design. It has evolved over the past 120 years, beginning with local social surveys and progressing to modern sample surveys [4].

The aim of the social survey “The importance of environmental education in the world” is to highlight the increasing interest of young people to environmental engineering and technical specialties.

Results

More than 1000 participants from Russia, Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, Azerbaijan, Syria, India and Congo were questioned as a result of the social survey “The importance of environmental education in the world”, 80% being women and 20% – men. The respondents were from different organizations – kindergartens, schools, colleges, universities and other organizations.

The age of the respondents ranged from 15 to more than 60. The more interested respondents were among 40-50 years old ones.

The social survey contains some questions which are presented in Table.

Table – “Yes – No” questions of the social survey “The importance of environmental education in the world”

№	Question	Yes	No
1	Have you studied ecology before?	75 %	25 %
2	What did ecology as a subject include in the educational program in your organization?	84 %	16 %
3	Do you think that ecology is the science of the future?	96 %	4 %
4	Do you apply environmental knowledge in your daily life, for instance, waste sorting or water saving, etc.?	94 %	6 %

The open question about the importance of environmental education was presented in different languages: Russian, English and Uzbek.

A participant from Russia wrote: “Экология позволяет мне глубже понять взаимосвязи в природе. Она раскрывает сложные механизмы, которые управляют жизнью на Земле, от циклов биогеохимических веществ до динамики”.

A participant from India wrote: “Ecology helps us understand how different organisms interact with each other and their environment. This knowledge is crucial for maintaining biodiversity and ensuring the health of ecosystems that provide essential”.

A participant from Uzbekistan wrote: “Ekologiya fani tabiatni ifloslanishdan saqlash, tabiiy resurslardan oqilona foydalanish va iqlim o'zgarishiga qarshi choralar ko'rishda muhim rol o'ynaydi. Ekologiya – nafaqat tabiatni, balki insoniyatning kelajagini saqlash”.

Discussion

Many events at the university are organized every year for increasing the interest in environmental education. One of the big projects is “The International Online School”, which includes lectures and workshops on environmental protection and rational use of natural resources and the sustainable development practices.

The Second International Online School was held from 17 March till 21 March in 2025 with more than 280 participants from 20 countries taking part in it [5].

To increase interest in environmental sciences, ecological seasonal camps – “Bios Schools” – are organized every year. The participants from different regions of Russia and different countries assess and analyze water quality of the Gulf of Finland basin for hydrological, hydrobiological and hydrochemical parameters [6].

Our students, lecturers and participants from Bios schools made a presentation about the research results at the scientific conference at the annual International Bios Forum [6].

The seminars and workshops for students of our university and students from other countries are also arranged. For instance, the unique workshop “InterArtScience” is organized for international students and students of the preparatory department. The

workshop includes two parts – art and science. Students from different fields of study can try themselves both in design and science, and this makes the workshop unique [7].

Such events promote the internationalization of environmental education in the world and attract participants from foreign countries to the engineering specialties [8].

The global community faces new prospects in the field of environmental education:

- development of green skills for future professions;
- deepening interdisciplinary connections (ecology in economics, law and technology);
- growing demand for ESG specialists (ecology, social, governance) [9].

Environmental education is no longer a narrowly specialized field and is becoming a mandatory element in the training of modern specialists and responsible citizens.

Список литературы:

1. Tomáš, H., Svatava, J., Bedřich, M. (2016) Sustainable Development Goals: A need for relevant indicators // *Ecological Indicators*. Vol. 60, 565-573.
2. Varsha, A., Gaurav, A., Kwok, Tai Chui (2024) A bibliometric analysis of environmental education and sustainable entrepreneurship development in a global perspective // *Sustainable Technology and Entrepreneurship*. Vol. 3, Issue 3, 100080.
3. Nixon, E. et al (2022) A mixed methods analysis of participation in a social contact survey // *Epidemics*. Vol. 41. December 2022, 100635.
4. Hanabeth, L. (2025) Designing social surveys for understanding farming and natural resource management: A purposeful review of best-practice survey methods // *Land Use Policy*. Vol. 153. June 2025, 107526.
5. Stroganova, M. S. Project "International online schools" / *Dialogue of Generations: Learn. Teach. Study. Proceedings of the V All-Russian Research and Practice Conference with International Participation* // In 2 parts. Part I. Saint Petersburg, 2024, 19-22 pp.
6. Строганова, М. С. Развитие российского проекта «БИОС – 2018» / М. С. Строганова, А. И. Кушнеров, А. И. Шишкин. – Текст : непосредственный // XXIII Международный Биос-форум и молодежная Биос-олимпиада: сборник материалов. Книга 2, Санкт-Петербург, 19–25 сентября 2018 года / сост.: А. И. Шишкин, доцент А. В. Елифанов, И. В. Антонов, Ю. Н. Бубличенко, Н. Ю. Быстрова – СПб. : СПбНЦ РАН, ВВМ ; СПб. : Любавич, 2019. – С. 250-258.
7. Stroganova, M. S. International cooperation in the field of environmental education / *Dialogue of Generations: Learn. Teach. Study. Proceedings of the IV All-Russian scientific and practical conference with international participation* // In 2 parts. St. Petersburg, 2023, 18-21 pp.
8. Oleksiyenko, A. V., Ros V. (2023) Human agency and legacy-innovation tensions in the internationalization of higher education: Re-orientations managed by internationally-educated scholars of Central Asia // *International Journal of Educational Development*. Vol. 97, 102716.
9. Wan, G. et al (2023) Hotspots and trends of environmental, social and governance (ESG) research: a bibliometric analysis // *Data Science and Management* . Vol. 6, Issue 2, 65-75.

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**DEVELOPMENT OF ORGANIZATIONAL AND MANAGEMENT
SOLUTIONS FACILITATING EFFECTIVE PROMOTION
OF RECOMBINANT ANTIBODIES ON THE RUSSIAN
PHARMACEUTICAL MARKET**

Abstract. The article is devoted to a comprehensive analysis of the development and promotion of monoclonal antibodies (mAbs) – high-tech therapeutic drugs transforming the treatment of oncological, autoimmune, and infectious diseases. Key challenges related to their production are considered: structural complexity of molecules, the need for multi-stage quality control, as well as the implementation of orthogonal methods to predict functionality and optimize therapeutic potential.

Special attention is paid to the specifics of promoting mAbs on the Russian pharmaceutical market. The importance of compliance with legislative norms (Federal Law No. 61, No. 38) and ethical standards (AIPM, EFPIA) is emphasized, and effective marketing strategies are analyzed: educational events, digital tools, direct communication through medical representatives. Quantitative (sales growth, market share), qualitative (patient satisfaction, brand reputation), economic (ROI), and clinical indicators (treatment adherence, research results) are provided, illustrating successful cases (rituximab, infliximab, secukinumab).

Keywords: monoclonal antibodies, medicinal products, drug marketing, drug promotion, drug distribution.

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РАЗРАБОТКА ОРГАНИЗАЦИОННО-УПРАВЛЕНЧЕСКИХ РЕШЕНИЙ, СПОСОБСТВУЮЩИХ ЭФФЕКТИВНОМУ ПРОДВИЖЕНИЮ РЕКОМБИНАНТНЫХ АНТИТЕЛ НА РОССИЙСКОМ ФАРМАЦЕВТИЧЕСКОМ РЫНКЕ

Аннотация. Статья посвящена комплексному анализу разработки и продвижения моноклональных антител (мАб) – высокотехнологичных терапевтических препаратов, трансформирующих лечение онкологических, аутоиммунных и инфекционных заболеваний. Рассмотрены ключевые вызовы, связанные с их производством: структурная сложность молекул, необходимость многоэтапного контроля качества, а также внедрение ортогональных методов для прогнозирования функциональности и оптимизации терапевтического потенциала.

Отдельное внимание уделено специфике продвижения мАб на российском фармацевтическом рынке. Подчеркивается важность соблюдения законодательных норм (ФЗ № 61, № 38) и этических стандартов (AIPM, EFPIA), а также анализируются эффективные маркетинговые стратегии: образовательные мероприятия, цифровые инструменты, прямая коммуникация через медицинских представителей. Приведены количественные (рост продаж, доля рынка), качественные (удовлетворенность пациентов, репутация бренда), экономические (ROI) и клинические показатели (приверженность лечению, результаты исследований), иллюстрирующие успешные кейсы (ритуксимаб, инфликсимаб, секукинумаб).

Ключевые слова: моноклональные антитела, лекарственные средства, маркетинг лекарственных средств, продвижение лекарственных средств, сбыт лекарственных средств.

