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DEVELOPMENT OF ADSORBENTS FOR RESERVOIR WATER TREATMENT

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Abstract. This article scientifically substantiates the technology for obtaining adsorbents used in the process of purifying formation waters produced in oil and gas fields. The physicochemical composition of formation waters was analyzed, and the importance of the adsorption process in reducing oil products, heavy metal ions, mechanical impurities, and dissolved salts in them was demonstrated. The thermal and chemical stages of obtaining adsorbents were analyzed, and their effectiveness was experimentally evaluated. activated carbon adsorbents used on the scale of the oil and gas industry, porous structure as a result of the process of activation by carbonization and oxidizing gases, the structure and properties of activated carbon biochemical composition depends on the nature of the precursor, which determines the dynamics, productivity, friction and ash content of the pyrolysis process.

Keywords: Layer water, activated carbons, oxidizing gases, cellulose biopolymers, synthesis, inorganic compounds, biomass, pyrolysis, biochemical properties.

Аннотация. В статье научно обоснована технология получения адсорбентов, применяемых в процессе очистки пластовых вод, образующихся на нефтегазовых месторождениях. Проанализирован физико-химический состав пластовых вод и показано значение процесса адсорбции в снижении содержания в них нефтепродуктов, ионов тяжелых металлов, механических примесей и растворенных солей. Были проанализированы термические и химические стадии получения адсорбентов, а их эффективность оценивалась экспериментально. применяемые в нефтегазовой промышленности адсорбенты с активированным углем в результате процесса карбонизации и активации окислительными газами имеют пористую структуру, структура и свойства активированного угля зависят от природы предшественника,

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биохимический состав которого определяет динамику процесса пиролиза, производительность, трение и зольность.

Ключевые слова: сточные воды, активированные угли, окислительные газы, целлюлозные биополимеры, синтез, неорганические соединения, биомасса, пиролиз, биохимические свойства

Annotasiya: Ushbu maqolada neft va gaz konlarida hosil bo‘ladigan qatlam suvlarini tozalash jarayonida qo‘llaniladigan adsorbentlarni olish texnologiyasi ilmiy jihatdan asoslab berilgan. Qatlam suvlarining fizik-kimyoviy tarkibi tahlil qilinib, ulardagi neft mahsulotlari, og‘ir metall ionlari, mexanik aralashmalar va erigan tuzlarni kamaytirishda adsorbsiya jarayonining ahamiyati ko‘rsatib o‘tilgan. Adsorbentlarni olishning termik, kimyoviy bosqichlari tahlil qilinib, ularning samaradorligi tajriba asosida baholangan. neft va gaz sanoati miqyosida ishlatiladigan faollashtirilgan uglerodli adsorbentlardan foydalanilgan, karbonizatsiya va oksidlovchi gazlar yordamida faollashtirish jarayoni natijasida g‘ovakli tuzilma, faollashgan uglerodning tuzilishi va xossalari biokimyoviy tarkibi piroliz jarayonining dinamikasini, unumdorligini, ishqalanishini va kul miqdorini belgilaydigan prekursorning tabiatiga bog‘liq.

Kalit so`zlar: Qatlam suvlari, faollantirilgan uglerodlar, oksidlovchi gazlar, sellyuloza biopolimerlari, sintezi, noorganik birikmalar, biomassa, piroliz, biokimyoviy xossalar.

INTRODUCTION

Protection of water resources from pollution and their rational use for the needs of the national economy are among the most important problems that require urgent solutions. Uzbekistan implements a wide range of environmental protection measures, in particular, on the rational use of water resources. One of the main areas of work on the protection of water resources is the introduction of new technological production processes, the transition to closed (drainless) cycles of water supply, where purified wastewater is not removed, but is repeatedly used in technological processes.

The current environmental situation and the state of environmental protection activities in the Republic of Uzbekistan contribute not only to the accelerated development and adoption of rational use of natural resources and effective environmental protection measures, but also to solving urgent scientific problems, in particular, hydrolysis and hydrolysis by growing algae, aquatic and marsh plants. This also requires the solution of appropriate biotechnologies for water purification in other industries. When processing raw materials in hydrolysis plants, a large amount of clean water is consumed. 500 m3 of wastewater is generated during the production of 1 liter of alcohol. The amount of wastewater discharged by a plant depends on its capacity. Thus, a medium-sized hydrolysis plant operating on wood waste discharges 6-7 thousand m3 of wastewater per day.

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Wastewater from the hydrolysis industry is polluted with organic and suspended solids compared to other wastewater. In this regard, the protection of reservoirs from wastewater pollution from the hydrolysis industry is of great economic and social importance. It is known that mechanical, physical, chemical and biological methods are used for wastewater treatment.

At the same time, biological reservoirs are used, the quality and nature of wastewater of which affect growth and development, as well as the composition of aquatic organisms and, ultimately, the intensity of wastewater treatment. Formation, composition and properties of wastewater. Depending on the conditions of formation, wastewater is divided into domestic, fecal, atmospheric and industrial. It also affects the composition of aquatic organisms and, ultimately, the intensity of wastewater treatment. Formation, composition and properties of wastewater. Depending on the conditions of formation, wastewater is divided into domestic, fecal, atmospheric and industrial. mixtures consisting of approximately 58% organic and 42% mineral substances are formed in these waters. Atmospheric wastewater is water that is formed as a result of melting rain and snow and drains from the territory of the enterprise. They are contaminated with organic and mineral additives. which are formed as a result of melting rain and snow and drain from the territory of the enterprise. They are contaminated with organic and mineral additives.

Domestic wastewater is water generated as a result of showering, washing, bathing, washing, mopping floors in dining rooms, toilets, etc. Mixtures consisting of approximately 58% organic and 42% mineral substances are formed in these waters. Atmospheric wastewater is water that is formed as a result of melting rain and snow and drains from the territory of the enterprise. They are contaminated with organic and mineral additives.

Industrial wastewater is generated during the processing and extraction of organic and inorganic raw materials. The sources that form wastewater in technological processes include:

1) waters formed as a result of chemical reactions (they are polluted by the starting materials and reaction products);
2) water in the form of free and bound moisture in raw materials and raw products, as well as moisture formed during processing;
3) water formed after washing of raw materials, products and water devices;
4) aqueous solutions;
5) Water extracts and absorbents;
6) heat carriers;

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7) other waste water; vacuum-waste water from pumps, mixing condensers, aerosol losses, washing dishes, appliances and buildings.

The amount and composition of wastewater depends on the type of production. It can be contaminated with various substances.: 1) biologically unstable organic compounds; 2) low-toxic inorganic salts; 3) petroleum products; 4) biogenic compounds; 5) specific toxic substances, including heavy metals, non-degradable organic synthetic compounds.

During the full technological cycle for the production of finished products, the water used is polluted by the initial, intermediate and final products. For example, wastewater from enterprises producing mineral fertilizers and inorganic substances with acids, alkalis, various salts (fluorides, sulfates, phosphates, phosphites, etc.), wastewater from enterprises of basic organic synthesis with fatty acids, aromatic compounds, alcohols, aldehydes; The waters of oil refineries - with petroleum products, oils, resins, phenols, SFM lar (surfactants); wastewater from enterprises producing artificial fibers, polymers, and various synthetic resins - will be contaminated with monomers, high-molecular substances, and polymer particles.wastewater from enterprises producing artificial fibers, polymers, and various synthetic resins will be contaminated with monomers, high-molecular substances, and polymer particles.

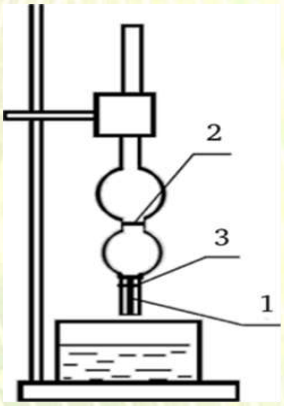


Figure 2.1. Stalagmometer. Hydrocarbon deposits g of activated carbon adsorbent is placed in a flask with a sample of reservoir water (0.5 - 1.5). It is shaken and stirred well and left alone for 20-30 minutes so that there is a balance in the solution. Then the layer in which the activated carbon is mixed is filtered through water, and the value of the solution that has reached the equilibrium state is determined by the method described above.

The degree of danger of wastewater depends on the nature and content of pollutants (toxicity) in them. Heavy metal salts, cyanides, phenols, hydrogen sulfide, carcinogens and other similar substances cause high toxicity of wastewater and a change in its odor.

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The amount of dissolved organic and inorganic substances, chemical oxygen demand and biochemical oxygen demand. The presence of impurities in the form of coarse, colloidal particles. I am on the following indicators:

1. Organoleptic parameters (color, taste, odor, transparency, turbidity of water, etc.).
2. Physico-chemical parameters (optical density, pH, temperature, electrical conductivity, alkalinity, acidity, hardness, fluidity, density, surface tension, etc.).
3. The amount of dissolved organic and inorganic substances, chemical oxygen demand and biochemical oxygen demand.
4. The presence of imp6urities in the form of coarse, colloidal particles.

Table-1

Elemental analysis of a water sample from the Northern Urtabulak m/r, exit from the CNS line

GdtcCjCP/	7Li	3Be 1	5	23Na	24Mg 27Al 31P	ЭЭК	44Ca	45Sc
The middle con-ration	24,31 mg/л	0,001 мэ/л	171,52 мг/л	21 233,06 мг/л	1 151,60 мг/л 0,398 мэ/л 1,38 мг/л	1 270,76 мг/л	7 044,63 мг/л	0,19 мг/л
Concentration	24,31 мэ/л	0,001 мг/л	171,52 мэ/л	21 233,06 мэ/л	1 151,60 мг/л 0,398 мг/л 1,38 мэ/л	1 270,76 мг/л	7 044,63 мг/л	0,19 мг/л
% CKO con-ration	m	нт	n/d	n/d	n/d	n/a		n/d
1 Category	51V	52Cr	55Mn	57Fe	59Cc	60Ni	63Cи	66Zn	71 Ga	
The middle con-ration	0,113 мэ/л	0,018 мэ/л	0,085 мэ/л	142,893 мэ/л	0,008 мг/л	0,033 мэ/л	0,055 мэ/л	0,047 мг/л	0,008 мэ/л	0,033 мг/л
Concentration	0,113 мэ/л	0,018 мэ/л	0,085 мг/л	142,893 мэ/л	0,008 мг/л	0,033 мг/л	0,055 мг/л	0,047 мг/л	0,008 мг/л	0,033 мг/л
% CKO con-ration	n/a	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Category					n/d					
The middle con-ration	1,755 мэ/л	0,311 мг/л	509,433 мг/л	0,754 мг/л	25.236 мг/л	0,001 мг/л	0,030 мг/л	0,414 мг/л	0,004 мг/л	0,004 мг/л
Concentration	1,755 мэ/л	0,311 мг/л	509,433 мг/л	0,754 мг/л	25.236 мг/л	0,001 мг/л	0,030 мг/л	0,414 мг/л	0,004 мг/л	0,004 мг/л
% CKO con-ration	m	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
1 Category	141 Pr	146Nd	147Sm	153Eи	157Gd	159Tb	163Dy	165 Ho	166Er	169Tr
The middle con-ration	0,005 мэ/л	0,002 мг/л	0,003 мг/л	0,005 мэ/л	0,002 мг/л	0,003 мг/л	0,003 мг/л	0,005 мг/л	0,001 мг/л	0,002 мг/л
Concentration	0,005 мэ/л	0,002 мэ/л	0,003 мг/л	0,005 мг/л	0,002 мг/л	0,003 мг/л	0,003 мг/л	0,005 мг/л	0,001 мг/л	0,002 мэ/л
% CKO con-ration	нт	n/d	n/a	n/d	n/d	n/a	n/d	n/d	n/a	n/d
	172Yb	1~5Lu185Re		205T!	208Pb 209Bi		232Th	233U
The middle con-ration	0,002 мэ/л	0,003 мэ/л	0,000 мг/л	0,000 мг/л	0,003 мг/л	0,001 мг/л	0,000 мг/л		0,002 мг/л
Concentration	0,002 мэ/л	0,003 мг/л	0,000 мг/л	0,000 мг/л	0,003 мг/л	0,001 мг/л	0,000 мг/л		0,002 мг/л
% CKO con-ration	n/d	n/d	нт	m	Ж	н/Д		н/Д	m.

When wastewater is heated, inorganic substances can also volatilize. Therefore, the presence of organic substances is proved by determining the chemical oxygen demand (COD) and the biochemical oxygen demand (BOD).the presence of organic substances in wastewater. When wastewater is heated, inorganic substances can also volatilize. Therefore, the presence of organic substances is proved by determining the chemical oxygen demand (COD) and the biochemical oxygen demand (BOD).

KBKE is the amount of oxygen consumed in an acidic environment for an oxidizing agent — potassium permanganate (KMnO4) or potassium bichromate (K2Cr2O7) in an equivalent amount. KBBE is the amount of oxygen that is spent on aerobic biodegradation of organic compounds over a period of time, and is determined by permanganate or bichromate oxidation. In both methods, the amount of oxygen consumed should be equivalent to the amount of oxidant used, i.e. KMnO4 or K2Cr2O7.

There are a number of ways to reduce the amount of contaminated wastewater. These include: 1) Creation and application of waste-free technological

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processes; 2) improvement of existing processes; 3) Creation and application of modern devices; 4) application of air cooling devices; 5) application of treated wastewater in circulating and closed systems.

Currently, the most optimal methods of reservoir water purification in oil fields are being developed. It can be said that there are many types of purification, among which the most preferred is adsorption purification. Currently, the demand for adsorbents is growing every day. As a local sorbent, it differs from other sorbents by improved sorption properties.