Monoclonal antibodies (mAbs) are a key class of therapeutic drugs that have revolutionized approaches to the treatment of oncological, autoimmune, and infectious diseases. However, their development and preparation for clinical application require significantly more resources than the creation of low-molecular-weight drugs. High costs are due not only to the complexity of production processes but primarily to the structural multi-component nature of the molecules themselves. To ensure the quality and stability of drugs, the following steps are necessary:

- in-depth analytical characterization;
- multi-stage production control;
- comprehensive assessment of safety and efficacy.

The development of next-generation drugs will require the implementation of highly sensitive orthogonal methods capable of revealing complex relationships between the structural features of molecules and their biological activity. These technologies are critically important for predicting the functionality of mAbs and optimizing their therapeutic potential [1].

Monoclonal antibodies (mAbs) have a unique ability to bind highly specifically to target molecules (primarily proteins), including membrane and secreted forms, due to the structural adaptation of variable domains, ensuring selective interaction with

antigenic epitopes [2, 3].

The promotion of medicinal products on the Russian pharmaceutical market requires compliance with legislative norms, ethical standards, and the use of effective marketing strategies. The main aspects of promotion include:

1. Legislative regulation. In Russia, the promotion of medicinal products is regulated by Federal Law № 61-FZ “On the Circulation of Medicinal Products” and Federal Law № 38-FZ “On Advertising”. These laws establish restrictions on the advertising of prescription drugs and requirements for information provided to healthcare professionals and patients [4, 5].

2. Ethical standards. The Code of Ethical Practice of the Association of International Pharmaceutical Manufacturers (AIPM) and the Code of Ethics for Pharmaceutical Marketing (EFPIA) set standards for interaction with healthcare professionals and patients [6].

3. Marketing strategies. Educational events such as conducting conferences, seminars, and webinars for doctors and pharmacists are essential.

4. Direct marketing. Distribution of informational materials through medical representatives [7].

5. Digital marketing. The use of internet resources, social networks, and mobile applications for promoting over-the-counter drugs.

6. Sales promotion. Providing discounts, bonuses, and other benefits to pharmacies and distributors.

7. Work with medical representatives. Medical representatives play a key role in promoting drugs by providing doctors and pharmacists with up-to-date information about products [8, 9].

8. Monitoring and analysis. Regular analysis of the effectiveness of marketing campaigns and feedback from healthcare professionals and patients.

Quantitative indicators

Quantitative indicators allow measuring the direct results of marketing efforts:

1. Sales volume – measured in monetary terms or number of packages.

A 15 % increase in sales of rituximab (MabThera) within a year after launching an educational program for doctors [9].

2. Market share – the percentage ratio of drug sales to the total market volume in a specific therapeutic area.

The market share of infliximab (Remicade) in the Russian market for Crohn’s disease drugs was 6 % in 2021 [10].

3. Audience reach – the number of doctors who participated in educational events or patients covered by support programs.

In 2022, Novartis’ educational programs on secukinumab (Cosentyx) reached over 1000 doctors [12].

4. Number of prescriptions – this indicator reflects the level of trust doctors have in the drug.

Qualitative indicators

Qualitative indicators help assess the impact of marketing initiatives on the perception of the drug.

1. Level of doctor awareness – measured through surveys and questionnaires.

85 % of rheumatologists noted an increase in knowledge about the use of infliximab after participating in educational programs [11].

2. Patient satisfaction – assessed through feedback from patients participating in support programs. 90 % of psoriasis patients treated with secukinumab reported an improvement in quality of life [12].

3. Brand reputation – assessed through analysis of reviews, media publications, and social media.

Economic indicators

These indicators help assess the profitability of marketing initiatives:

1. Return on investment (ROI) – the ratio of marketing costs to profit received. The ROI of the educational program for promoting infliximab was 150 % [13].

2. Cost per patient acquisition – marketing costs divided by the number of new patients starting treatment.

Clinical indicators

These indicators reflect the effectiveness of the drug in real clinical practice:

1. Clinical trial results – data on efficacy and safety obtained from local studies. The study showed that 70 % of Crohn's disease patients achieved remission with infliximab treatment [13].

2. Treatment adherence rates – the percentage of patients continuing treatment for a long time. Adherence to secukinumab treatment was 80 % after one year of therapy [14].

Regulatory and ethical indicators

These indicators reflect the compliance of marketing initiatives with legislative and ethical norms:

1. Compliance with legislation – no violations in advertising and promotion of the drug.

All Roche educational programs comply with the requirements of Federal Law № 61-FZ “On the Circulation of Medicinal Products” [15].

2. Compliance with ethical standards – compliance with the AIPM Code of Ethical Practice.

Johnson & Johnson received a certificate of compliance with AIPM ethical standards in 2021 [16].

Conclusions

Monoclonal antibodies (mAbs) represent a revolutionary tool in modern medicine, but their implementation is associated with complex challenges. The high specificity of mAbs ensures their effectiveness in oncological (breast cancer, lymphoproliferative diseases), autoimmune (rheumatoid arthritis, Crohn's disease), and infectious pathologies.

The structural complexity of the molecules requires:

- multilevel quality control (analysis of post-translational modifications, aggregation);
- investments in the development of orthogonal analytical methods for assessing biological activity.

Thus, the successful implementation of mAbs requires synergy between

scientific developments, regulatory support, and well-thought-out marketing solutions. Advances in analytical methods and ethical approaches to promotion will become critical factors for expanding access to this therapy.

Список литературы:

1. John, E. Sheil (2014) Monoclonal antibody therapy: The need for biopharmaceutical reference materials / John E. Sheil, Anthony Mire-Sluis, Darryl Davis. National Institute of Standards and Technology, Biomolecular Measurement Division, Gaithersburg, Maryland 20899, USA, 2014, 34 p.
2. Waller-Pulido, A., Jimenez-Perez, M. I., Gonzalez-Sanchez, F. A., Rojo-Gutierrez, R. P., Torres-Angiano E. et al (2023) Production of monoclonal antibodies for therapeutic purposes: a review // International Immunopharmacology. Vol. 120. P. 110376. ISSN 1567-5769.
3. Hafeez, U., Gan, H. K., Scott, A. M. (2018). Monoclonal antibodies as immunomodulatory therapy against cancer and autoimmune diseases // Current Opinion in Pharmacology, Vol. 41, 114-121.
4. Российская Федерация. Законы. Об обращении лекарственных средств: Федеральный закон № 61-ФЗ: [принят Государственной думой 24 марта 2010 года : одобрен Советом Федерации 31 марта 2010 года]. – URL: https://www.consultant.ru/document/cons_doc_LAW_99350/ (дата обращения: 28.03.2025). – Текст : электронный.
5. Российская Федерация. Законы. О рекламе: Федеральный закон № 38 ФЗ: [принят Государственной думой 22 февраля 2006 года : одобрен Советом Федерации 3 марта 2006 года]. – URL: https://www.consultant.ru/document/cons_doc_LAW_58968/ (дата обращения: 28.03.2025). – Текст : электронный.
6. Ассоциация Международных Фармацевтических Производителей : [сайт]. – 2025. – URL: <https://www.aipm.org> (дата обращения: 20.03.2025). – Текст : электронный.
7. Гарифуллина, Г. Х. Фармацевтический маркетинг: учебно-методическое пособие для обучающихся по специальности / Г. Х. Гарифуллина, И. А. Григорьева – М. : ГЭОТАР-Медиа, 2023. – 27 с. – Текст : непосредственный.
8. Pharmaceutical marketing: strategy and tactics / Smith M. S., Kolassa E. M., Perkins G., Sicker B. Boca Raton: CRC Press, 2002, 392 p.
9. Rituximab Market Size & Share, by Distribution Channel (Hospital Pharmacies, Retail Pharmacies, Online Pharmacies), Application (Blood Cancer, Rheumatoid Arthritis, Wegener Granulomatosis) – Global Supply & Demand Analysis, Growth Forecasts, Statistics Report 2025-2037. URL: <https://www.researchnester.com/reports/rituximab-market/3315> (date accessed: 30.03.2025)
10. Фармакоэкономическая оценка применения генно-инженерных биологических препаратов, применения в терапии болезни Крона, в условиях системы здравоохранения Российской Федерации / А. Ю. Куликов, В. Г. Серпик,

- А. В. Веселов, [и др.]. – Текст : непосредственный // Фармакоэкономика теория и практика. – 2020. – № 2. – С. 6-16.
11. Gibofsky, A. McCabe, D. (2020) US rheumatologists' beliefs and knowledge about biosimilars: a survey // Rheumatology (Oxford, England). 60, 1-6 10.1093/rheumatology/keaa502.
12. Foley, P., Manuelpillai, N., Dolianitis, C., Cains, G. D., Mate, E., Tronnberg, R., & Baker, C. (2022). Secukinumab treatment demonstrated high drug survival and sustained effectiveness in patients with severe chronic plaque psoriasis: 21-month analysis in Australian routine clinical practice (SUSTAIN study) // The Australasian journal of dermatology, 63(3), 303-311. URL: <https://doi.org/10.1111/ajd.13895> (date accessed: 30.03.2025).
13. Melsheimer, R., Geldhof, A., Apaolaza, I., & Schaible, T. (2019). Remicade® (infliximab): 20 years of contributions to science and medicine // Biologics: Targets and Therapy, 13, 139-178. URL: <https://doi.org/10.2147/BTT.S207246> (date accessed: 30.03.2025).
14. Novartis clinical data. Annual report 2021. URL: https://www.novartis.com/sites/novartis_com/files/novartis-annual-report-2021.pdf (date accessed: 30.03.2025).
15. Sustainability Report 2023. Roche Diagnostics International AG. URL: <https://assets.roche.com/f/164639/x/8e64e63c71/en-sustainability-report-2023.pdf> (date accessed: 30.03.2025).
16. Рынок фармацевтической продукции России: призма развития в разрезе существующих проблем современности / М. Г. Гришина, Е. А. Кабачевская, А. В. Коваленко, А. А. Халимова. – Текст : электронный // Modern Economy Success. – 2023. – № 2. – С. 129-134. – URL: https://elibrary.ru/download/elibrary_50323096_24092385.pdf (дата обращения: 1.04.2025). – EDN ETDBLB.

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STATIC BENDING AND VIBRATION ANALYSIS OF FUNCTIONALLY GRADED NANOBEMS USING MODIFIED NONLOCAL STRAIN GRADIENT THEORY

Abstract. A new modified nonlocal strain gradient theory is established for the static bending and free vibration analysis of functionally graded nanobeams. The novelty of the present study is that the nonlocal phenomenon not only influences classical stress but also influences the higher-order stresses associated with deviatoric, dilatation and deviatoric stretch gradient tensors. The proposed theory is validated via some specific comparison studies. A parametric study is provided to demonstrate the effects of the nonlocal parameter, material length-scale parameter, and power-law index on the mechanical behaviors of the nanobeams. The method and results of this study can be used for designing, testing, and optimization of the nanostructures.

Keywords: modified nonlocal strain gradient theory, nonlocal elasticity theory, modified strain gradient theory, strain gradient theory, nanobeams.

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АНАЛИЗ СТАТИЧЕСКОГО ИЗГИБА И ВИБРАЦИИ ФУНКЦИОНАЛЬНО ГРАДИЕНТНЫХ НАНОБАЛОК С ИСПОЛЬЗОВАНИЕМ МОДИФИЦИРОВАННОЙ НЕЛОКАЛЬНОЙ ТЕОРИИ ГРАДИЕНТА ДЕФОРМАЦИИ

Аннотация. Новая модифицированная нелокальная теория градиента деформации разработана для анализа статического изгиба и свободных колебаний функционально градиентных нанобалок. Новизна данного исследования заключается в том, что нелокальное явление влияет не только на классическое напряжение, но также на напряжения высшего порядка, связанные с девиаторными, дилатационными и градиентными тензорами девиаторного растяжения. Предлагаемая теория подтверждена с помощью некоторых сравнительных исследований. Было выполнено параметрическое исследование, направленное на выявление влияния нелокального параметра, масштабной длины материала и показателя степенного закона на механические свойства

нанобалок. Полученный метод и результаты данного исследования могут найти применение в процессе проектирования, испытаний и оптимизации наноструктур.

Ключевые слова: модифицированная теория градиента деформации, нелокальная теория упругости, теория градиента деформации, нанобалки.

1. Introduction

The use of micro- and nanostructures is rapidly expanding, particularly in micro-electromechanical systems (MEMS) and nano-electromechanical systems (NEMS). According to many investigations, classical elasticity theories may give wrong results (Reddy et al. [1]). Therefore, many higher-order elasticity theories have been introduced for analysis of these small-scale structures. Eringen [2, 3] introduced the nonlocal elasticity theory (NET) for the analysis of nanostructures. In this theory, stress at a solid point depends not only on the strain at that point but also on the neighbors' points. This theory has been applied to analyze the static bending, free vibration, buckling, and dynamic response of nanoplates, nanobeams, and nanoshells (Zenkour [4], Thai [5], Zhu et al. [6]). For microstructures, there are many theories such as modified couple stress theory, strain gradient theory, and modified strain gradient theory (MSGT) that were developed and applied to investigate mechanical and thermal behaviors (Gorji Azandariani et al. [7], Eremeyev et al. [8], Karamanli et al. [9], Hung et al. [10]). These theories are compatible only for the analysis of microstructures.

The main goal of this study is to develop a unique higher-order elasticity theory that is compatible for the analysis of both micro- and nanostructures. This theory considers simultaneously nonlocal and strain gradient effects for classical and higher-order strains, stresses. Then it is applied to investigate the static bending and free vibration characteristics of nanobeams.

2. Functionally graded nanobeam model

In this study, an FG nanobeam with the length of L , the thickness of h , as presented in Figure 1, is examined. The material properties are calculated as follows:

$$P(z) = P_c V_c(z) + P_m V_m(z)$$

$$V_c(z) = \left(\frac{1}{2} + \frac{z}{h}\right)^k, \quad V_m(z) = 1 - V_c(z),$$

where P , P_c , P_m denote the material properties of the FG material, ceramic, and metal component, respectively; V_c, V_m denote the volume fraction of the ceramic and metal phases; k is the order of the graded variation of the volume fractions.

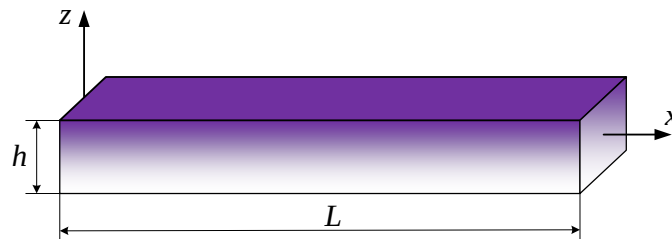


Figure 1 – Model of FG nanobeams

3. Theoretical formulations

3.1. Modified nonlocal strain gradient theory

Based on the MSGT proposed by Lam et al. [11], in addition to the conventional strain ε_{ij} , the dilatation gradient tensor γ_i , the deviatoric stretch gradient tensor η_{ijk} , and the symmetric curvature tensor χ_{ij} are incorporated into MSGT. Therefore, the strain gradient energy described in MSGT can be formulated as (Lam et al. [11]):

$$U = \frac{1}{2} \int_V (\sigma_{ij} \varepsilon_{ij} + p_i \gamma_i + \tau_{ijk} \eta_{ijk} + m_{ij} \chi_{ij}) dV \quad (1)$$

where σ_{ij} represents the Cauchy stress tensor, ε_{ij} denotes the strain tensor, and m_{ij} is the deviatoric part of the symmetric couple stress tensor. Additionally, χ_{ij} is the symmetric curvature tensor, γ_i represents the dilatation gradient tensor, and η_{ijk} stands for the deviatoric stretch gradient tensor. The higher-order stress tensors, p_i and τ_{ijk} are associated with the dilatation gradient and deviatoric stretch gradient tensors, respectively. The relationships between the components of the strain, symmetric curvature, dilatation gradient and deviatoric stretch gradient tensors and the displacement vector (u_1, u_2, u_3) can be given in the form of (Lam et al. [11]):

$$\begin{aligned} \varepsilon_{ij} &= \frac{1}{2} (u_{i,j} + u_{j,i}) \\ \chi_{ij} &= \frac{1}{4} (e_{imn} u_{n,mj} + e_{jmn} u_{n,mi}) \\ \gamma_i &= \varepsilon_{mm,i} \\ \eta_{ijk} &= \frac{1}{3} (\varepsilon_{jk,i} + \varepsilon_{ki,j} + \varepsilon_{ij,k}) - \frac{1}{15} \delta_{ij} (\varepsilon_{mm,k} + 2\varepsilon_{mk,m}) \\ &\quad - \frac{1}{15} \delta_{jk} (\varepsilon_{mm,i} + 2\varepsilon_{mi,m}) - \frac{1}{15} \delta_{ki} (\varepsilon_{mm,j} + 2\varepsilon_{mj,m}) \end{aligned}$$

where e_{ijk} and δ_{ij} denote the permutation symbol and Kronecker delta, respectively.