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PO‘LAT SIM ARQONLI EKSKAVTORLARDA YUZAGA KELUVCHI KUCHLAR O‘ZGARISHINING NAZARIY TAHLILI

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Annotasiya. Mazkur ishda yurtimizdagi konchilik korxonalarini rivojlantirish strategiyasi doirasida texnika parkini modernizasiya qilish, zamonaviy va yuqori quvvatli uskunalarni joriy etish masalalari ko‘rib chiqilgan. Ochiq usulda kon qazib olish jarayonida ekskavatorlar tog‘ jinslarini qazib olish ishlarini mexanizasiyalashning asosiy vositasi ekanligi ta'kidlangan. Shuningdek, po‘lat sim arqonli va gidravlik ekskavatorlarning turli modellari hamda ularning texnik ko‘rsatkichlari tahlil qilingan. Tadqiqotlarda ekskavatorlarning texnik darajasini baholashda cho‘mich hajmiga nisbatan metall sarfi va energiya samaradorligi muhim ko‘rsatkichlar sifatida ko‘rib chiqilgan. Natijada, kon ekskavatorlarining konstruksiyasini takomillashtirish va ularning ish samaradorligini oshirish bo‘yicha ilmiy xulosalar keltirilgan.

Kalit so‘zlar: konchilik sanoati, ochiq usulda qazib olish, gidravlik ekskavator, po‘lat sim arqonli ekskavator, cho‘mich hajmi, energiya samaradorligi, metall sarfi.

Аннотация. В данной работе рассматриваются вопросы модернизации технического парка и внедрения современной и мощной техники в рамках стратегии развития горнодобывающих предприятий нашей страны. Подчеркивается, что экскаваторы являются основным средством механизации добычи горных пород в процессе открытой добычи. Также анализируются различные модели стальных канатных и гидравлических экскаваторов и их технические показатели. В исследованиях в качестве важных показателей оценки технического уровня экскаваторов рассматриваются расход металла и энергоэффективность относительно объема ковша. В результате представлены научные выводы по совершенствованию конструкции горных экскаваторов и повышению их эксплуатационной эффективности.

Ключевые слова: горнодобывающая промышленность, открытая добыча, гидравлический экскаватор, стальной канатный экскаватор, объем ковша, энергоэффективность, расход металла.

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Abstract. This paper examines the modernization of the equipment fleet and the introduction of modern, powerful machinery as part of the development strategy for mining enterprises in our country. It emphasizes that excavators are the primary means of mechanizing rock extraction in open-pit mining. Various models of steel rope and hydraulic excavators and their technical performance are also analyzed. The study considers metal consumption and energy efficiency relative to bucket capacity as important indicators for assessing the technical level of excavators. As a result, scientific conclusions are presented on improving the design of mining excavators and increasing their operational efficiency.

Keywords: mining industry, open-pit mining, hydraulic excavator, steel rope excavator, bucket capacity, energy efficiency, metal consumption.

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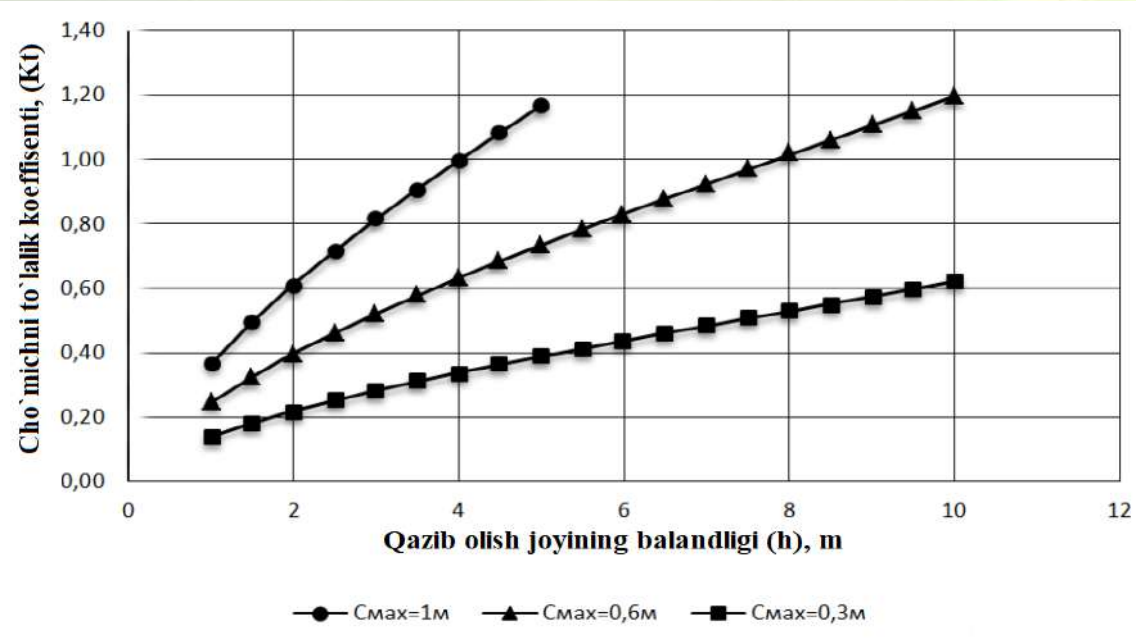
Yurtimizdagi yirik konchilik korxonalarini rivojlantirish strategiyasi, mahsulot sifati va raqobatbardoshligini yanada oshirishga va ishlab chiqarish hajmini bosqichma-bosqich oshirishga qaratilgan. Shu munosabat bilan, konchilik sanoati korxonalarida texnika parkini faol ravishda yangilanib modernizasiya qilishga va katta quvvatli yangi uskunalar xarid qilishga asosiy e'tibor qaratilmoqda.

Koʻpgina tadqiqotlar orqali shuni ta'kidlash mumkinki, ochiq usulda qazib olishda ekskavatorlar katta hajmdagi togʻ jinslarini qazib olish ishlarini mexanizasiyalashning asosiy vositasi hisoblanadi. Hozirgi vaqtda poʻlat sim arqonli ekskavatorlar va gidravlik ekskavatorlarning juda koʻp turli xil modellari ishlab chiqarilmoqda.

Tadqiqotlarda kon ekskavatorining texnik darajasini tavsiflovchi eng muhim koʻrsatkichlar bu, choʻmich unumdorlik birligiga nisbatan oʻziga xos metall sarfi va energiya samaradorligi hisoblanadi. Kon va transport uskunalarining ishlash samaradorligini aniqlash boʻyicha olib borilgan tadqiqotlar tahlili shuni koʻrsatdiki, ekskavatorlarning oʻziga xos metall mustahkamligining oshirib borilishiga e'tibor qaratilmoqda. Hozirgi vaqtda bu koʻrsatkichlar gidravlik ekskavatorlar uchun oʻrtacha 14-25 t/m3, poʻlat sim arqonli ekskavatorlar uchun 30-35 t/m3 ni tashkil qiladi. Shu bilan birga, bir qator tadqiqotchilar ekskavator massasini kamaytirish, boshqa jihozlari ogʻirligiga teng boʻlishiga ham salbiy ta'sir koʻrsatishini ta'kidlashadi, chunki bu mashinistning ish joyida kuchli tebranishlarga olib keladi va uning ish sharoitlarini yomonlashtiradi.

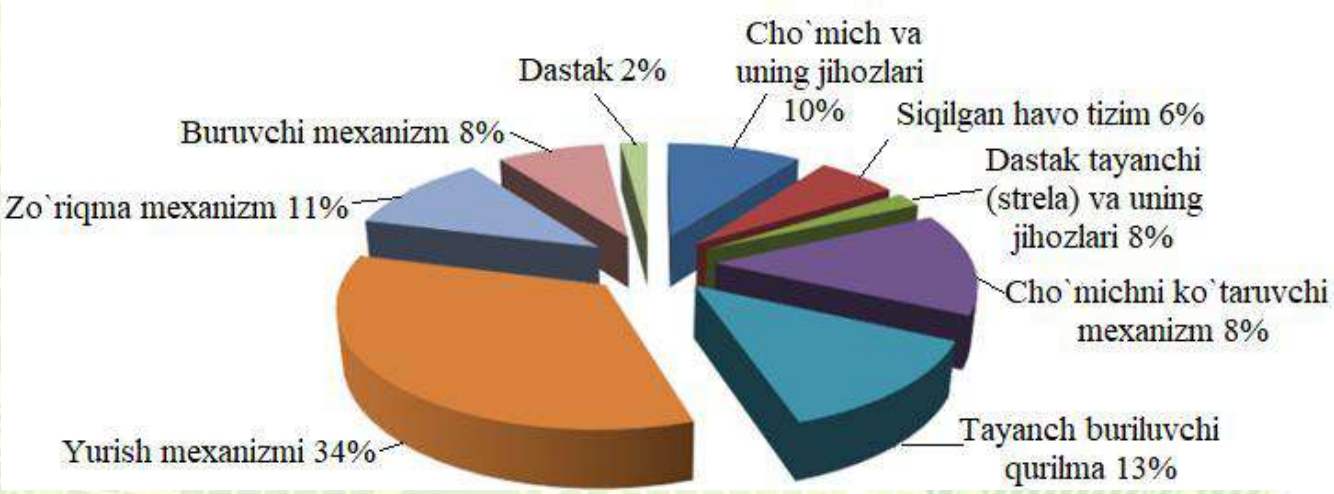
Ekskavator choʻmichining toʻlalik koeffisientining aniq qiymatlarini aniqlovchi $K_t = f(\Delta xu)$ funksiyaga bogʻliq (1-rasm). Ekskavatorning bir marta qamrashida choʻmichning toʻlishi (G) uchun qazish joyi balandligi $\Delta x = 4m$ boʻlishi kerakligi aniqlangan.

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1-rasm. Ekskavator cho‘michi to‘lalik koeffisientining turli qamrash qalinliklarida qazish joyi balandligiga bog‘liqlik grafigi

Qazish jarayonini boshqarish cho‘michning teng masofadagi traektoriyalari bo‘ylab harakatlanishini ta'minlaydi, bu esa asosiy yuritmalarning yuklamasining bir xilligini ta'minlab, qazish paytida ekskavatorning to‘xtalishlar sonini kamaytiradi. Po‘lat sim arqonli ekskavatorlar mexanik qismlarining ishdan chiqishi orqali ekskavatorlarning vaqt birligida to‘xtab qolishlari taqsimoti 1.6-rasmda keltirilgan.



2-rasm. Po‘lat sim arqonli ekskavator mexanik qismlari ishdan chiqishi orqali to‘xtab qolishlarning vaqt birligida taqsimoti

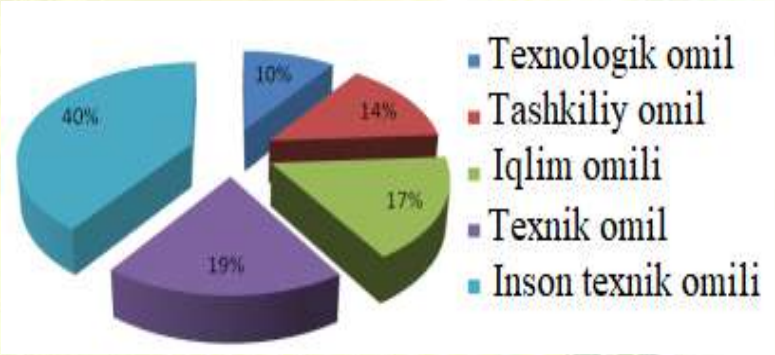
Unga asosan, yurish mexanizmi eng katta ko‘rsatkichga ega bo‘lib 34 %, tayanch buriluvchi qurilmasida 13 % ni, zo‘riqma mexanizmida 11 % ni, cho‘mich va uning jihozlarida 10 % ni, siqilgan havo tizimi 6 % ni, cho‘michni ko‘taruvchi mexanizmda 8 % ni tashkil etadi.

ADABIYOTLAR TAHLILI

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Respublikamizdagi yirik konchilik korxonalarida ekskavator parkining asosi hisoblanadigan cho‘mich hajmi 10-20 m3 bo‘lgan EKG-10, EKG-12,5, EKG-15 va EKG-20 ekskavatorlarini ta'mirlash va texnik xizmat ko‘rsatish tizimining qulayligi, bardoshliligi, mustahkamligi va ta'mirlashning oddiyligi bilan ajralib turadi. Bu kon uskunalari og‘ir sharoitlarda, ya'ni kon-geologik, tog‘ jinsining fizik-mexanik xususiyatlariga va iqlim sharoitlariga mos kelishi bilan ajralib turadi.

Ekskavatorlarning ishlashi va texnik holatining samaradorligini baholash va ta'minlashning ilmiy-uslubiy bazasini tahlil qilish asosida, ularning ish sharoitlari va rejimlariga qarab hamda ekskavatorlarning davriy harakatiga ta'sir etuvchi omillari tasniflanadi. Tasnifga ko‘ra, ta'sir etuvchi omillar oltita asosiy guruhga bo‘linadi: 1-kon-geologik va kon-texnik; 2 - iqlim; 3 - tog‘ jinsini tayyorlash sifati; 4 - ekskavatorni boshqarish; 5 - ekskavatorning texnik holati; 6 - kon qazish ishlarini
tashkil etish kabilar kiradi.

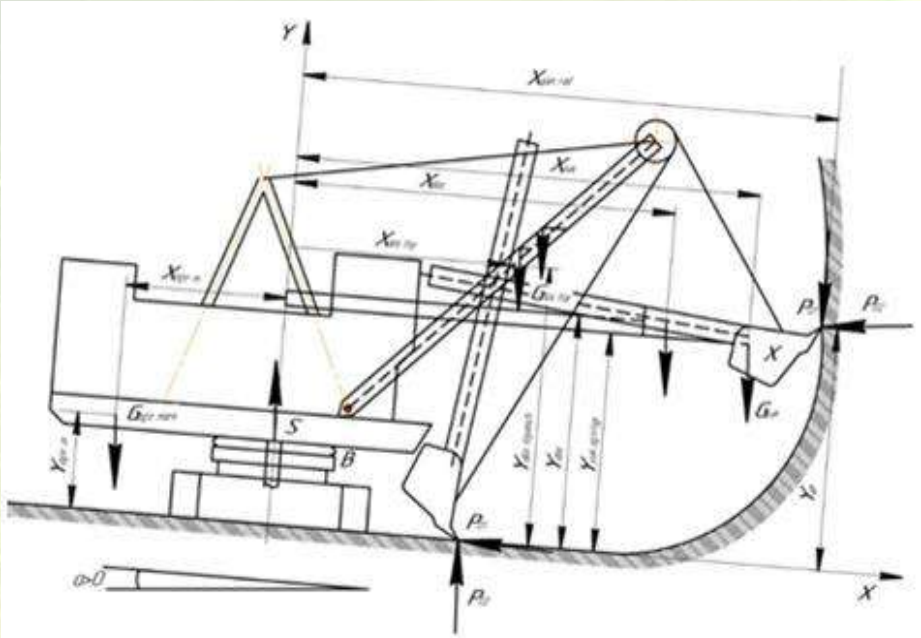


3-rasm. Ekskavatorlar mexanik uskunalarini ishlatish paytidagi ta'sir etuvchi omillari

Ekskavatorlar mexanik uskunalarini ishlatish paytidagi ta'sir etuvchi omillari 2-rasmda keltirilgan. Unga asosan, texnologik omillar 10 % ni, tashkiliy omillar 14 % ni, iqlim omillari 17 % ni, texnik omillari 19 % ni va inson, texnika omillari 40 % ni tashkil etadi.

3-rasmda ekskavator ma'lum bir qiyalikda turganida va ishchi maydonning notekis bo‘lganida mexanizmlarining muvozanati buzilishiga hamda ko‘pgina harakatlanish mexanizmlarining (yurish tasmalari burilishlarda yurish zvenolarining uzilishiga, ekskavatorni harakatlantiruvchi elektr yuritmasi va reduktori tishli uzatmalarining ishdan chiqishiga, markaziy sapfaga zo‘riqma tushishiga) ishdan chiqishiga olib keladi. Buning uchun ishchi maydonni maxsus mashinalar bilan tekislash va ekskavatorni tekislangan qazish joyiga olib borish lozim bo‘ladi.

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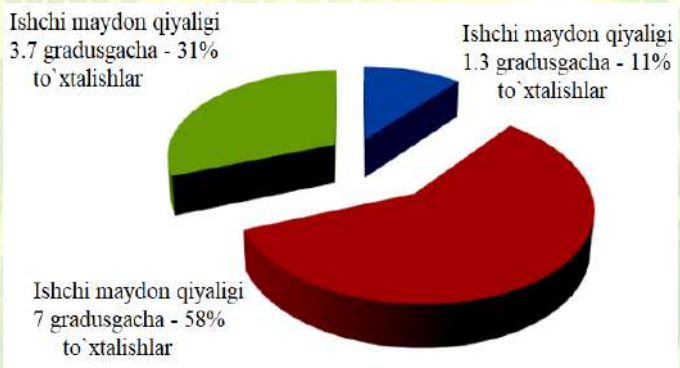


4-rasm. Ekskavator ish joyining burchak ostida joylashuvida muvozanat holatining o‘zgarish sxemasi

Po‘lat sim arqonli ekskavatorlarga tog‘ jinslarini qazib olish joyida gorizontal holatda yoki 0-3 gradus oralig‘ida ish jarayonini ta'minlash kerak. Keltirilgan burchakning oshib borishi bilan ekskavator uskunalarining ishdan chiqishiga, ya'ni tez ta'mir talab holatga kelib.

MUHOKAMA VA NATIJALAR

Olib borilgan tadqiqotlarga asosan, qiyalikning ortib borishi bilan ishchi jihozlarining ishdan chiqishi ortib borishi kuzatilgan bo‘lib, 31 % to‘xtalishlar ishchi maydonining qiyaligi 3,7 gradus bo‘lganda, 58 % to‘xtalishlar 7 gradusgacha bo‘lgan holatlarda kuzatilgan (4-rasm).



5-rasm. Qiyalik ostida joylashgan ekskavatorlar uskunalarining ishdan chiqishi statistik ma'lumoti

Po‘lat sim arqonli ekskavatorlarni ishlatishda yuqorida keltirilgan omillarga e'tiborni qaratgan holda gorizontal tekislikda ish jarayonini tashkil etish va mexanik qismlari jihozlarining butligini hamda uzoq muddat ishlashini ta'minlash mumkin bo‘ladi.

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Yuqorida ta’kidlab o‘tilganidek karyer ekskavatorlarning ishlash jarayonida yuzga keladigan o‘zgarishlarni, qanday burchak ostida ishlashi zarurligi, ularning ish jarayonini nazariy tahlilini amalga oshirish eng muhim masaladir. Ushbu masalalarni yechishda strela uzunligi, kovsh hajmi, ishchi elementlarning ko‘ndalang kesim yuzalari va uzunliklari, og‘irliklari, elektr yuritmalar quvvati, tog‘ jinsining qattiqligi hamda zichligi kabi kattaliklarni inobatga olish zarur hisoblanadi.

Hozigi vaqtda ekskavatorlarning ishlash jarayonini modellashtirish, ishchi mexanizimlarga tushadigan kuchlarini hisoblash maxsus dasturlar yordamida amalga oshirilmoqda. Ekskavatorning ish jarayonini loyihalash masalala bo‘lsa o‘z ichiga quyidagi bosqichlarni oladi:

- ekskavatorning ishchi hududi
- aniq ishchi nuqtalardagi qazish kuchini oshirish
- elektr yuritmalarning asosiy yuklanganlik ish koeffisienti
- ekspluatatsiya vaqtidagi tsikl davomiyligi va h.k.

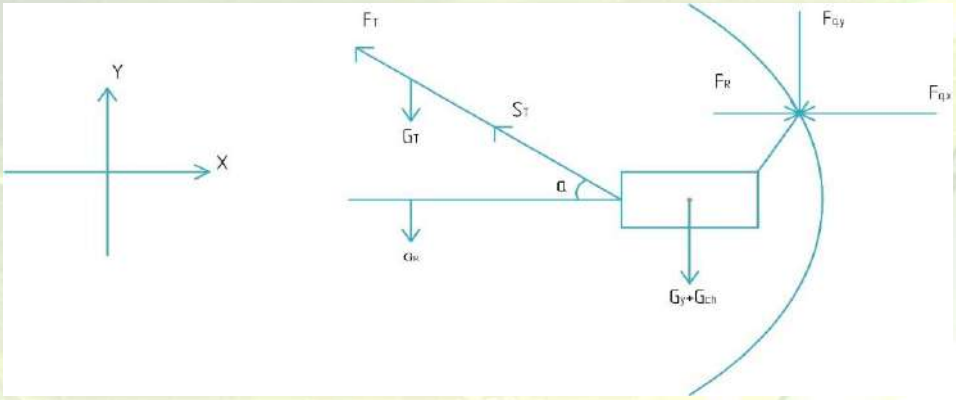
Modellashtirishdan asosiy maqsad taklif etilayotgan o‘zgarishlarni ishlab chiqarishga qo‘llashdan olidin dasturiy ta’minotlar yordamida sinab ko‘rish natijalarni amaldagi natijalar bilan taqqoslashdan iboratdir.

Bizga ma’lumki ekskavatorlarda yuzaga keladigan bir qator salbiy omillar bu uskunaning ma’lum bir kuchlar hisobiga yuzaga keladigan silkinishlar natijasida cho‘michni ko‘tarib turuvchi po‘lat arqonning chiqib ketishi orqali yuzaga keladi. Po‘lat arqonning chiqib ketishi hisobiga yuzaga keladigan saliy omillar quyidagilardan iborat:

- bosh blok o‘qining yeyilishi
- cho‘mich muvazanatining yo‘qotilishi
- po‘lat arqonning uzilishi
- ko‘taruvchi reduktor yuritmasiga yuklamaning ortib ketishi va h.k.

Yuqorida sanab o‘tilgan omillar unumdorlikning pasayib ketishi, rejasiz to‘xtalishlarning sodir bo‘lishi va ishchi elementlarning tez-tez ishdan chiqishiga sabab bo‘ladi. Shunday ekan ekskavatorlarning po‘lat sim arqonlariga ta’sir etuvchi kuchlar nazariyasi orqali barabanda hosil bo‘ladigan dinamik jarayonlarning matematik modelini ko‘rib chiqish maqsadga muvoffiq hisoblanadi.

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6-rasm. Ekskavator cho‘michi ilgarilanma harakat davomida qaizish jarayoni boshlanish onida vujudga keladigan kuchlar yo‘nalishi.

Bu yerda; $F_{q.y}$ va $F_{q.x}$ -vertikal va gorizontal qarshilik kuchlari, F_R- cho‘michning tog‘ jinsiga aks ta’sir kuchi, G_y va G_{ch}- yukning va cho‘michning og‘irlik kuchlari, S_T- po‘lat arqonida vujudga keladigan taranglik kuchi, G_T- po‘lat arqonning cho‘michga ulanish nuqtasidan barabanga tegish yuzasigacha bo‘lgan masofadagi og‘irlik kuchi, G_R- rukoyat og‘irligi, γ – po‘lat arqonning goorizont bilan tashkil qilgan burchagi.

Bir sikl davomida harakatda bo‘lganligi bois yuqoridagi parametrlarni o‘zgaruvchan va o‘zgarmaslarni aniqlab olamiz.

Quyidagicha:

$$F_{q.y} \neq const; \qquad 0 \leq F_{q.y}$$
$$F_{q.x} \neq const; \qquad 0 \leq F_{q.x}$$
$$F_R \neq const; \qquad 0 \leq F_R$$
$$G_{ch} = const;$$
$$G_y \neq const; \qquad 0 \leq G_y$$
$$S_T \neq const; \qquad S_T \neq 0$$
$$G_T \neq const; \qquad G_T \neq 0$$
$$G_R = const;$$
$$\gamma \neq const; \qquad 0 \leq \gamma < 90^0$$

Yuqorida aniqlab olingan o‘zgaruvchan va o‘zgarmas parametrlar asosida tortuvchi kuchni arqon bo‘ylab yo‘nalishi yuk va cho‘michga tezlanish beradi.

$$\begin{cases} \sum F_x = ma_x \\ \sum F_y = ma_y \end{cases}$$

$$\sum F_X = F_R - F_{q.x} - S_T \cos\alpha - F_T \cos\alpha = ma_x$$

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$$\sum F_y = -F_{q.y} - (G_y + G_{ch}) - G_R - G_T + (S_T + F_T)\sin\alpha$$

$$= ma_y \sqrt{(ma_x)^2 + \left(ma_y\right)^2} = F_T$$

$$\begin{cases} S_T \cos\alpha = ma_x + F_T \cos\alpha + F_{q.x} - F_R \\ S_T \sin\alpha = ma_y - F_T \sin\alpha + G_T + G_R + \left(G_y + G_{ch}\right) + F_{q.y} \end{cases}$$

$$ma_x + F_T \cos\alpha + F_{q.x} - F_R$$

$$= \tan\alpha\,(ma_y$$

$$- F_T \sin\alpha + G_T + G_R + G_y + G_{ch} + F_{q.y}) => F_T \cos\alpha + F_T \frac{\sin^2\alpha}{\cos\alpha}$$

$$= ma_y \tan\alpha + ma_x - F_{q.x} + F_R$$

$$+ \tan\alpha\left(G_T + G_R + G_y + G_{ch} + F_{q.y}\right)$$

$$\frac{F_T(\cos^2\alpha + \sin^2\alpha)}{\cos\alpha} = \tan\alpha\left(ma_y + G_T + G_R + G_y + G_{ch} + F_{q.y}\right) - F_{q.x} + F_R$$

$$F_{T=} \sin\alpha\left(ma_y + G_T + G_R + G_y + G_{ch} + F_{q.y}\right) + (F_R - F_{q.x} + ma_x)$$

$$F_{T=} f_1\left(\alpha; G_T; G_y; F_{q.y}; F_{q.x}; F_R\right).$$

Po‘lat arqonda vujudga keladigan taranglik kuchi yuqoridagi parametrlarga bog‘liq holda o‘zgarib turadi. Funksiyada o‘zgaruvchilar ham quyidagi parametrlarga bog‘liq holda o‘zgaradi.

$$G_y = \rho_t V_k g K$$

Bu yerda ρ_t- qazib olingan tog‘ jinsi zichligi

V_{k-} cho‘mich hajmi

g - erkin tushish tezlanishi

K – ko‘pshish koeffitsienti

Cho‘mich harakati trayektoriyasini murakkab jarayon hisoblanganligi evaziga cho‘mich tezlanishini oniy qiymatini aniqlash uchun difrensial tenglamalarga koordinata bo‘yicha aniqlaymiz.

$$\begin{cases} \frac{dv_x}{dt} = da_x => & dv_x = da_x dt \\ \frac{dv_y}{dt} = da_y => & dv_y = da_y dt \end{cases}$$

$$\int dv_x = a_x \int dt => \quad v_x = a_x t + C_1$$

$$\int dv_y = a_y \int dt => \quad v_y = a_y t + C_2$$

$$\frac{dx}{dt} = a_x t + C_1 \quad => \int dx = (a_x t + C_1) \int dt$$

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$$\frac{dy}{dt} = a_y t + C_2 \quad => \int dy = (a_y t + C_2) \int dt$$

$$x = \frac{a_x t^2}{2} + C_1 t + C_3; \qquad C_1 = 0 \quad C_2 = 0$$

$$y = \frac{a_y t^2}{2} + C_2 t + C_4; \qquad C_3 = 0 \qquad C_4 = 0$$

$$x = \frac{a_x t^2}{2} => \quad \frac{2x}{t^2} = a_x - \frac{v_{0x}}{t}$$

$$y = \frac{a_y t^2}{2} => \quad \frac{2y}{t^2} = a_y - \frac{v_{0y}}{t}$$

$$a_x = \frac{2x}{t^2} + \frac{v_{0x}}{t} = \frac{1}{t}(\frac{2x}{t} + v_{0x})$$

$$a_y = \frac{2y}{t^2} + \frac{v_{0y}}{t} = \frac{1}{t}(\frac{2y}{t} + v_{0y})$$

Cho‘mich olayotgan tezlanish yuqoridagi parametrlar orqali aniqlanib olinadi.