The stress tensor σ_{ij} , m_{ij} , p_i , and τ_{ijk} can be calculated by the following linear elastic constitutive relations (Lam et al. [11]):

$$\sigma_{ij} = 2\eta \varepsilon_{ij} + \lambda \varepsilon_{mm} \delta_{ij} \quad (2)$$

$$p_i = 2\eta l_0^2 \gamma_i \quad (3)$$

$$\tau_{ijk} = 2\eta l_1^2 \eta_{ijk} \quad (4)$$

$$m_{ij} = 2\eta l_2^2 \chi_{ij} \quad (5)$$

where l_0, l_1, l_2 are the material length scale parameters corresponding to the dilatation gradient, deviatoric stretch gradient and symmetric curvature, while η, λ denote Lamé's coefficients. In conventional local elasticity theories, the stress at a given point is determined solely by the strain at that same point. In contrast, Eringen's nonlocal elasticity theory [2, 3] postulates that the stress at a point is influenced by strains throughout the entire solid body. The fundamental constitutive equations for a nonlocal homogeneous material in the absence of body forces can be expressed as:

$$\sigma_{ij} = \int_V \alpha(|\mathbf{x}' - \mathbf{x}|, \varsigma) C_{ijkl} \varepsilon_{kl}(\mathbf{x}') dV$$

where $\alpha(|\mathbf{x}' - \mathbf{x}|, \varsigma)$ represents the modulus of nonlocal phenomenon, $|\mathbf{x}' - \mathbf{x}|$ is the Euclidean distance, and $\varsigma = e_0 a / l$ depends on the characteristic of internal and external lengths, e_0 is a material constant which depends on the essence of the material,

and has to be determined for each material independently, a is an internal characteristic length parameter, l is an external characteristic length parameter of the system. Applying the nonlocal elasticity assumptions to the deviatoric part of the symmetric couple stress tensor m_{ij} , the higher order stress tensors, associated with the dilatation gradient and deviatoric stretch gradient tensors, p_i and τ_{ijk} , one gets:

$$\begin{aligned} m_{ij} &= \int_V \alpha(|\mathbf{x}' - \mathbf{x}|, \varsigma) m_{ij}^{cl}(\mathbf{x}') dV \\ p_i &= \int_V \alpha(|\mathbf{x}' - \mathbf{x}|, \varsigma) p_i^{cl}(\mathbf{x}') dV \\ \tau_{ijk} &= \int_V \alpha(|\mathbf{x}' - \mathbf{x}|, \varsigma) \tau_{ijk}^{cl}(\mathbf{x}') dV \end{aligned}$$

According to Eringen [2, 3], using certain assumptions, the integral different equations of nonlocal elasticity can be simplified to partial differential equations. Therefore, the nonlocal constitutive relations can be written as follows:

$$(1 - \mu \nabla^2) \sigma_{ij} = 2\eta \varepsilon_{ij} + \lambda \varepsilon_{mm} \delta_{ij} \quad (6)$$

$$(1 - \mu \nabla^2) p_i = 2\eta l_0^2 \gamma_i \quad (7)$$

$$(1 - \mu \nabla^2) \tau_{ijk} = 2\eta l_1^2 \eta_{ijk} \quad (8)$$

$$(1 - \mu \nabla^2) m_{ij} = 2\eta l_2^2 \chi_{ij} \quad (9)$$

where $\mu = (e_0 a)^2$ is the nonlocal parameter. The nonlocal constitutive relations Eqs. (6)-(9) will be used instead of Eqs. (2)-(5).

3.2. Governing equations

The displacement field of the FG nanobeams can be written as follows:

$$\begin{aligned} U(x, z, t) &= u(x, y, t) - z \frac{\partial w_b(x, t)}{\partial x} + f(z) \frac{\partial w_s(x, t)}{\partial x} \\ W(x, z, t) &= w_b(x, t) + w_s(x, t) \end{aligned}$$

The formulation of $f(z)$ is given as follows (Shi et al. [12]):

$$f(z) = \frac{z}{4} - \frac{5z^3}{3h^2}; \quad g(z) = 1 + f'(z) = \frac{5}{4} - \frac{5z^2}{h^2}$$

Since the nonlocal behavior is introduced through the constitutive relations, and Hamilton's principle remains independent of these relations, it can still be utilized to derive the equations of motion. The principle can be stated in the following form:

$$\int_0^t (\delta \Pi^\sigma + \delta \Pi^p + \delta \Pi^\tau + \delta \Pi^m + \delta W - \delta K) dt = 0,$$

where $\delta \Pi^\sigma$ describes the variation of the strain energy related to the classical stress tensor, $\delta \Pi^p$ and $\delta \Pi^\tau$ are the variation of the strain energy related to higher-order stresses tensor, and $\delta \Pi^m$ describes the variation of the strain energy related to couple stress tensor, δW denotes the virtual work done by external forces, and δK denotes the variation of the kinetic energy of the beams.

Based on Hamilton's principle (Eq. (1)) and the constitutive relations of MNSGT (Eqs. (6)-(9)), the governing equations of motion of the nanobeams considering the nonlocal effects can be given as follows:

$$\begin{aligned}\delta u: & -\frac{\partial \bar{N}_x}{\partial x} + \frac{\partial^2 \bar{N}_x^p}{\partial x^2} + \frac{2}{5} \frac{\partial^2 \bar{N}_{xxx}^\tau}{\partial x^2} - \frac{1}{5} \frac{\partial^2 \bar{N}_{yyx}^\tau}{\partial x^2} - \frac{1}{5} \frac{\partial^2 \bar{N}_{zzx}^\tau}{\partial x^2} \\ & = (1 - \mu \nabla^2) \left(-I_0 \ddot{u} - I_1 \frac{\partial \ddot{w}_b}{\partial x} - I_2 \frac{\partial \ddot{w}_s}{\partial x} \right)\end{aligned}\quad (10)$$

$$\begin{aligned}\delta w_b: & -\frac{\partial^2 \bar{M}_x}{\partial x^2} - \frac{1}{2} \frac{\partial^2 \bar{N}_{xy}^m}{\partial x^2} - \frac{\partial^2 \bar{N}_z^p}{\partial x^2} + \frac{\partial^3 \bar{M}_x^p}{\partial x^3} + \frac{1}{5} \frac{\partial^2 \bar{N}_{zzz}^\tau}{\partial x^2} - \frac{4}{15} \frac{\partial^2 \bar{N}_{xxz}^\tau}{\partial x^2} \\ & + \frac{1}{15} \frac{\partial^2 \bar{N}_{yyz}^\tau}{\partial x^2} + \frac{2}{5} \frac{\partial^3 \bar{M}_{xxx}^\tau}{\partial x^3} - \frac{1}{5} \frac{\partial^3 \bar{M}_{yyx}^\tau}{\partial x^3} - \frac{1}{5} \frac{\partial^3 \bar{M}_{zzx}^\tau}{\partial x^3} \\ & = (1 - \mu \nabla^2) \left[-I_0 (\ddot{w}_b + \ddot{w}_s) + I_1 \left(\frac{\partial \ddot{u}}{\partial x} \right) + I_3 \left(\frac{\partial^2 \ddot{w}_b}{\partial x^2} \right) + I_4 \left(\frac{\partial^2 \ddot{w}_s}{\partial x^2} \right) + R_f \right. \\ & \quad \left. - q \right]\end{aligned}\quad (11)$$

$$\begin{aligned}\delta w_s: & \frac{\partial^2 \bar{P}_x}{\partial x^2} - \frac{\partial \bar{Q}_{xz}}{\partial x} - \frac{1}{4} \frac{\partial^2 \bar{N}_{xy}^m}{\partial x^2} + \frac{1}{4} \frac{\partial^2 \bar{M}_{xy}^m}{\partial x^2} - \frac{1}{4} \frac{\partial \bar{Q}_{yz}^m}{\partial x} - \frac{\partial^3 \bar{P}_x^p}{\partial x^3} + \frac{\partial^2 \bar{Q}_z^p}{\partial x^2} \\ & - \frac{1}{5} \frac{\partial^2 \bar{N}_{zzz}^\tau}{\partial x^2} + \frac{4}{15} \frac{\partial^2 \bar{N}_{xxz}^\tau}{\partial x^2} - \frac{1}{15} \frac{\partial^2 \bar{N}_{yyz}^\tau}{\partial x^2} - \frac{2}{5} \frac{\partial^3 \bar{P}_{xxx}^\tau}{\partial x^3} + \frac{1}{5} \frac{\partial^3 \bar{P}_{yyx}^\tau}{\partial x^3} \\ & + \frac{1}{5} \frac{\partial^3 \bar{P}_{zzx}^\tau}{\partial x^3} \\ & - \frac{2}{5} \frac{\partial^2 \bar{Q}_{zzz}^\tau}{\partial x^2} + \frac{8}{15} \frac{\partial^2 \bar{Q}_{xxz}^\tau}{\partial x^2} - \frac{2}{15} \frac{\partial^2 \bar{Q}_{yyz}^\tau}{\partial x^2} + \frac{1}{5} \frac{\partial \bar{R}_{xxx}^\tau}{\partial x} + \frac{1}{15} \frac{\partial \bar{R}_{yyx}^\tau}{\partial x} \\ & + \frac{4}{15} \frac{\partial \bar{R}_{zzx}^\tau}{\partial x} \\ & = (1 - \mu \nabla^2) \left[-I_0 (\ddot{w}_b + \ddot{w}_s) + I_2 \left(\frac{\partial \ddot{u}}{\partial x} \right) + I_4 \left(\frac{\partial^2 \ddot{w}_b}{\partial x^2} \right) + I_5 \left(\frac{\partial^2 \ddot{w}_s}{\partial x^2} \right) + R_f - q \right],\end{aligned}\quad (12)$$

where

$$\{\bar{N}_{ijk}, \bar{M}_{ijk}, \bar{P}_{ijk}, \dots\} = (1 - \mu \nabla^2) \{N_{ijk}, M_{ijk}, P_{ijk}, \dots\}; \quad i, j, k = x, y, z$$

3.3. Solution

In this study, a simply supported FG nanobeam is considered. The Navier's solution technique is used to solve the equations of motion (10)-(12), the unknown displacement functions of the beams are assumed to be explained in trigonometrical series as follows:

$$u = \sum_{m=1}^{\infty} U_m e^{i\omega t} \cos \alpha_m x; \quad \{w_b, w_s\} = \sum_{m=1}^{\infty} \{Wb_m, Ws_m\} e^{i\omega t} \sin \alpha_m x,$$

where $\alpha_m = m\pi/L$, $i^2 = -1$, and ω is the frequency of the micro-/nanobeams, U_m, Wb_m, Ws_m are the unknown coefficients, and m are the number of the half wavelength along with length and width of the micro-/nanobeams.

4. Results and discussions

4.1. Validations

The proposed theory is used to analyze homogeneous isotropic nanobeams. The obtained results are compared to the available solutions of Thai [5] using many shear deformation theories, including Euler-Bernoulli beam theory (EBT), Timoshenko beam theory (TBT), Reddy's beam theory (RBT), and higher-order shear deformation beam theory (HBT). The material and geometrical dimensions of the beams are $E = 380$ GPa, $\rho = 3800$ kg/m³, $\nu = 0.3$, $L = 10$ nm, the shear correction factor for TBT is 5/6. The dimensionless deflections, frequencies, and buckling loads are calculated as follows:

$$\bar{w} = w \frac{100EI}{q_0 L^4}; \quad \bar{\omega} = \omega L^2 \sqrt{\frac{\rho h}{EI}}; \quad I = \frac{h^3}{12}$$

The comparison is given in Tables 1 and 2 for various values of length-to-height ratio $L/h = 10$ and nonlocal parameter μ . The present results are in good agreement with the published data. Therefore, the present theory and algorithm are compatible for predicting the static bending, vibration and buckling behaviors of the nanobeams.

Table 1 – Comparison the dimensionless deflections of the isotropic nanobeams

μ	EBT ([5])	TBT ([5])	RBT ([5])	HBT ([5])	Present
0	1.3021	1.3346	1.3346	1.3346	1.3345
2	1.5521	1.5898	1.5898	1.5898	1.5896
4	1.8021	1.8449	1.8450	1.8450	1.8448

Table 2 – Comparison the dimensionless frequencies of the isotropic nanobeams

μ	EBT ([5])	TBT ([5])	RBT ([5])	HBT ([5])	Present
0	9.8293	9.7075	9.7075	9.7075	9.7076
2	8.9826	8.8713	8.8714	8.8714	8.8714
4	8.3228	8.2196	8.2197	8.2197	8.2198

4.2. Parameter study

In this subsection, a simply supported FG nanobeam with $L = 10$ nm and thickness h is investigated. The FG nanobeams are made of $\text{Al}_2\text{O}_3/\text{Al}$, with the material properties of $E_c = 380$ GPa, $\rho_c = 3800$ kg/m³, $\nu_c = 0.3$, $E_m = 70$ GPa, $\rho_m = 2707$ kg/m³, $\nu_m = 0.3$. In this study, it can be assumed that μ varies in the range of $0 \div 4$ nm², and $l_0/h = l_1/h = l_2/h = l/h$ varies in the range of $0 \div 1$. The following dimensionless quantities are used through numerical study:

$$w^* = \frac{100E_c h_0^3}{q_0 L^4} w \left(\frac{L}{2} \right); \quad \sigma_x^* = \frac{10h_0}{q_0 L} \sigma_x \left(\frac{L}{2}, \frac{h}{2} \right);$$

$$\tau_{xz}^* = \frac{10h_0}{q_0 L} \tau_{xz}(0,0); \quad \omega^* = \omega(10h_0) \sqrt{\frac{\rho_c}{E_c}}; \quad h_0 = \frac{L}{10}.$$

For static bending problem, the FG nanobeam is subjected to sinusoidal distributed loads $q = q_0 \sin(x\pi/L)$. The dimensionless deflections and stresses of the FG nanobeams under sinusoidal loads are presented in Table 3, the dimensionless frequencies of the FG nanobeams are given in Table 4 for various values of nonlocal parameters and material length-scale parameters.

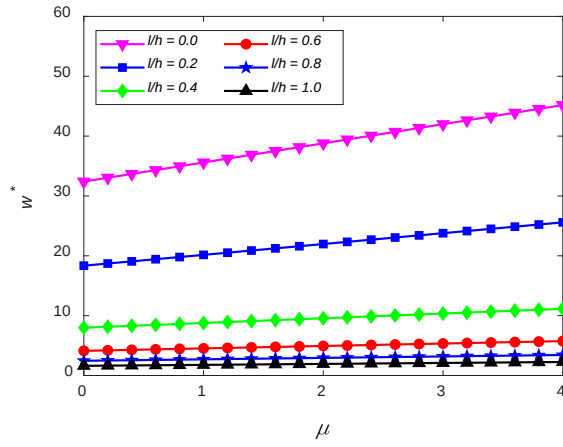
The variations of the dimensionless deflections and frequencies of the FG nanobeams versus nonlocal parameter and material length-scale parameter are demonstrated in Figures 2 and 3. When the nonlocal parameter increases, the deflections of the FG nanobeams increase, but the frequencies decrease. This means that the nonlocal parameters make the FG nanobeams softer than local beams. On the other hand, when the material length-scale parameters increase, the deflections of the FG nanobeams drop down rapidly, while the frequencies increase. The reason is that when the higher-order strain gradient tensors are considered, the beam needs more strain energy for deformations; therefore, the rigidity of the FG nanobeams is higher.

Table 3 – Dimensionless deflections, stresses of SS FG nanobeams ($L/h = 10$)

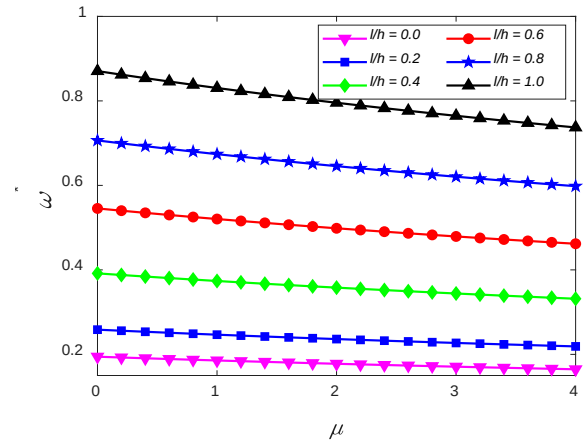
l/h	k	$\mu = 0$				$\mu = 4$		
		w^*	σ_x^*	τ_{xz}^*		w^*	σ_x^*	τ_{xz}^*
0	0	12.6348	61.0508	4.7732		17.6229	85.1527	6.6575
	5	38.6385	129.5964	3.8614		53.8924	180.7591	5.3858
	10	42.5830	155.3163	4.2294		59.3941	216.6328	5.8991
1	0	0.7356	3.4782	0.5576		1.0260	4.8513	0.7777
	5	2.2572	7.3781	0.2553		3.1483	10.2909	0.3561
	10	2.7695	9.9550	0.2659		3.8628	13.8850	0.3708

Table 4 – Dimensionless frequencies ω_m^* of SS FG nanobeams ($L/h = 10$)

l/h	k	$\mu = 0$					$\mu = 4$			
		ω_1^*	ω_2^*	ω_3^*	ω_4^*		ω_1^*	ω_2^*	ω_3^*	ω_4^*
0	0	0.2802	1.0709	2.2566	3.7164		0.2373	0.6668	1.0576	1.3739
	5	0.1836	0.6951	1.4480	2.3589		0.1555	0.4328	0.6786	0.8721
	10	0.1775	0.6693	1.3873	2.2484		0.1503	0.4168	0.6501	0.8312
1	0	1.1616	4.4255	9.4155	15.9333		0.9836	2.7556	4.4126	5.8905
	5	0.7596	2.9283	6.2585	10.5587		0.6432	1.8234	2.9331	3.9035
	10	0.6960	2.6945	5.7904	9.8093		0.5893	1.6778	2.7137	3.6265