Bu yerda x – cho‘michning gorizontal ko‘chish masofasi

v_{0x} – cho‘michning goorizontal tezligi

v_{0y} – cho‘michning vertical tezligi

t - vaqt

Po‘lat arqonda vujudga keladigan taranglik kuchi yuqoridagi ifodalarni hisobga olgan holda quyidagi ko‘rinishda hosil bo‘ladi:

$$F_{T=} \sin\alpha \left(m\left(\frac{1}{t}\left(\frac{2y}{t} + v_{oy}\right)\right) + G_T + G_R + \rho_T V_k g K + G_{ch} + F_{q.y} \right)$$

$$+ \cos\alpha \left(m\left(\frac{1}{t}\left(\frac{2x}{t} + v_{0y}\right)\right) + F_R - F_{q.x}\right)$$

Tog‘ jinsi tomonidan cho‘michga ta’sir etuvchi qarshilik kuchi quyidagicha kinematik va dinamik bog‘liqligini tuzamiz:

$$\begin{cases} F_{q.x} = Rv_x^2 = R(a_x t + v_{0x})^2 \\ F_{q.y} = Rv_y^2 = R(a_y t + v_{0y})^2 \end{cases}$$

$$F_T = \sin\alpha \left(m\left(\frac{1}{t}\left(\frac{2y}{t} + v_{oy}\right)\right) + G_T + G_R + \rho_T V_k g K + G_{ch} + R\left(a_y t + v_{0y}\right)^2 \right)$$

$$+ \cos\alpha \left(m\left(\frac{1}{t}\left(\frac{2x}{t} + v_{oy}\right)\right) + F_R - R\left(a_x t + v_{0y}\right)^2\right)$$

Yuqorida keltirilgan matematik model ifoda yordamida bugungi kunda ochiq kon korxonalarida foydali qazilmani qazib olish va yuklash uchun qo‘llanilayotgan ekskavator qurilmasi po‘lat arqonlari va ishchi qismlariga tushadigan yuklama qiymatini nazariy hisoblashlar asosida aniqlash imkoniyati yaratildi.

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XULOSA VA TAKLIFLAR

Maqolada po‘lat sim arqonli ekskavatorlarning ish jarayonida yuzaga keladigan kuchlarning o‘zgarishi nazariy jihatdan tahlil qilindi hamda cho‘mich, po‘lat arqon va baraban tizimida hosil bo‘ladigan dinamik jarayonlar matematik modellashtirish asosida o‘rganildi. Tadqiqot natijalariga ko‘ra, qazish jarayonida cho‘michga ta’sir etuvchi qarshilik kuchlari, yuk og‘irligi, po‘lat arqon tarangligi hamda ekskavator ishchi mexanizmlarining geometrik parametrlari o‘zaro bog‘liq holda o‘zgarib borishi aniqlandi.

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IMPROVEMENT OF SERVICE LIFE OF A WORM GEAR REDUCER BY INTRODUCING AN ELASTIC SUPPORT ELEMENT

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Abstract. The reliability and service life of worm gear reducers largely depend on vibration levels and the wear of gear elements during operation. In this study, a modified design of a worm gear transmission with an elastic support element was developed in order to reduce vibration and mechanical wear. Experimental measurements were carried out for the conventional gearbox and the modified gearbox with the elastic element. Vibration parameters were analyzed in the axial direction. The obtained results show that the introduction of an elastic element into the gearbox structure leads to a noticeable reduction in vibration acceleration, velocity and displacement, which contributes to the decrease of wear processes and the increase of the operational life of the transmission system.

Keywords: worm gear reducer, vibration reduction, elastic support element, vibration diagnostics, gearbox reliability.

Аннотация. Надежность и срок службы червячных редукторов в значительной степени зависят от уровня вибрации и износа элементов передачи в процессе эксплуатации. В данном исследовании была разработана модифицированная конструкция червячной передачи с использованием упругого опорного элемента с целью снижения вибрации и механического износа. Экспериментальные измерения были проведены для традиционной конструкции редуктора и модифицированного редуктора с упругим элементом. Параметры вибрации анализировались в осевом направлении. Полученные результаты показали, что введение упругого элемента в конструкцию редуктора приводит к заметному снижению ускорения, скорости и перемещения вибрации, что способствует уменьшению процессов износа и увеличению срока службы механической передаточной системы.

Ключевые слова: червячный редуктор, снижение вибрации, упругий опорный элемент, вибрационная диагностика, надежность редуктора.

Annotatsiya. Chervyakli reduktorlarning ishonchliligi va xizmat muddati ko‘p jihatdan ishlash jarayonida yuzaga keladigan vibratsiya darajasi hamda uzatma elementlarining yeyilishiga bog‘liq. Ushbu tadqiqotda vibratsiya va mexanik yeyilishni kamaytirish maqsadida elastik tayanch elementiga ega bo‘lgan

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chervyakli uzatmaning modifikatsiyalangan konstruksiyasi ishlab chiqildi. Tajribaviy o‘lchovlar an’anaviy reduktor konstruksiyasi hamda elastik element bilan jihozlangan modifikatsiyalangan reduktor uchun amalga oshirildi. Vibratsiya parametrlari valning o‘q yo‘nalishi bo‘yicha tahlil qilindi. Olingan natijalar reduktor konstruksiyasiga elastik element kiritilishi vibratsiya tezlanishi, tezligi va siljishining sezilarli darajada kamayishiga olib kelishini ko‘rsatdi. Bu esa yeyilish jarayonlarining kamayishiga va mexanik uzatma tizimining xizmat muddatining oshishiga xizmat qiladi.

Kalit so‘zlar: chervyakli reduktor, vibratsiyani kamaytirish, elastik tayanch elementi, vibratsion diagnostika, reduktor ishonchliligi.

INTRODUCTION.

Worm gear reducers are widely used in various branches of mechanical engineering due to their compact structure, high transmission ratio, and ability to provide smooth and stable motion transmission. These gear systems are commonly applied in industrial machinery, transport equipment, lifting mechanisms, and automated production systems where reliable torque transmission and compact design are required.

Despite their advantages, worm gear transmissions are often subjected to considerable mechanical and dynamic loads during long-term operation. The sliding contact between the worm and the worm wheel leads to frictional effects that generate heat, vibration, and progressive wear of gear surfaces. As a result, the operational reliability and service life of worm gear reducers can significantly decrease under intensive working conditions.

One of the most important factors affecting the durability of worm gear transmissions is vibration generated during operation. Mechanical vibrations occur due to dynamic loading, misalignment, gear meshing irregularities, and shaft rotation. Increased vibration levels accelerate wear processes in gear teeth and bearings, reduce transmission efficiency, and may cause premature mechanical failure of gearbox components. [1]In recent years, considerable attention has been devoted to improving the dynamic performance and reliability of mechanical transmission systems. Researchers have proposed different approaches to reduce vibration and mechanical wear in gear mechanisms. These methods include optimization of gear geometry, improvement of lubrication conditions, enhancement of material properties, and application of vibration-damping or elastic elements in structural components.

The introduction of damping elements into mechanical systems is considered one of the effective approaches to reduce vibration transmission. Elastic components are capable of absorbing part of the dynamic energy generated during

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mechanical interaction of rotating elements, thereby decreasing vibration amplitude and reducing the load transferred to bearings and structural parts of the gearbox.

In the case of worm gear reducers, the use of elastic support structures can significantly influence the distribution of dynamic forces within the gearbox system. Properly designed elastic elements can act as vibration isolators, limiting the propagation of dynamic loads and improving the overall stability of the mechanical transmission. [2] Therefore, the development of improved structural design solutions aimed at reducing vibration and increasing the operational life of worm gear reducers remains an important scientific and engineering challenge.

In this study, a modified design of a worm gear reducer is proposed, which incorporates an elastic element into the bearing support structure. The proposed modification forms an updated mechanical transmission system intended to reduce vibration levels and mechanical wear.

Experimental investigations were carried out to evaluate the effectiveness of the proposed design. Vibration parameters of the gearbox were measured in the axial direction before and after the installation of the elastic support element. The obtained results allow assessment of the influence of the elastic element on vibration characteristics and operational reliability of the worm gear reducer.[3]

MATERIALS AND METHODS

Object of study

The object of the present study is a single-stage worm gear reducer used for transmitting rotational motion and torque in mechanical transmission systems. The main components of the reducer include a worm shaft, a worm wheel, a gearbox housing, and bearing supports that ensure stable positioning and rotation of the transmission elements.

The worm shaft acts as the primary driving element of the transmission system and interacts with the worm wheel to transfer motion and mechanical power. The technical drawing and main geometrical parameters of the worm shaft used in the experimental gearbox are presented in Figure 1.

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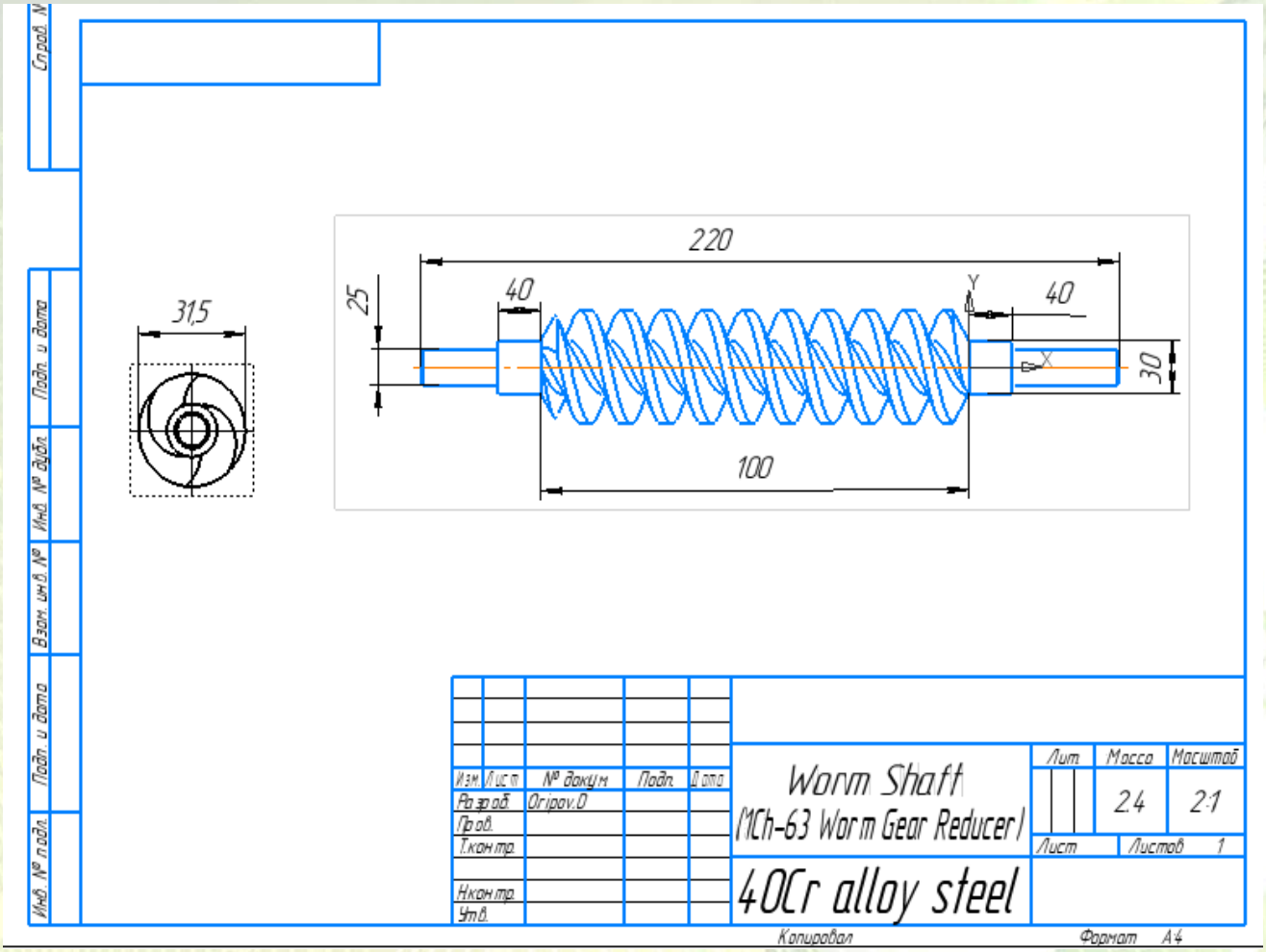


Figure 1. Technical drawing of the worm shaft used in the experimental worm gear reducer.

In the conventional gearbox design, the bearings are rigidly mounted inside the gearbox housing. Under such conditions, dynamic loads and vibrations generated during the meshing process of the worm and worm wheel are directly transmitted to the gearbox structure and supporting elements.[4]To improve the dynamic performance of the transmission system, a modified gearbox design was proposed. In the proposed design, an elastic element was introduced into the bearing support assembly in order to absorb part of the vibration energy generated during operation and reduce dynamic loads acting on the gearbox components. The location of the elastic support element in the modified worm shaft support is illustrated in Figure 2.

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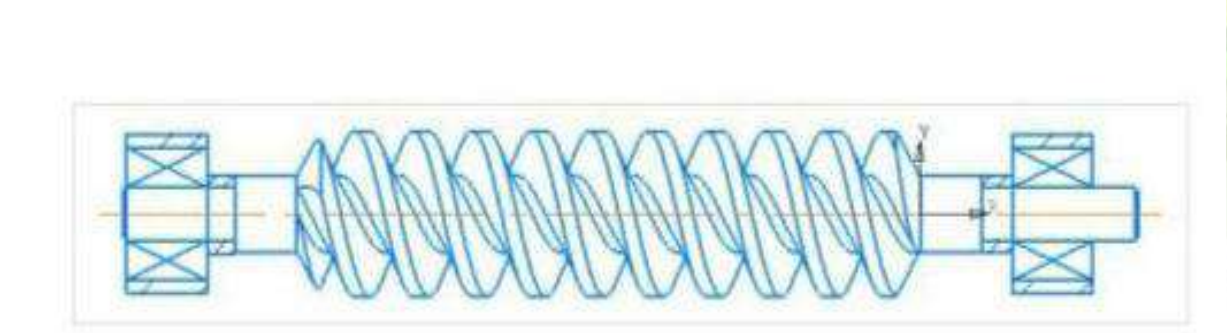


Figure 2. Location of the elastic vibration-damping element in the modified worm gear reducer.