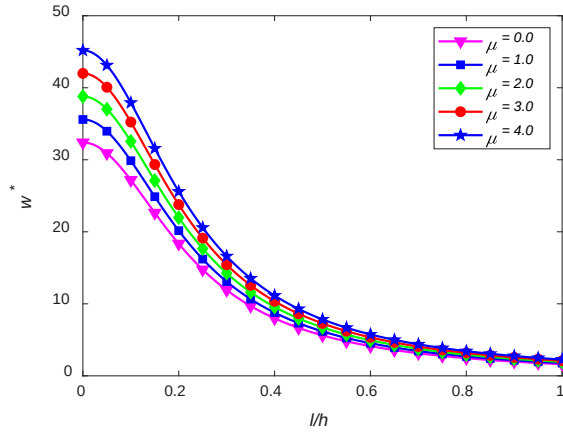


a) The deflections

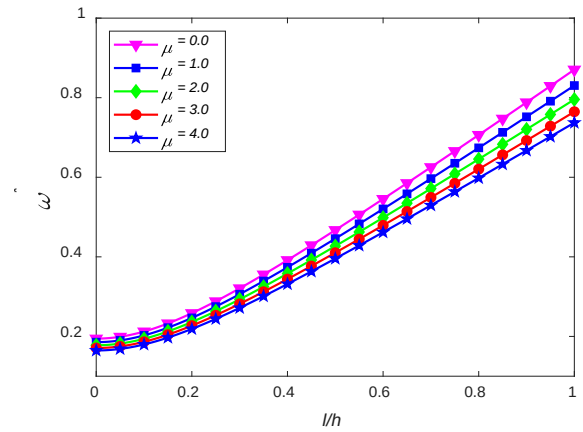


b) The frequencies

Figure 2 – The effects of the nonlocal parameters μ on the deflections and frequencies



a) The deflections



b) The frequencies

Figure 3 – The effects of ratio l/h on the deflections and frequencies

5. Conclusions

In this study, a new modified nonlocal strain gradient theory was developed for static bending and free vibration analysis of FG nanobeams. The proposed theory considers the effects of nonlocal phenomenon on classical and higher-order stress tensors simultaneously; therefore, it is compatible for analysis of a wide range of the small-scale structures from nano to macro dimensions. The present results shown that the nonlocal phenomenon has softening effects while the strain gradient has hardening effects on the mechanical behavior of the FG nanobeams. The proposed theory can be extended for predicting the mechanical and thermal behaviors of micro and nanostructures.

Список литературы:

1. Reddy, J. N., Pang, S. D. (2008) Nonlocal continuum theories of beams for the analysis of carbon nanotubes // *Journal of Applied Physics*. 103, 23511.
2. Eringen, A. C., Edelen, D. G. B. (1972) On nonlocal elasticity // *International Journal of Engineering Science*. 10, 233-48.
3. Eringen, A. C. (1972) Linear theory of nonlocal elasticity and dispersion of plane waves // *International Journal of Engineering Science*. 10: 425-435.
4. Aria, A. I., Friswell, M. I. (2019) A nonlocal finite element model for buckling and vibration of functionally graded nanobeams // *Composites Part B: Engineering*. 166, 233-246.
5. Thai, H. T. (2012) A nonlocal beam theory for bending, buckling, and vibration of nanobeams // *International Journal of Engineering Science*. 52, 56–64.
6. Zhu, C., Fang X., Yang, S. (2019) Nonlinear free vibration of functionally graded viscoelastic piezoelectric doubly curved nanoshells with surface effects // *The European Physical Journal Plus*. 134: 486.
7. Gorji Azandariani, M., Gholami, M., Vaziri, E., Nikzad, A. (2021) Nonlinear Static Analysis of a Bi-directional Functionally Graded Microbeam Based on a Nonlinear Elastic Foundation Using Modified Couple Stress Theory // *Arabian Journal for Science and Engineering*. 46, 12641-12651.
8. Eremeyev, V. A., Scerrato, D., Konopińska-Zmysłowska, V. (2023) Ellipticity in couple-stress elasticity // *Zeitschrift für angewandte Mathematik und Physik*. 74, 18.
9. Karamanli, A., Vo, T. P., Civalek, O. (2023) Finite element formulation of metal foam microbeams via modified strain gradient theory. *Engineering with Computers*. 39, 751-772.
10. Hung, P.T., Phung-Van, P., Thai, C.H. (2023) Small scale thermal analysis of piezoelectric–piezomagnetic FG microplates using modified strain gradient theory // *International Journal of Mechanics and Materials in Design*. 19, 739-761.
11. Lam, D. C. C., Yang, F., Chong, A. C. M., Wang, J., Tong, P. (2003) Experiments and theory in strain gradient elasticity // *Journal of the Mechanics and Physics of Solids*. 51, 1477-1508.
12. Shi, G. (2007) A new simple third-order shear deformation theory of plates // *International Journal of Solids and Structures*. 44, 4399-4417.

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VERBUNDWERKSTOFFE. IHRE ROLLE IN DER MODERNEN INDUSTRIE (DIE ÜBERSICHT)

Annotation. Im Artikel werden die Besonderheiten polymerer Verbundwerkstoffe und die Perspektiven ihrer Anwendung in verschiedenen Industriezweigen untersucht. Anhand von Beispielen werden einige aktuelle Forschungs- und Entwicklungsrichtungen aufgezeigt, die auf die Verbesserung der Eigenschaften dieser Materialien abzielen.

Schlüsselwörter: Verbundwerkstoffe, Entwicklung, Forschung, Markt, Eigenschaften, Anwendung.

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COMPOSITE MATERIALS. THEIR ROLE IN MODERN INDUSTRY (REVIEW)

Abstract. The article examines the characteristics of polymer composite materials and their potential for application across various industries. Through specific examples, it highlights current research and development trends aimed at enhancing the properties of these materials.

Keywords: composite materials, development, research, market, properties, application.

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КОМПОЗИЦИОННЫЕ МАТЕРИАЛЫ. ИХ РОЛЬ В СОВРЕМЕННОЙ ПРОМЫШЛЕННОСТИ (ОБЗОР)

Аннотация. В статье рассмотрены особенности полимерных композиционных материалов и перспективность их применения в различных отраслях промышленности. На примерах показаны некоторые актуальные направления исследований и разработок, нацеленных на улучшение свойств данных материалов.

Ключевые слова: композиционные материалы, разработки, исследования, рынок, свойства, применение.

In der modernen Welt ersetzen synthetische Materialien in vielen Bereichen der menschlichen Tätigkeit allmählich traditionelle natürliche Materialien. Dies ist auf ihre geringeren Kosten und die größere Vielfalt an Eigenschaften zurückzuführen, die traditionelle Materialien nicht aufweisen. Die vielversprechendsten Materialien im Hinblick auf die Weiterentwicklung von Herstellungstechnologien und deren anschließende Anwendung sind Verbundwerkstoffe. Dabei handelt es sich um Materialien, die aus zwei oder mehr Komponenten bestehen, deren Kombination zu der gewünschten Struktur und den gewünschten Eigenschaften führen soll. Eine dieser Komponenten, die als Matrix oder Bindemittel bezeichnet wird, ist ein durchgehender Bestandteil, in dem andere Komponenten, sogenannte Füllstoffe, verteilt sind.

In letzter Zeit gewinnen polymere Verbundwerkstoffe immer mehr an Bedeutung und Verbreitung, bei denen ein Polymer, wie beispielsweise Epoxid-, Polyester- oder Vinylesterharze, als Matrix dient. Als Füllstoffe werden am häufigsten Glasfasern, Kohlenstofffasern, Aramidfasern, verschiedene pulverförmige Materialien und andere verwendet [1].

Verbundwerkstoffe begegnen uns in den unterschiedlichsten Lebensbereichen – von Alltagsgegenständen über Transportmittel bis hin zur Medizin. Viele Dinge, die wir täglich nutzen, bestehen aus Kompositen: Möbel (Tische und Stühle aus Glasfaser-Kunststoff, Gehäusemöbel mit Holz-Polymer-Verbundstoffen), Arbeitsplatten aus Kunststein, Duschkabinen und Wannen aus Glasfaser-Kunststoff, Laminatböden (mehrschichtige Verbundmaterialien), Sportschuhe mit Komposit-Dämpfungssystemen, Mehrweg-Lebensmittelbehälter aus Polypropylen mit Zusätzen (z. B. Talkum zur Versteifung), Sportausrüstung (Helme, Schläger, Angelruten, Skier u. Ä.), Gehäuse von Haushaltsgeräten und vieles mehr. Dies zeigt, dass Verbundwerkstoffe zu einem unverzichtbaren Teil unseres Lebens geworden sind.