As a result of the proposed structural modification, an updated mechanical transmission system with an elastic support element was obtained. The modified design is expected to improve vibration damping characteristics and increase the operational reliability and service life of the worm gear reducer.

Experimental setup

Experimental studies were conducted to evaluate the vibration characteristics of the worm gear reducer before and after the installation of the elastic support element. The main objective of the experiment was to determine the influence of the proposed structural modification on the vibration behavior of the gearbox and to assess its impact on the operational reliability of the mechanical transmission system. [5]For this purpose, vibration measurements were performed using the portable vibration diagnostic device VibXpert, which is widely used for industrial condition monitoring and vibration analysis of rotating machinery. The VibXpert system allows accurate measurement and analysis of vibration parameters in mechanical systems such as gearboxes, electric motors, pumps and compressors.

During the experiment, the vibration sensor of the VibXpert device was mounted on the gearbox housing near the bearing support area of the worm shaft. This measurement position was selected because vibration generated by the worm–wheel interaction and bearing operation is most clearly transmitted through this structural region.

The measurements were carried out in the axial direction of the gearbox shaft, since axial vibration components are significantly influenced by gear meshing forces and dynamic loads in worm gear transmissions.

The following vibration parameters were measured and analyzed:

• vibration acceleration (m/s^2) – characterizing the intensity of dynamic loads acting on the gearbox structure

vibration velocity (mm/s) – commonly used as a general indicator of mechanical condition and vibration severity

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vibration displacement (μm) – describing the amplitude of mechanical oscillations of the system

The VibXpert diagnostic system recorded vibration signals under stable operating conditions of the worm gear reducer. The obtained data were processed using the internal analysis functions of the device, which allow evaluation of vibration characteristics in different operating modes.

To determine the effectiveness of the proposed design modification, vibration measurements were conducted under two different operating conditions:

1. **Conventional gearbox design (before modification)** – the worm gear reducer operating with a standard rigid bearing support configuration.

2. **Modified gearbox design (after modification)** – the same worm gear reducer equipped with the proposed elastic support element integrated into the bearing assembly.

By comparing vibration parameters obtained in these two configurations, it was possible to evaluate the influence of the elastic element on vibration reduction and mechanical performance of the worm gear transmission.

The experimental results were then used to analyze the effectiveness of the proposed structural solution in reducing vibration levels and improving the operational durability of the gearbox.

RESULTS

The results of the experimental investigation carried out on the worm gear reducer are presented in Table 1. The measurements were performed in the axial direction of the gearbox shaft in order to compare the vibration characteristics of the conventional gearbox design and the modified gearbox equipped with the elastic support element.The comparative vibration parameters obtained during the experiment are summarized in Table 1.

Table 1

Comparative vibration parameters of the worm gearbox before and after modification (axial direction)

Parameter	Before	After	Unit
Acceleration	2.504	2.310	m/s²
Acceleration (max)	11.994	11.381	m/s²
Velocity	2.104	2.002	mm/s
Velocity (max)	7.424	6.789	mm/s
Displacement	8.754	8.423	μm
Displacement (max)	18.704	15.476	μm

The obtained results indicate that after the installation of the elastic support element, a noticeable reduction in vibration parameters was observed.

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The average vibration acceleration decreased from 2.504 m/s² to 2.310 m/s², which corresponds to a reduction of approximately 7.7%. Similarly, the maximum acceleration value decreased from 11.994 m/s² to 11.381 m/s², indicating a reduction in dynamic loading acting on the gearbox structure.

The vibration velocity also demonstrated a decrease after modification. The measured velocity decreased from 2.104 mm/s to 2.002 mm/s, while the maximum velocity value was reduced from 7.424 mm/s to 6.789 mm/s. Since vibration velocity is commonly used as a general indicator of the mechanical condition of rotating machinery, the observed reduction confirms the improvement in the dynamic stability of the gearbox.

A decrease in vibration displacement was also recorded. The displacement amplitude was reduced from 8.754 μm to 8.423 μm, while the maximum displacement value decreased from 18.704 μm to 15.476 μm. This reduction in oscillation amplitude indicates a lower level of mechanical vibration within the gearbox structure.

In addition to the general vibration parameters, additional vibration signals were recorded in fast signal mode for the bearing and machine components. These results are presented in Table 2.

Table 2.

Additional vibration parameters recorded in fast signal mode

Parameter	Before	After	Unit
Acceleration	75.353	52.641	m/s²
Velocity	3.848	3.454	mm/s
Displacement	34.343	31.076	μm

The fast signal mode measurements revealed a significant reduction in vibration acceleration. The acceleration value decreased from 75.353 m/s² to 52.641 m/s², which corresponds to a reduction of approximately 30%. This indicates that the elastic support element effectively absorbs dynamic loads generated during the operation of the worm gear transmission.

Similarly, vibration velocity decreased from 3.848 mm/s to 3.454 mm/s, while vibration displacement was reduced from 34.343 μm to 31.076 μm. These reductions demonstrate that the modified gearbox structure provides improved vibration damping characteristics.

Overall, the experimental results confirm that the introduction of the elastic support element into the worm gear reducer structure leads to a reduction in vibration acceleration, velocity, and displacement. This reduction in vibration

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levels contributes to the improvement of mechanical stability and potentially increases the operational service life of the gearbox components.

DISCUSSION.

The experimental results obtained in this study indicate that the proposed structural modification of the worm gear reducer leads to a noticeable reduction in vibration levels in the system. The comparison of vibration parameters before and after the installation of the elastic support element demonstrates that the modified gearbox configuration provides improved dynamic behavior.

The observed reduction in vibration acceleration, velocity and displacement can be explained by the damping properties of the elastic element introduced into the bearing support structure. In conventional worm gear reducers, the bearing assembly is rigidly mounted to the gearbox housing. Under such conditions, dynamic loads generated during gear meshing and shaft rotation are directly transmitted to the housing and other structural components of the gearbox.[6]

In the proposed design, the elastic element acts as a vibration-damping component. Due to its elastic properties, it is capable of partially absorbing and dissipating the dynamic energy generated during the operation of the worm gear transmission. [7]As a result, the intensity of vibration transmitted to the gearbox housing and bearing supports is significantly reduced.

The reduction in vibration acceleration and displacement indicates that the amplitude of mechanical oscillations in the gearbox system decreases after the modification. This improvement contributes to the stabilization of the rotating elements and reduces the influence of dynamic loads acting on the worm–wheel pair.

Another important observation is related to the reduction of vibration parameters recorded in the fast signal mode. The acceleration value decreased from **75.353 m/s² to 52.641 m/s²**, which corresponds to a considerable decrease in high-frequency vibration components. Such a reduction confirms that the elastic support element effectively mitigates dynamic impacts occurring in the gearbox during operation. Lower vibration levels in mechanical transmission systems lead to several important practical advantages. First, the reduction of dynamic loads decreases the wear rate of worm gear teeth, since excessive vibration often accelerates surface fatigue and friction processes. Second, reduced vibration improves the operating conditions of bearings, which can significantly extend their service life. Third, the overall mechanical stability of the transmission system increases, which contributes to more reliable and smoother operation of the gearbox.[8]

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In addition, the reduction of vibration levels may lead to a decrease in noise generation during operation, which is particularly important for industrial machinery operating in continuous production environments.

Thus, the results of the experimental investigation confirm that the introduction of an elastic support element into the structure of the worm gear reducer is an effective engineering solution for reducing vibration levels. The proposed design modification improves the dynamic performance of the gearbox and can contribute to increasing the reliability and durability of worm gear transmission systems.

CONCLUSION.

In this study, a modified design of a worm gear reducer incorporating an elastic support element was proposed and experimentally investigated. The main objective of the research was to evaluate the influence of the elastic element on the vibration characteristics and operational performance of the worm gear transmission system.

Experimental vibration measurements were carried out using the VibXpert diagnostic device in the axial direction of the gearbox shaft. The measurements were performed for two operating configurations: the conventional worm gearbox with a rigid bearing support structure and the modified gearbox equipped with the proposed elastic support element.

The comparative analysis of vibration parameters demonstrated that the installation of the elastic element leads to a noticeable reduction in vibration acceleration, velocity and displacement. In particular, the results obtained in the fast signal mode showed a significant decrease in vibration acceleration, indicating a reduction in dynamic loads generated during the operation of the gearbox.

The observed reduction in vibration levels confirms the effectiveness of the proposed structural modification. The elastic element functions as a vibration damping component, partially absorbing dynamic energy generated during gear meshing and shaft rotation. As a result, the dynamic loads transmitted to the gearbox housing and bearing supports are reduced.

Lower vibration levels contribute to improved operating conditions of gearbox components. In particular, reduced vibration intensity can decrease wear processes in worm gear teeth, improve bearing operating conditions and enhance the overall mechanical stability of the transmission system.

Therefore, the proposed modified mechanical transmission system with an elastic support element can significantly improve the operational reliability and service life of worm gear reducers. The results obtained in this study demonstrate that the introduction of elastic support structures is a promising engineering

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approach for increasing the durability and vibration resistance of worm gear transmission systems used in mechanical engineering applications.

Future research may focus on further optimization of elastic element parameters, investigation of vibration characteristics in other measurement directions, and analysis of the influence of the proposed design on long-term gearbox performance under different operating conditions.

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ЭНЕРГЕТИКА ТИЗИМЛАРИ САМАРАДОРЛИГИНИ ОШИРИШДА ГИДРОЭЛЕКТР СТАНЦИЯЛАРНИНГ ИШ РЕЖИМЛАРИНИ РОСТЛАШНИНГ АҲАМИЯТИ

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Аннотация. Ўзбекистон Республикаси энергетикаси тизимида юқори маневрли гидроэлектр ва гидротўплаш электр станциялар ёрдамида энергия ишлаб чиқариш ва истеъмол қилишни оптимал ростлашнинг зарурияти асосланган, мазкур станцияларнинг энергия ишлаб чиқариш жараёнида қатнашиш масалалари энерготизимнинг кунлик юклама графиги мисолида кўриб чиқилган. Мавжуд сув ресурсларидан максимал фойдаланган ҳолда иссиқлик ва гидроэлектр станциялар ўртасида юкламаларни оптимал тақсимлаш орқали иссиқик электр станцияларда ёқилғини тежаш имконияти ҳисоблар натижасида кўрсатилган.

Калит сўзлар: гидроэлектр станция, иссиқлик электр станцияси, сув сарфи, ёқилғи сарфи, кунлик юклама графиги, электр станцияси қуввати.

Abstract. The need for optimal regulation of energy production and consumption in the energy system of the Republic of Uzbekistan using highly maneuverable hydroelectric power plants and pumped-storage hydroelectric power plants is substantiated. Methods for distributing power between hydroelectric and thermal power plants are examined using the example of a daily load schedule for the energy system. Calculation results demonstrate the potential for fuel savings at thermal power plants through optimal load distribution between thermal and hydroelectric power plants, maximizing the use of available water resources.

Keywords: hydroelectric power plant, thermal power plant, water consumption, fuel consumption, daily load schedule, power plant capacity.

Аннотация. Обоснована необходимость оптимальной корректировки производства и потребления энергии с использованием высокоманевренных гидроэлектростанций и накопительных электростанций в энергетической системе Республики Узбекистан, рассмотрены вопросы участия этих станций в процессе производства энергии на примере суточного графика нагрузки энергетической системы. Результаты расчетов показывают возможность экономии топлива на тепловых электростанциях за счет оптимального

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распределения нагрузок между тепловыми и гидроэлектростанциями с максимальным использованием имеющихся водных ресурсов.

Ключевые слова: гидроэлектростанция, тепловая электростанция, водопотребление, расход топлива, график суточной нагрузки, мощность электростанции.

КИРИШ.

Ўзбекистон Республикаси энергетика тизимининг самарадорлигини оширишнинг асосий йўналишларидан бири электр энергиясини ишлаб чиқариш ва унинг истеъмолини оптималлаштириш зарурати билан боғлиқ кенг кўламли ишларни амалга оширишдир [1,2,3,4].

Бу ишлар қуйидагиларни ўз ичига олади:

- энергетика тизимининг кундалик юкламасини оптимал ростлаш ва тизимда электр энергияси кучланиши ҳамда частотасининг стандарт қийматларини таъминлаш асосида энергия тизимининг ишончлилигини ошириш;
- иссиқлик электр станциялари (ИЭС) иш режимларини оптималлаштириш, уларнинг техник ва иқтисодий кўрсаткичларини яхшилаш ва барча турдаги электр станцияларининг қувватидан оқилона фойдаланиш орқали зарарли чиқиндиларни камайтириш;
- тез ишга тушириладиган, фавқулоддаги захира энергия қувватининг доимий мавжудлигини таъминлаш;
- бошқа энергия тизимлари, жумладан, марказлаштирилмаган, локал тизимлар, микрогридлар ва бошқалардан энергия таъминоти самарадорлигини ошириш учун фойдаланиш [5,6];
- энергияни тўплаш ва сақлаш тизимларидан фойдаланиш [2].

Энергия тизимларидаги электр станцияларнинг иш режимларини ростлаш тизимнинг ёки станциянинг самарадорлигини ошириш мақсадида энергия истеъмоли талабини тўлиқ қондирган ҳолда электр энергиясини ишлаб чиқариш миқдорини ва муддатини ўзгартириш ишларини бажариш маъносини билдиради.

Гидроэлектр станция (ГЭС)лар энергия тизимидаги юклама ўзгаришларига тезда жавоб бериш қобилияти туфайли тизимда кунлик энергия истеъмоли графигини ростлашда фаол иштирок этиши мумкин, бу эса энергия ишлаб чиқаришни барқарорлаштиришнинг муҳим шартларидан бири ҳисобланади. ГЭСни тўхтаб турган ҳолатдан ишга тушириш, барқарор иш режимига чиқиш ва қувватни ошириш бор йуғи 1...2 дақиқа муддатни талаб қилади [2,3,7].