Der globale Markt für Verbundwerkstoffe entwickelt sich in den letzten Jahren dynamisch. Die hohen Wachstumsraten des Marktes für polymere Verbundwerkstoffe sind auf die breite Palette ihrer Eigenschaften zurückzuführen, die die Eigenschaften traditioneller Materialien übertreffen, sowie auf die Möglichkeit, zahlreiche verschiedenartige Ansätze zur Herstellung von Produkten zu nutzen. Dies beginnt bei der Modellierung ihrer Struktur, Eigenschaften und Form und reicht bis zur Auswahl der Produktionstechnologien [2]. Der globale Markt für Verbundwerkstoffe wird rasch mit innovativen Produkten gefüllt und hat breite Entwicklungsperspektiven. Zu den wichtigsten Trends, die diesen Markt prägen, gehören:

- Die steigende Nachfrage aus vielen Wirtschaftsbereichen – Luftfahrt, Automobilbau, Schiffbau, alternative Energieerzeugung, Maschinenbau, die Sportbranche, Medizin, Luft- und Raumfahrt, Schienenfahrzeugbau und Bauindustrie;
- Die Verbesserung der technologischen und ökologischen Eigenschaften bekannter Arten von Bindemitteln und Faserverstärkungen;
- Die zunehmende Nutzung von computergestützter Modellierung und Konstruktion von Produkten aus Verbundwerkstoffen [3].

Polymere Verbundwerkstoffe besitzen einzigartige Eigenschaften:

- Sie vereinen hohe Festigkeit mit geringer Dichte;
- Sie weisen eine hohe chemische und biologische Beständigkeit auf;
- Sie haben eine geringe Wärmeleitfähigkeit;
- Sie besitzen eine hohe Widerstandsfähigkeit gegen zyklische Belastungen;
- Sie sind in der Regel Dielektrika;
- Oft haben sie Eigenschaften, die von der Belastungsrichtung abhängen, was eine Optimierung des Materials für spezifische Anwendungen ermöglicht;
- Sie können hohe Temperaturen aushalten (wenn ein hitzebeständiges Polymer enthalten ist).

Darüber hinaus können bei der Herstellung von Verbundwerkstoffen für spezielle Anwendungen viele der genannten Eigenschaften je nach Zweck des Materials angepasst und verändert werden. Beispielsweise können Verbundwerkstoffe mit hoher elektrischer Leitfähigkeit hergestellt werden.

Daher ist die Weiterentwicklung von Technologien im Bereich der Verbundwerkstoffe – die Entwicklung innovativer Herstellungsmethoden oder die Schaffung neuer Materialien mit besonderen Eigenschaften – eine der prioritären materialwissenschaftlichen Aufgaben unserer Zeit [4]. Die bestehenden Forschungen zielen darauf ab, die Eigenschaften der Matrix und der Füllstoffe sowie der Verbundwerkstoffe insgesamt zu verbessern. Viele Arbeiten konzentrieren sich auf die Entwicklung umweltfreundlicherer Materialien und Technologien. Betrachten wir einige Beispiele.

Es gibt viele Forschungen, die darauf abzielen, die Eigenschaften von Harzen zu verbessern. Hier sind einige Beispiele.

Neues Epoxydharz mit verbesserten betrieblichen Eigenschaften wurde von koreanischen Forschenden des Korea Institute of Science and Technology (KIST) entwickelt. Es enthält latente Härter und zweidimensionales Nanomaterial MXene. Der latente Härter hat eine stark unterdrückte Reaktivität, wegen Nanozusatzstoffes. Dadurch konnte eine Lagerstabilität von über 180 Tagen bei einer Temperatur von 60 °C erreicht werden. Üblicherweise können solche Harze bei Raumtemperatur nur kurz gelagert werden.

Das neue Epoxidharz hat andere zahlreiche Vorteile:

- erhöhte Flammhemmung (wegen eines anorganischen Zusatzstoffes);
- verbesserte mechanische Festigkeit;

- Harz und Härter werden in voraus gemischt, deshalb werden Fehler beim Mischungsverhältnis ausgeschlossen, und es gibt hohe Qualität der erhaltenen Materialien sowie weniger schädliche Abfälle.

Die Aushärtung dieses Materials wird nur unter bestimmten Bedingungen ausgelöst, beispielsweise durch Wärme oder UV-Licht.

Dieses Material hat einen großen Bereich für potenzielle Verwendungen als:

- Klebstoffe und Beschichtungen;
- hochleistungsfähige Verbundwerkstoffe;
- Baumaterialien und so weiter [5].

Es gibt viele Arten von Kunststoffen, die als Konstruktionsmaterialien verwendet werden. Werden sie im Schiffsbau, für Flugzeuge, Windkraftanlagen oder für den Automobilbau verwendet, müssen diese Kunststoffe widerstandsfähig sein und über besondere thermische Eigenschaften verfügen. In solchen Fällen benutzt man faserverstärkte Kunststoffe, zum Beispiel, Epoxidverbundwerkstoffe. Aber sie haben auch mehrere Nachteile: sie lassen sich nicht recyceln und sie sind entflammbar.

Schweizer Forschenden haben neuen Kunststoff auf Basis von Epoxidharz entwickelt, der sich nicht nur vollständig recyceln lässt, sondern auch feuerbeständig und reparierbar ist. Dieser Kunststoff heißt «Vitrimere».

Sie haben einen besonderen Zusatz gefunden, der die Rolle eines Flammenschutzmittels spielt und den Kunststoff unter höheren Temperaturen zu schmelzen und zu verformen erlaubt. Das ist funktionale Molekül aus der Klasse der Phosphonsäureester.

Wegen dieser Eigenschaften kann man dieses Harz in verschiedenen Konstruktionen verwenden und das Problem der Verarbeitung und Wiederverwendung lösen. Die Fasern und die Kunststoffmatrix können komplett voneinander getrennt und wiederverwendet werden. Darüber hinaus lassen sich Kratzer und Beschädigungen am Material mit Druck und Wärme wieder entfernen [6].

Viele Arbeiten widmen sich der Verbesserung der Eigenschaften oder Technologien zur Herstellung von Faserfüllstoffen. Betrachten wir einige Beispiele.

Die Kohlenstofffasern werden oft als kontinuierlicher Füllstoff verwendet. Sie ermöglichen die Kunststoffe mit guten Betriebs-, Festigkeits- und Designeigenschaften zu erhalten. Es gibt jedoch ein ökologisches Problem.

Kohlenstofffasern entstehen aus organischen Ausgangsmaterialien der Petrochemie. In 95 % aller Fälle handelt es sich um Polyacrylnitril. Aber es gibt andere Präkursoren: Phenolformaldehydharz, Ölpäckchen. Doch der Druck auf Hersteller, nachwachsende umweltfreundliche Rohstoffe einzusetzen, wächst auch in diesem Bereich. Deshalb haben Forscher am Potsdamer Fraunhofer-Institut für Angewandte Polymerforschung IAP einen Weg gefunden, Kohlenstofffasern aus der Zellulose zu erhalten. Für dieses Verfahren haben sie einen neuartigen Ofen verwendet und weiter entwickelt, um Temperaturen von bis zu 2900 Grad Celsius zu erzeugen. Die Ausgangsstoffe werden in Graphitrohr erwärmt und gleichzeitig gestreckt.

Die Produktion von Kohlenstofffasern aus Präkursoren, die auf pflanzlichen Rohstoffen wie Zellulose und Lignin basieren, wurde bereits entwickelt, aber bei den üblichen Pyrolysetemperaturen von bis zu 1.600 Grad sind die mechanischen Eigenschaften, solche wie Steifigkeit und Festigkeit viel schlechter als bei klassischen

Kohlenstofffasern. Die Forscher bekamen Carbonfasern mit mechanischen Eigenschaften, wie man nur von erdölbasierten Produkten kennt.

Das Anwendungsgebiet von Kohlenstoffmaterialien und Kohlenstoffverbundwerkstoffen ist sehr breit. Das sind Baubranche, Windkrafterzeugung, Flugzeugbau, Sportindustrie und so weiter [7].

Ein wichtiger Entwicklungsschwerpunkt ist die Herstellung von Verbundwerkstoffen aus natürlichen Rohstoffen. So, zum Beispiel, ermittelte das Ford-Forschungszentrum naturfaserverstärkte Polymermaterialien für die Automobilindustrie.