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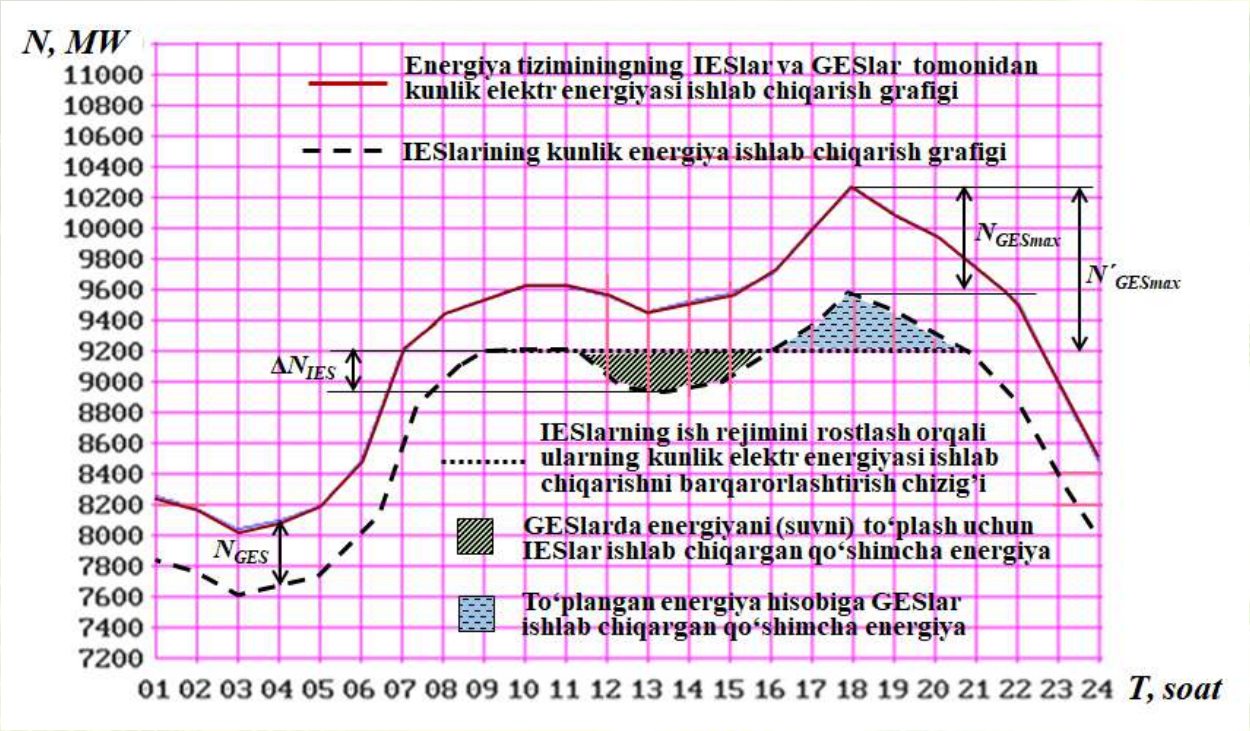
ИЭСларнинг маневр қилиш (тез иш режимини ўзгартириш, ишдан тўхтатиб яна ишга тушириш) имкониятлари чекланган. Замонавий газ турбинаси қурилмалари турбогенераторни совуқ ҳолатдан номинал юклама остида ишлашга ўтказиш учун камида 10 дақиқа, комбинацияланган циклли газ турбинаси қурилмаларига эса 120...240 дақиқа вақт талаб қилинади [8]. Масалан, General Electric компаниясининг авиацияда ва энергетикада фойдаланиладиган LMS100 маркали газ турбинали двигателлари, газ оқими сарфи 122 кг/с бўлганда 10 дақиқа ичида 73,2 тонна ёқилғи эквивалентини сарфлайди [9]. Талимаржон ИЭС унитар корхонасининг маълумотларига кўра битта қуввати 300 МВт ва ҳар бирининг қуввати 150 МВт бўлган иккита ПГУ қурилмаларидан ташкил топган ПГУ – 2 энергия блокининг ишдан тўхтатишлар сони 2017 йилда 7 тани ташкил қилди ва бунга турбоагрегатларни ҳар сафар ишга тушириб, режимга чиқариш учун ўртача 113,7 минг. $м^3$, жами йил давомида 796 тыс. $м^3$ табиий газ сарф қилинди [10].

Ушбу маълумотлар шуни кўрсатадики, ИЭС энергия блокларининг ўзгарувчан юкламали режимларда ишлаши жуда катта ёқилғи харажатлари билан боғлиқ ва бу режимларда юқори маневрли, ёқилғи сарф қилмайдиган агрегатлардан фойдаланиш ёқилғи ресурсларини сезиларли даражада тежашга олиб келади.

Ўзбекистонда юқори маневрли қувватлардан фойдаланиш имкониятини таҳлил қилиш, ушбу соҳада, айниқса гидротўплаш электр станция (ГТЭС)ларни қуришда мавжуд ишларнинг етарли эмаслигини кўрсатади.

Маълумотлар ва усуллар. Қиш даврида Ўзбекистон Республикаси электр энергияси тизимининг кунлик юклама графигининг нотекислик коэффициенти 0,72 дан 0,78 гача бўлган қийматларни ташкил этади (1-расм). Шунга ўхшаш нотекислик коэффициентларига эга ИЭСлар устунлик қиладиган хорижий энергия тизимларида юқори маневрли агрегатлар (асосан ГЭС ва ГТЭС агрегатлари)нинг улушини ошириш орқали энергия тизимининг барқарорлигини оширишга катта эътибор беришади [11].

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1 – расм. Ўзбекистон Республикаси энергия тизимининг 18.12.2017 даги кунлик юклама графиги

Ўзбекистон Республикаси ГЭСларнинг қуввати асосан электр энергияси юклама графигининг ўрта ва ярим чўққи қисмларида кунлик сув оқимини тартибга солиш асосида қўлланилади. Маълумки, ГЭСларнинг юкламаларни тартибга солишда иштирок этиш даражаси сув омборларига эга бўлса, сезиларли даражада ошиши мумкин. Бироқ, Республикада бундай иншоотларга эга ГЭСларнинг улуши ҳозирда уларнинг умумий қувватининг 48 % дан ошмайди. Бу шуни англатадики, энг юқори юкламаларни қоплашда ГЭСларнинг тартибга солиш қуввати энергия тизимидаги барча электр станциялари қувватининг 6...7% дан ошмайди.

Шу сабабли сув оқимларининг паст даражада тартибга солиниши туфайли, Республика энергия тизимидаги ГЭСларнинг тахминий иш режими 1-расмда кўрсатилган кўринишда бўлади.

Ушбу график Ўзбекистон Республикаси Энергетика вазирлиги ва "Ўзбекгидроэнерго" АЖ маълумотларига асосланган бўлиб, бу 2017 йил 18-декабр санасига тўғри келади.

ГЭС кунлик электр энергияси ишлаб чиқариш барча ГЭСларнинг қувватини соатбай йиғиш ва натижаларни шу санадаги энергия тизими юклама графигида акс эттириш орқали аниқланди. Юқорида келтирилган санада ГЭСларнинг энергия ишлаб чиқариши 12640 МВт·соат ни ташкил этди, бу 2017 йилдаги умумий ўртача кунлик ишлаб чиқарилган энергиянинг

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деярли ярмига тенг. Бундай ҳолат қишда манбалардан сув оқими камайиши ва суғориш учун сув омборларида тўпланиши билан изоҳланади.

НАТИЖАЛАР. Юқорида келтирилган графикда ИЭСлар иш режимини барқарорлаштириш, яъни турбоагрегатларни ишдан тўхтатиш ва ишга тушириш сонини камайтириш ГЭСлар иш режими ростлаш орқали амалга оширилиши мумкинлиги кўрсатилган. Масалан, соат 9^{00} дан 21^{00} гача ИЭСлар ўзгарувчан иш режимида ишлайди, яъни соат 11^{30} дан 16^{00} гача ишлаб чиқариш қувватини камайтириш (бу турбоагрегатларни ўчириш орқали бажарилади), соат 16^{00} дан 18^{00} гача ошириш (бу турбоагрегатларни ишга тушириш орқали бажарилади) ва яна 18^{00} дан 21^{00} гача камайтириш зарур бўлади.

Иссиқлик турбоагрегатларини тез-тез тўхтатиб ва яна ишга тушириш ёқилғининг ортиқча сарфланишига, иситиш ускуналарининг хизмат муддатининг қисқаришига, техник хизмат кўрсатиш харажатларининг ошишига, авариялар сонининг кўпайишига ва нормал ишлашни тиклаш вақтининг қисқаришига олиб келади [11].

ИЭСларнинг ушбу ўзгарувчан иш режимини барқарорлаштиришни қуйидаги тарзда амалга ошириш мақсадга мувофиқ ҳисобланади. Соат 9^{00} дан 16^{00} гача бўлган оралиқда ИЭСлар ўзгармас иш режимида (агрегатларни ўчиримасдан) қўшимча қувват $\Delta N_{ИЭС}$ билан ишлайди, бунинг ўрнига ГЭСлар қуввати гидротурбиналарга берилаётган сув сарфини қисқартириш ҳисобига камайтирилади ва бунинг натижасида сув омборларида ортиқча сув (энергия) тўпланади. Кейин соат 16^{00} дан 21^{00} гача ГЭСлар тўпланган сувдан фойдаланиб ва қувватни ошириб қўшимча электр энергиясини ишлаб чиқаради, бунда ИЭСларда турбоагрегатлар ишга туширилмайди, ГЭСлар қуввати N'_{GESmax} гача оширилади.

Энергия тизими агар мана шундай режимда ишласа, соат 9^{00} дан 21^{00} гача ИЭСлар иш режими барқарор бўлади ва катта миқдорда агрегатларни ишга тушириш учун сарф бўладиган ёқилғини тежаш имконияти тўғилади.

Буни қуйидаги ҳисоблар натижалари орқали кўрсатиш мумкин. Юқорида келтирилган график бўйича соат 11^{30} дан 16^{00} гача бўлган муддатда ГЭСлар ишлаб чиқарадиган энергия миқдори 600 МВт·соат эканлигини аниқлаш мумкин. Ушбу энергия сув омборларида қуйидаги миқдорда тўпланадиган сув ҳажмига эквивалентдир.

$$V = Э_Г \cdot 367/H \cdot \eta_{гэс} = 600 \cdot 367/70 \cdot 0{,}7 = 4500 \text{ тыс. м}^3$$

Бунда $Э_Г$ - ГЭСлар ишлаб чиқарадиган энергия миқдори, H – сув омборлари мавжуд бўлган ГЭСлар (Чорвоқ, Андижон, Тупаланг, Гисарак ва

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Оҳангарон)нинг ўртача напори, $\eta_{гэс}$ – ГЭСларнинг ўртача фойдали иш коэффициенти.

Ушбу сув ҳажмидан соат 16^{00} дан 21^{00} гача муддатда ГЭСларда қуйидаги миқдорда электр энергиясини ишлаб чиқариш мумкин

$$Э = V \cdot H \cdot \eta_{гэс} / 367 = 4500 \cdot 70 \cdot 0{,}7 / 367 = 600 \text{ МВт·соат}$$

Бунда шуни ҳисобга олиш зарурки, жаҳондаги деярли барча давлатларда энергия тиғиз бўлган (пик) пайтларда ИЭСларда ёқилғи сарфи кундузгига нисбатан 0,16...0,20 кг/(кВт·соат) кўп сарф сарф бўлиши ҳисобга олинади ва шунга қараб энергия тарифлари белгиланади [2]. Шу сабабли Ўзбекистон Республикаси Вазирлар Маҳкамасининг 2024-йил 31-майдаги “Электр энергияси ва табиий газдан фойдаланиш қоидаларини тасдиқлаш тўғрисида”ги 319-сон қарорига асосан энергия тиғиз бўлган пайтларда (17^{00} дан 22^{00} гача бўлган муддатларда) энергия тарифи кундузги ярим пик соатлар 9^{00} дан 17^{00} гача бўлган муддатдаги тарифга нисбатан 1,5 коэффициент билан аниқлаш таклиф қилинган [12].

Юқоридагилардан хулоса қилиш мумкинки, энергия тизимида 11^{30} дан 16^{00} оралиғида ИЭСлар ишлаб чиқарадиган энергияни ГЭСлар энергияси билан алмаштириш натижасида 600·0,18=108 тонна шартли ёқилғи тежалади. Бундан ташқари, ГЭСлар иш режими шундай ташкил этилмаса, ИЭСларда 1 – расмда келтирилган график бўйича 14^{00} дан 16^{00} гача қуввати 220 МВт, 16^{00} дан 18^{00} гача қуввати 400 МВт бўлган турбоагрегатларни ишга тушириш керак бўлар эди ва бунга камида 350 тонна шартли ёқилғи керак бўлар эди.

МУҲОКАМАЛАР. Сув оқимини ўзгартириш орқали ГЭС қувватини 1-2 дақиқа ичида тезда ростлаш имкониятини ҳисобга олсак, барча ГЭСлардан маълум даражада қувватни, шунингдек, қувват сифатини (стандартлаштирилган частота ва кучланиш қийматларини таъминлаш) тартибга солиш учун қисқа муддатли (бир неча соатда) юклама ўзгариши режимларида қўллаш учун фойдаланиш мумкин [2,3,7].

Ривожланган мамалакатлар энергия тизимларидаги тажриба шуни кўрсатадики, энергия тизим иш режимини оптимал равишда ростлаш учун, барча юқори маневрли агрегатларнинг улуши энергия тизимининг умумий ўрнатилган қувватининг камида 25 % ни ташкил қилиши керак [11].

Бугунги кунда Республикамизда ГЭСларнинг максимал тартибга солиш қуввати барча электр станцияларининг умумий ўрнатилган қувватининг 9,7 % дан ошмайди (ГЭС ларнинг умумий ўрнатилган қуввати 2500 МВт, барча электр станцияларики эса 25797 МВт) [13].

Шунинг учун, кунлик энергия истеъмоли юкламаси ва манбалардаги

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сув оқими сарфининг ўзгарувчанлиги сабабли, ГЭС қувватини тартибга солиш энергия тизими юкламасининг қисқа муддатли ўзгариши режимларида махсус ишлаб чиқилган дастурий таъминот пакетларидан фойдаланган ҳолда амалга оширилиши керак, бу эса ГЭС ларнинг оптимал иш режимларини сув ресурсларидан бошқа мақсадлар учун ҳам фойдаланишни ҳисобга олиб таъминлашни талаб қилади.

ХУЛОСАЛАР.

1. Ўзбекистон Республикаси энергия тармоғидаги ГЭСлар таҳлили шуни кўрсатдики, ГЭСларнинг асосий қисми паст босимли дарё оқими асосида ишлаётганлиги ва уларда сув омборлари йўқлиги сабабли энергия тизимининг юклама графигини ростлашда фаол иштирок эта олмайди. Бунинг натижасида энергия тиғиз (пик) бўлган соатларда ГЭСларнинг энергия тизими иш режимини ростлашдаги ҳиссаси 6...7 % дан ошмайди.

2. ГЭСларнинг энергия тизимидаги ростловчи сифатидаги иш режимининг бирламчи ҳисоблари Республика энергия тизимининг 18.12. 2017 йилдаги кунлик юклама графиги мисолида кўриб чиқилди. Ушбу ҳисоблар натижаларига кўра энергия тизими иш режимини ўзгартириб, кундузи 4,5 млн. $м^3$ сув ҳажмини сув омборларида тўплаш ва ундан энергия тиғиз (пик) бўлган кечки соатларда ГЭСлар ёрдамида электр энергиясини ишлаб чиқариш натижасида ҳар куни 458 тонна шартли ёқилғини тежаш мумкин. Бундан ташқари тубоагрегатларни ўчириб-ёқишнинг камайиши жиҳозларнинг хизмат муддатининг узайишига, техник хизмат кўрсатиш харажатларининг, авариялар сонининг қисқаришига олиб келади ва ИЭСлар самарадорлигини оширади.

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TEMIR YO‘LLARDAGI TEXNIK VOSITALARINI XAVFSIZLIK QOIDALARIGA MUVOFIQLIGINI TA’MINLASH CHORA TADBIRLARI

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Annotatsiya. Respublikamizda har bir sohaning mehnat sharoitlari xavfsizligini oshirishda ish joyidagi xavfli ishlab chiqarish omillari manbalarining yuzaga kelish sabablari, mehnat jarayonining og‘irligi va zo‘riqish parametrlari son va sifat ko‘rsatkichlarini baholash hamda innovatsion-texnik yechimlar, tashkiliy va sanitar-gigiyenik tavsiyalar ishlab chiqish yuzasidan keng qamrovli ishlar amalga oshirilib, bu borada muayyan natijalarga erishilmoqda. 2022-2026 yillarga mo‘ljallangan Yangi O‘zbekistonning taraqqiyot strategiyasida, jumladan, “Barcha transport turlarini uzviy bog‘lagan holda yagona transport tizimini rivojlantirish, transport va logistika xizmatlari bozori va infratuzilmasini rivojlantirish, transport sohasida tashqi savdo uchun “yashil koridorlar” hamda tranzit imkoniyatlarini kengaytirish” bo‘yicha muhim maqsadlar belgilab berilgan. Ushbu maqsadlarga erishishda, jumladan, temir yo‘l stansiyalari poyezd tuzuvchilarining kasbiy muvofiqligini belgilovchi jismoniy harakat sifatlari mezonlari asosida kasbiy faoliyatga muvofiqlikni baholash algoritmlari va ma’lumotlar bazasi ko‘rinishidagi instrumental vositalarni yaratish hamda kasbiy muvofiqligini belgilovchi harakat sifatlari, asab-ruhiy tavsiflarini o‘rganish bo‘yicha eksperimentlar o‘tkazish va kasbiy muvofiqligini belgilovchi harakat sifatlarini baholash uslubini asoslash muhim vazifalardan biri hisoblanadi.

Kalit so‘zlar: Temir yo‘l transporti, mehnat sharoitlari, innovatsion-texnik yechimlar, logistika, instrumental, yuklar, avariya-tiklash, sertifikatlashtirish.

Аннотация. В целях повышения безопасности условий труда в каждой отрасли нашей республики установлены причины возникновения источников опасных производственных факторов на производстве, тяжести трудового процесса и оценка количественных и качественных показателей стрессовых параметров, а также по разработке инновационных и технических решений, организационных и санитарно-гигиенических рекомендаций проводятся комплексные работы и в этом отношении достигаются определенные результаты. В стратегии развития Нового Узбекистана на 2022-2026 годы, в том числе «Развитие единой транспортной системы с интегральной связью

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всех видов транспорт, развитие рынка и инфраструктуры транспортно-логистических услуг», для иностранных торговля в транспортном секторе Определены важные цели для «зеленых коридоров» и расширения транзитных возможностей. Для достижения этих целей в том числе создание инструментальных средств в виде алгоритмов и баз данных для оценки пригодности к профессиональной деятельности на основе критериев двигательных качеств, определяющих профессиональную пригодность проводников поездов железнодорожных станций, а также изучение двигательных качеств и нервно-психологических характеристик, определяющих профпригодность, одной из важных задач является проведение экспериментов по обучению и обоснование методики оценки действий, определяющих профпригодность.

Ключевые слова: железнодорожный транспорт, условия труда, инновационно-технические решения, логистика, инструментальный, грузы, аварийно-восстановительный, сертификация.

Abstract. In order to improve the safety of working conditions in each industry of our republic, the causes of sources of hazardous production factors, the severity of the labor process, and quantitative and qualitative indicators of stress parameters are determined, and comprehensive work is being carried out to develop innovative and technical solutions, organizational and sanitary and hygienic recommendations, and in this regard certain results are being achieved. In the development strategy of the new Uzbekistan for 2022-2026, including “Development of a unified transport system with integral communication of all types of transport, development of the market and infrastructure of transport and logistics services”, trade in the field of transport for foreign countries defines “green corridors" and important goals to expand transit opportunities. To achieve these goals, including the creation of instrumental tools in the form of algorithms and databases for assessing suitability for professional activities. One of the important tasks is to conduct experiments on the criteria of motor qualities that determine the professional preparedness of passengers at railway stations, as well as to study the motor qualities and neuropsychological characteristics that determine professional preparedness. on research and justification of the method for assessing the qualities of action that determine professional suitability.

Keywords: railway transport, working conditions, innovative technical solutions, logistics, instrumental, cargo, emergency recovery, certification.

KIRISH.

O‘zbekiston Respublikasi Prezidenti Shavkat Mirziyoyev 2017-2021 yillarda O‘zbekiston Respublikasini rivojlantirishning beshta ustuvor yo‘nalishini

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harakatlar strategiyasida ko‘rsatib o‘tgan uchinchi yo‘nalishi “Mamlakatimiz iqtisodiyotini yanada rivojlantirish va liberallashtirish” yo‘nalishida quyidagilar alohida ko‘rsatilib o‘tilgan.

Inson hayotining xavfsizligini ta’minlash muammosi har bir jamiyat uchun dolzarb masala bo‘lib, u davlatning iqtisodiy rivojlanganligi va barqarorligiga bog‘liq. Bu hozirgi vaqtda ilmiy–texnik taraqqiyot keltirib chiqargan murakkab muammolarni har tomonlama yechishni, katta miqdorda mablag‘ va ishlab chiqarishning yuqori madaniyatini talab qiladigan muammodir. Ushbu muammoni hal etishda O‘zbekiston Respublikasi Prezidentining “O‘zbekiston Respublikasini yanada rivojlantirish bo‘yicha Harakatlar strategiyasi to‘g‘risida”gi 2017 yil 7 fevralda imzolangan Farmoni dastur amal bo‘lib xizmat qilmoqda. Bu esa O‘zbekiston Respublikasini iqtisodiy qudratli, kuchli ilmiy–texnik va intellektual imkoniyatlarga ega bo‘lgan davlat ekanligini ko‘rsatib, belgilab olingan vazifalardan kelib chiqqan holda xavfsizlik muammolarining yechimini topishda, jamiyatning barcha a’zolarining faol ishtirokini, yuqori fuqarolik ongini, ayrim hollarda jamiyat, kelajak avlod manfaati uchun, shaxsiy manfaatlardan kechishini, jamiyat a’zolaridan yuksak madaniyatli va kuchli ma’naviyatlikni talab qiladi. Bu tamoyillarning yechimi chuqur tahlil qilingan va tashkil qilingan uzluksiz, ya’ni ta’limning barcha o‘timlarini qamrab olgan ta’lim va tarbiya tizimlari, shuningdek ishlab chiqarish korxonalarida faoliyat yuritayotgan ma’sul rahbar-xodimlar zimmasida bo‘ladi. Xurmatli Prezidentimiz SH.M.Mirziyoyev ta’kidlaganlaridek, “Biz yangicha mustaqil fikrlaydigan, ma’suliyatli, tashabbuskor, ilg‘or boshqaruv usullarini puxta o‘zlashtirgan, halol, o‘z Vatani va xalqiga sodiq kadrlarni tayyorlash bo‘yicha samarali tizim yaratish ustida jiddiy ishlaymiz.

Rahbarlar faoliyatiga, ularga bo‘lgan ishonch va aholini o‘ylantirayotgan muammolarni samarali hal etish darajasidan kelib chiqqan holda, xalqning o‘zi baho beradi”.

Korxonalarda mehnatni muhofaza qilishni boshqarish tizimini takomillashtirish shuningdek inson xavfsizligini ta’minlash, ayniqsa uni ish jarayonida bevosita ishlab chiqarishda o‘z dolzarbligini ko‘rsatadi. Chunki zamonaviy korxonalarning xarakterli tomoni shundaki, unda bir korxonaning o‘zida turli-tuman va tez o‘zgaruvchan texnologik jarayonlarda materiallar, yuqori darajali mexanizatsiyalashgan va avtomatlashtirilgan elektr hisoblash texnikasi bilan jihozlangan zamonaviy potok tizimlar qo‘llanilmoqda. Bular albatta bir tomondan jarayonlarni qisqartirishga maxsulot sifatini yaxshilashga va mehnat sharoitini xavfsizlantirishga qaratilgan, lekin ikkinchi tomonidan ularda ishlovchi ishchilardan katta diqqat, sezuvchanlik va butun ish kuni davomida aqliy zo‘riqish

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talab qiladi. Bu esa asablarning taranglashuviga va pirovard natijada kasbiy kasallik va jarohatlarga sabab bo‘lishi mumkin.

Temir yo‘llardan texnikaviy foydalanish qoidalari.

Temir yo‘l bekatlari, vokzallar va temir yo‘lning tashish jarayoni bilan bog‘liq boshqa bo‘linmalari hududlari, poezdlar harakati amalga oshiriladigan hamda manyovr va yuk ortish, yuk tushirish ishlari bajariladigan yo‘lovchilar platformalari va temir yo‘l tarmoqlari o‘ta xavfli zonalar hisoblanadi va zarurat bo‘lganda atrofi o‘rab qo‘yiladi. O‘ta xavfli zonalarda fuqarolarning bo‘lishi va ob’ektlarning joylashtirilishi, bunday zonalarda ishlar bajarish, temir yo‘llar orqali yurish va ularni kesib o‘tish qoidalari davlat temir yo‘l transportini boshqarish organi tomonidan belgilanadi.

Harakatdagi tarkib, shu jumladan harakatdagi maxsus sostav va konteynerlar, temir yo‘llarning er ustki qurilmalari qismlari hamda temir yo‘l transportiga etkazib beriladigan boshqa texnika vositalari va mexanizmlar, shuningdek yo‘lovchilarga ko‘rsatiladigan xizmatlar tegishli normativ hujjatlar bilan belgilangan harakat xavfsizligi, mehnatni muhofaza qilish va ekologiya xavfsizligi talablariga mos kelishi lozim.

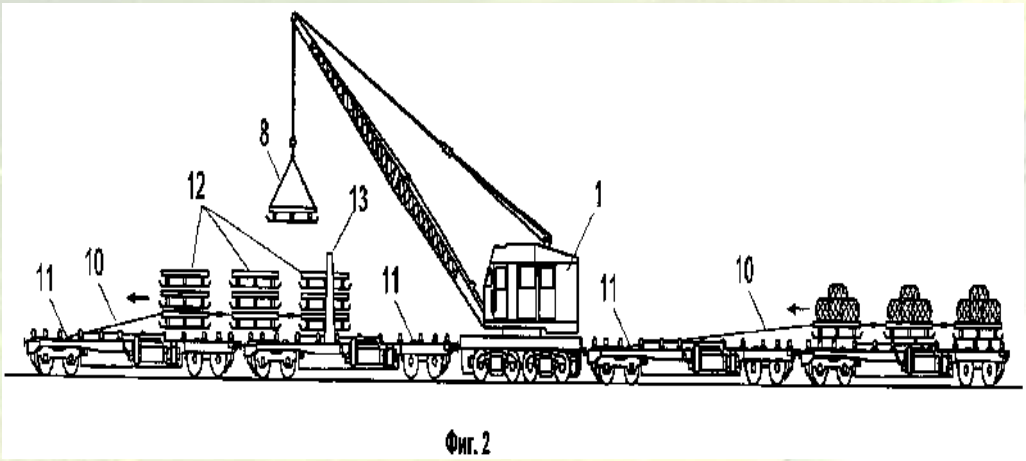
Temir yo‘l transporti faoliyatida foydalaniladigan texnika vositalari va mexanizmlarni, shuningdek ko‘rsatiladigan xizmatlarni sertifikatlashtirish qonunchilikda belgilangan tartibda amalga oshiriladi.