Die Forscher wollten ein komplexes spritzgegossenes Bauteil aus naturfaserverstärktem Thermoplast herstellen und parallel die Herstellung sowie daraus resultierende mechanische Eigenschaften mittels Simulation berechnen. Sie benutzten viele unterschiedliche Naturfaser-Compounds mit Fasern aus Zelluloseregeneraten, Sisal-, Hanf-, Weizenstroh- und Holzfasern. Diese wurden zu Probekörpern gespritzt, an denen die Wissenschaftler unterschiedliche Parameter untersuchten: Faserverteilung, Faserorientierung, Faseragglomerate. Ergänzend führten die Forscher rheologische, thermische und mechanische Tests sowie mikroskopische Untersuchungen durch.

Für die weitere Arbeit im Projekt entschieden sich die Forscher schließlich für das Sisal-Polypropylen-Compound, weil dieses Material die besten Parameter zeigte. Später konnte Ford die ersten Fahrzeuginnenraum-details (z.B. Handschuhkästen) aus Sisal-PP-Compound der Fachöffentlichkeit präsentieren. Die Forscher haben auch eine Möglichkeit entwickelt, die Eigenschaften solcher Materialien mit der speziellen Software zu modellieren [8].

Darüber hinaus muss man auch die Eigenschaften der Verbundwerkstoffe verbessern. Zum Beispiel gibt es viele Entwicklungen für die Luftfahrt.

Die Leichtmaterialien finden häufig Anwendung im Fahrzeug und Flugzeugbau. Carbon ist einer der bekanntesten Werkstoffe in der Leichtbauweise. Es besteht aus Epoxidharz und faserigem Kohlenstofffüller. Ein Problem besteht darin, dass Schäden oder Brüche schwer zu erkennen sind.

Bei der Verwendung von Verbundwerkstoffen im Flugzeugbau muss man sicherstellen, dass Beschädigungen oder Spannungen in den Teilen erkannt werden können. Das neue Baumaterial ist ein beschichteter Verbundwerkstoff. Dieses Material ist transparent, unzerbrechlich, leicht. Das Material besteht aus mehreren Schichten und zwar aus Polymer, Glasplatten (künstliches Perlmutter) und einem speziellen Polymer-Indikator.

Die Forschungsgruppe der Eidgenössischen Technischen Hochschule Zürich (ETH) und der Universität Fribourg fügte dem Polymer ein Indikatormolekül hinzu. Wenn Expansionskräfte im Polymer erzeugt werden, wird dieses Molekül aktiviert. Aus diesem Grund ändert sich die Fluoreszenz und die Farbänderung gibt Auskunft über den Zustand des Materials. Die Fluoreszenz ermöglicht den Forschern, Bereiche innerhalb des Materials zu finden, die einer übermäßigen Belastung ausgesetzt sind. Auf diese Weise können solche Veränderungen frühzeitig erkannt werden, noch bevor das Material spröde wird. Die Früherkennung kann das Auftreten von Fehlern verhindern, die katastrophale Folgen haben können [9].

Ein wesentlicher Bestandteil der Entwicklung jedes Konstruktionswerkstoffs oder Werkstoffs für Sonderanwendungen ist die Modellierung. Sie ermöglicht die Vorhersage des Materialverhaltens unter sich ändernden Parametern der Umgebung und des Materials selbst. Durch computergestützte Modellierung lassen sich zudem die Kosten für reale Experimente erheblich reduzieren. Mit der Entwicklung der künstlichen Intelligenz sind die Möglichkeiten zur Modellierung von Bauteilen und Produktionsprozessen noch größer geworden. Heute stellt dies ein weiteres hochaktuelles Forschungs- und Entwicklungsfeld dar.

Zum Beispiel wurde das Projekt „Machine Learning for Simulation Intelligence in Composite Process Design“ gestartet. Gefördert durch die Leibniz-Gemeinschaft wurde ein interdisziplinäres Konsortium unter Beteiligung dreier Leibniz-Einrichtungen und zweier weiterer Forschungsinstitute gebildet. Gemeinsam entwickelte das Konsortium eine Vielzahl neuer Ansätze für die Werkstoff- und Prozesssimulation.

Sie werden insbesondere zur Optimierung des Herstellungsprozesses von Glasfaser-Kunststoff-Bauteilen verwendet. Mithilfe künstlicher Intelligenz wurden die Prozesse der Harzimprägnierung des Glasfaserverstärkungsmaterials während der Formgebung untersucht und simuliert, da deren Parameter entscheidenden Einfluss auf die Qualität des Endprodukts und die Materialkosten der Produktion haben [10].

Somit lässt sich feststellen, dass der Markt für Verbundwerkstoffe sich dynamisch entwickelt. Die Perspektiven für den Einsatz von polymeren Verbundwerkstoffen sind aufgrund der Einzigartigkeit ihrer Eigenschaften und ihrer Verarbeitbarkeit offensichtlich, während die Verwendung traditioneller Konstruktionsmaterialien oft ineffizient wird.

In diesem Zusammenhang ist ein aktives Wachstum von Forschung und Entwicklung zu beobachten, die darauf abzielen, die Produktionstechnologien dieser Materialien zu verbessern, ihre Gebrauchseigenschaften zu optimieren sowie umweltfreundlichere Materialien und Technologien zu schaffen. Dies lässt den Schluss ziehen, dass Verbundwerkstoffe die Materialien der Zukunft sind und dass ihre Eigenschaften und Herstellungstechnologien weiter verbessert, ihre Anwendungsbereiche erweitert und die Produktionsmengen erhöht werden.

Список литературы:

1. Колосова, А. С. Современные полимерные композиционные материалы и их применение / А. С. Колосова, М. К. Сокольская, И. А. Виткалова [и др.]. – Текст: непосредственный // Международный журнал прикладных и фундаментальных исследований. – 2018. – № 5-1. – С. 245-256.
2. Гладунова, О. И. Мировой и российский рынок полимерных композиционных материалов. Тенденции и перспективы / О. И. Гладунова, А. А. Лысенко. – Текст: непосредственный // Композитный мир. – 2021. – № 3. – С. 28-33.
3. Гавриленко, В. А. Композиты 21 века: возможности и реальность / В. А. Гавриленко // Деловой журнал Neftegaz.RU. – Текст : непосредственный. – 2019. – № 2. – С. 30-33.
4. Христофоров, Д. Е. Возможности реализации стеклопластиковых отходов производства композиционных материалов / Д. Е. Христофоров, Ю. А. Петраш.

- Текст : непосредственный // Вестник молодых ученых СПбГУПТД. – 2024. – № 4. – С. 81-88.
5. Jung, S. (2024) All-In-One Epoxy/MXene Nanocomposites with Bead-Type Polymeric Imidazole Latent Curing Agent for Enhancing Storage Stability and Flame Retardancy // Advanced Materials. Korea, 36 (50), 2408674.
6. Neuer Kunststoff lässt sich recyceln und schützt vor Flammen. – URL: <https://www.ingenieur.de/technik/fachbereiche/werkstoffe/neuer-kunststoff-laest-sich-recyceln-und-schuetzt-vor-flammen/> (Datum des Zugriffs: 26.02.2025).
7. Biobasierte Carbonfasern mit neuer Pyrolysetechnologie. – URL: <https://www.ingenieur.de/technik/fachbereiche/werkstoffe/biobasierte-carbonfasern-mit-neuer-pyrolysetechnologie/> (Datum des Zugriffs: 1.03.2025).
8. FNR fördert Einsatz naturfaserverstärkter Spritzgießmaterialien im Auto. – URL: <https://www.kunststoffe.de/a/news/fnr-foerdert-einsatz-naturfaserverstaerk-264626> (Datum des Zugriffs: 10.03.2025).
9. Revolution beim Leichtbau: Material verfärbt sich, wenn es brüchig wird. – URL: <https://www.ingenieur.de/technik/fachbereiche/werkstoffe/durchbruch-beim-leichtbau-material-verfaerbt-sich-wenn-es-bruechig-wird/> (Datum des Zugriffs: 11.03.2025).
10. May, D. (2024) Von der Faser bis zum Bauteil – Vision einer digitalisierten Prozessentwicklung // Kunststoffe. Deutschland, München, 10, 52-56.

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VI Всероссийской научно-практической конференции
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«ДИАЛОГ ПОКОЛЕНИЙ: ИЗУЧАЕМ. ОБУЧАЕМ. УЧИМСЯ»

2025 • Часть II

PROCEEDINGS
of the VI All-Russian Research and Practice Conference
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«DIALOGUE OF GENERATIONS: LEARN. TEACH. STUDY»

2025 • Part II

Редактор и корректор А. А. Чернышева
Технический редактор М. Д. Баранова

Научное электронное издание сетевого распространения

Системные требования:
электронное устройство с программным обеспечением
для воспроизведения файлов формата PDF

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Дата подписания к использованию 08.07.2025 г. Рег. № 5278/25

Высшая школа технологии и энергетики СПб ГУПТД
198095, СПб., ул. Ивана Черных, 4.