Hududida xavfli yuklarni ishlab chiqarish, saqlash, ortish, tashish va tushirish ishlari amalga oshiriladigan ob’ektlar umumiy foydalanishdagi temir yo‘llardan va inshootlardan ularning xavfsiz ishlashini ta’minlaydigan masofada uzoqlashtirilgan bo‘lishi kerak.

“O‘zbekiston temir yo‘llari” AJ tasarrufida Toshkent, Xovos, Qo‘qon, Andijon, Samarqand, Tinchlik, Buxoro, Qarshi, Termez, Qo‘ng‘irot, Urganch temir yo‘l bekatlarida tiklash poezdlaridan iborat texnika vositalari zaxirasi mavjud (1-rasm).



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1-rasm Tiklash poezdi.

Tiklash poezdi quyidagi texnik vositalari bilan jixozlangan bo‘lishi lozim:

- ko‘tarma kranlar va moslamalar;
- gidravlik domkratlar;
- lebedka tortqichlri bilan;
- traktor va buldozer;
- elektr dizel stansiyasi;
- yoritgich (projektor) o‘rnatgich moslama;
- avtomashinalar;
- yong‘inga qarshi uskunalar;
- metall kesuvchi va payvandlash mashinasi;
- tezkor operativ aloqa vositalari;
- Bundan tashqari rels va shpallarning zahirasi;

Temir yo‘llar, shahobcha yo‘llar va ulardagi inshoot va qurilmalarni loyihalashtirish, qurish va qayta qurishda, ikkinchi yo‘llarni elektrlashtirish va qurishda, shuningdek, ko‘rsatilgan gabaritlarga tenglashtirilgan foydalanishdagi qurilmalarda S va Sp gabaritlariga rioya qilish kerak. Ta’mirlash, qurilish va boshqa xil ishlarni amalga oshirishda inshoot va qurilmalarning gabaritlarini buzish man etiladi.

Temir yo‘lning barcha elementlari (tuproq ko‘tarma, yuqori tuzilmalar va sun’iy inshootlar) mustahkamligi, barqarorligi va holati bo‘yicha ushbu uchastkada poezdlarning belgilangan tezlikda xavfsiz va tekis harakatlanishini ta’minlashi lozim.

Lokomotiv depolari, lokomotivlarga texnikaviy xizmat ko‘rsatish punktlari, ustaxonalar, anjomlash (ekipirovka) qurilmalari hamda lokomotiv xo‘jaligining boshqa inshoot va qurilmalarining joylashuvi va texnikaviy jihozlanishi poezdlar harakatining belgilangan miqdorini, lokomotivlardan samarali foydalanishni, sifatli ta’mir va texnikaviy xizmat ko‘rsatish, moddiy resurslardan oqilona foydalanish va mehnatning xavfsiz sharoitlarini ta’minlashi lozim.(2-rasm).

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2-rasm Lokomotiv depo.

Vagon depolari va uchastkalari, vagonlarga texnikaviy xizmat ko‘rsatish punktlari, yuvish-bug‘lash statsiyalari hamda vagon xo‘jaligining boshqa inshoot va qurilmalarining joylashuvi va texnikaviy jihozlanishi poezdlar harakatining belgilangan miqdorini, sifatli ta’mir va texnikaviy xizmat ko‘rsatishni, moddiy resurslardan oqilona foydalanish va mehnatning xavfsiz sharoitlarini ta’minlashi lozim. Ta’mirlash-anjomlash depolari va yo‘lovchi texnikaviy stansiyalari yo‘lovchi vagonlarni reysga sifatli tayyorlash uchun zarur (3-rasm Ilova).




3-rasm Vagon depolari.

Mehnatni muhofaza qilish bo‘yicha nazorat va takliflar.

Nazorat mehnatni muhofaza qilishni boshqarishning muhim vazifasi hisoblanadi. Quyidagilar nazoratga olinadi:

a) ish joylari holatining ularning mehnatni muhofaza qilish talablariga muvofiqliligi;

b) mehnat qonunchiligi, direktiv organlarning qarorlariga, mehnatni muhofaza qilishning boshqa me’yoriy hujjatlari, davlat standartlari va qoidalari talablariga rioya qilinishi;

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v) mehnatni muhofaza qilishni boshqarish vazifalarining amalga oshirilishi bo‘yicha ishlarning bajarilishi;

g) ishlab chiqarishdagi baxtsiz hodisalarni o‘z vaqtida va to‘g‘ri tekshirilishi;

d) mehnatni muhofaza qilish bo‘yicha buyruqlar, farmoyishlar, ko‘rsatmalar, tadbirlar va rejalarning bajarilishi;

Nazorat tizimi asosan sex va bo‘lim xizmatlari, ustalar, brigadirlar va muayyan ish bajaruvchilarning mehnatni muhofaza qilish bo‘yicha o‘z vazifalarini bajarishini tekshirishga qaratilishi kerak. Nazoratning barcha turlari nafaqat mehnatni muhofaza qilish standartlari, qoidalari va me’yorlaridan chetga chiqishlarni aniqlashi, balki qoida buzarliklarni keltirib chiqaruvchi sabablarni tahlil qilishi, shuningdek ularni bartaraf etish tadbirlari ishlab chiqilishini qamrab olishi lozim.

Mehnatni muhofaza qilish holatini nazorat qilishda mehnat sharoitlari parametrlari, ishlab chiqarish uskunalari va texnologik jarayonlarning xavfsizligi, xodimlarning himoyalash vositalari sifati ustidan nazorat qilish bo‘yicha o‘lchash uslublari va vositalarini qamrab olgan metrologik ta’minot ko‘zda tutilishi lozim. Mehnatni muhofaza qilish holatini taxlil qilish uchun quyidagilardan foydalanish mumkin:

- baxtsiz hodisa va kasb kasalliklar haqidagi materiallar (N-1 shaklidagi dalolatnoma)dan;
- kasallikka chalinishi va mehnatga qobiliyatini vaqtincha yo‘qotganligi haqidagi ma’lumotlar (3-1 shaklidagi mehnatga qobiliyatsizlik varaqalari) dan;
- avariya, yong‘in chiqish, qulash va h.k.ni tekshirish dalolatnomalaridan;
-nazorat organlari, mehnat texnik inspeksiyasi, mehnat sharoitlari bo‘yicha davlat ekspertlarining ko‘rsatmalaridan;
- ish joylarini attestatsiya qilish ma’lumotlaridan;
- sexlarning sanitariya-texnik holati pasportlari ma’lumotlaridan;
-nazoratning 1 va 2-bosqichlarni tekshiruv jurnallaridan, 3-bosqich dalolatnomalaridan.

Mehnatni muhofaza qilish ishlarini tahlil qilishda quyidagilardan foydalanish mumkin:

- mehnatni muhofaza qilish bo‘yicha ish rejalari va ularning bajarilishi to‘g‘risidagi hisobotlardan;
- mehnatni muhofaza qilish bo‘yicha yo‘l-yo‘riqlarni o‘tkazilganini qayd etish jurnallaridan;
- mehnat sharoitlari bo‘yicha ish joylarini attestatsiyalash bayonnomalaridan;
- nazoratning 2 va 3 - bosqichlarini o‘tkazish jadvallaridan;

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- mehnatni muhofaza qilish bo‘yicha majlislarlarning bayonnomalaridan;
- uskunalarni rejali oldindan ta’mirlash va sinov jadvallaridan;
- mehnatni muhofaza qilishni moddiy ta’minlash buyurtmalari va boshqa hujjatlardan;

Mehnatni muhofaza qilish masalalari bilan shug‘ullanadiganlar ishlab chiqarishning o‘ziga xos xususiyatlaridan, xodimlarning tayyorgarligidan kelib chiqqan holda korxonalarda mehnatni muhofaza qilish holatini baholash uchun ko‘rsatkichlarning har-xil tizimlarini ishlab chiqishlari va ulardan foydalanishlari mumkin. Masalan, sexlar va ishlab chiqarish brigadalarida mehnatni muhofaza qilish holatini baholash uchun ish joylarida mehnat sharoitlarini, xodimlarni mehnat xavfsizligi qoidalariga sifatli o‘qitilishini, mehnatni muhofaza qilish bo‘yicha ma’muriyat va muxandis-texnik xodimlarning ijroiya faoliyatini tavsiflaydigan ko‘rsatkichlardan foydalanish tavsiya etiladi.

XULOSA. Temir yo‘l transportida poezdlar harakati xavfsizligini ta’minlash ustidan nazorat qiluvchi maxsus tarkibiy bo‘linma, shuningdek temir yo‘lda avariyalar oqibatlarini tugatuvchi avariya-tiklash bo‘linmalari faoliyat ko‘rsatadi. Ana shu bo‘linmalar to‘g‘risidagi nizom, shuningdek harakat xavfsizligi buzilishlarini tasniflash, xizmat tekshiruvini olib borish va hisobga olish tartibi davlat temir yo‘l transportini boshqarish organi tomonidan belgilanadi.

Temir yo‘lda tashish xavfsizligini ta’minlashga qaratilgan davlat nazorati va boshqa choralar ichki ishlar, Davlat xavfsizlik xizmati organlari hamda O‘zbekiston Respublikasi Temir yo‘llarda yuk va yo‘lovchilar tashish xavfsizligini nazorat qilish davlat inspeksiyasi tomonidan ularning vakolatlari doirasida amalga oshiriladi.

Temir yo‘l bekatlari, vokzallar va temir yo‘lning tashish jarayoni bilan bog‘liq boshqa bo‘linmalari hududlari, poezdlar harakati amalga oshiriladigan hamda manyovr va yuk ortish, yuk tushirish ishlari bajariladigan yo‘lovchilar platformalari va temir yo‘l tarmoqlari o‘ta xavfli zonalar hisoblanadi va zarurat bo‘lganda atrofi o‘rab qo‘yiladi.

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KIMYO DARSLARIDA INTERFAOL O‘QITISH METOTLARIDAN FOYDALANISH USULLARI

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Annotatsiya. Zamonaviy ta’lim tizimida talabalarning nafaqat bilim olishi, balki tanqidiy va ijodiy fikrlash qobiliyatlarini rivojlantirish muhim vazifalardan biri hisoblanadi. Axborotlar hajmining keskin ortib borishi sharoitida talaba o‘zlashtirilayotgan bilimlarni tahlil qila olishi, baholashi va amaliyotda qo‘llay bilishi zarur. Shu nuqtai nazardan, interfaol metodlar ta’lim jarayonining samaradorligini oshiruvchi asosiy vositalardan biri sifatida namoyon bo‘lmoqda. Ta'lim- tarbiya tizimini zamonaviy rivojlanish talablariga moslashtirish fanlardan elektron ta'lim resurslarini takomillashtirish, o‘quvchilarning elektron manbalar bilan faol muloqotini ta'minlash, mustaqil ta'limini amalga oshirish va o‘z-o‘zini baholash, zaruriy ma'lumotni operativ izlab topish va yuzaga kelayotgan muammolarni hal etishda undan foydalanish kompetensiyalarini shakllantirish, zamonaviy yondashuvlar o‘qitish jarayonida pedagogik va axborot texnologiyalarini o‘zaro integratsiyalash orqali o‘quvchilarda tayanch va fanga oid xususiy kompetensiyalarni shakllantirishni nazarda tutadi. Ta’lim-tarbiya jarayoniga innovatsiyalarni tadbiq etish va shaxsni kasbiy faoliyatga tayyorlashda ijtimoiy psixologik treninglar o‘tkazish.

Kalit so‘zlar: Asalari galasi, oksidlovchi, qaytaruvchi, galereya, metodik - didaktika, interfaol, metod, shaxsiy fikrlash.

Аннотация. В современной системе образования одной из важных задач является не только приобретение знаний, но и развитие критического и творческого мышления. В условиях резкого увеличения объема информации необходимо, чтобы студент умел анализировать, оценивать и применять полученные знания на практике. В этой связи интерактивные методы становятся одним из основных инструментов повышения эффективности образовательного процесса. Адаптация системы образования к требованиям современного развития предполагает совершенствование электронных учебных ресурсов по предметам, обеспечение активного взаимодействия студентов с электронными ресурсами, внедрение самостоятельного обучения и самооценки, формирование компетенций для оперативного поиска необходимой информации и ее использования при решении возникающих проблем, а также современные подходы к формированию базовых и предметно-специфических компетенций у студентов посредством взаимной интеграции педагогических и информационных технологий в учебный процесс. Внедрение инноваций в образовательный процесс и проведение

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социально-психологической подготовки в рамках подготовки личности к профессиональной деятельности.

Ключевые слова: сотовая структура, окисление, восстановление, галерея, методическо-дидактический, интерактивный, метод, личностное мышление.

Abstract. In the modern education system, one of the important tasks is not only to acquire knowledge, but also to develop critical and creative thinking skills. In the conditions of a sharp increase in the volume of information, it is necessary for the student to be able to analyze, evaluate and apply the acquired knowledge in practice. In this regard, interactive methods are emerging as one of the main tools that increase the effectiveness of the educational process. Adapting the education system to the requirements of modern development involves improving electronic educational resources in subjects, ensuring active interaction of students with electronic resources, implementing independent learning and self-assessment, forming competencies for the prompt search for necessary information and its use in solving emerging problems, and modern approaches to the formation of basic and subject-specific competencies in students through the mutual integration of pedagogical and information technologies in the teaching process. Introducing innovations into the educational process and conducting socio-psychological training in preparing individuals for professional activity.

Keywords: Honeycomb, oxidizing, reducing, gallery, methodological - didactic, interactive, method, personal thinking.

KIRISH

Interfaol o‘qitish “ta’lim jarayonining asosiy ishtirokchilari - o‘qituvchi, o‘quvchi va o‘quvchilar guruhi o‘rtasida yuzaga keladigan hamkorlik, qizg‘in bahs munozalar, o‘zaro fikr almashish imkoniyatiga egalik asosida tashkil etiladi, ular da erkin fikrlash, shaxsiy qarashlarini ikkilanmay bayon etish, muammoli vaziyatlarda yechimlami birgalikda izlash, o‘quv materiallarini o‘zlashtirishda o‘quvchilarning o‘zaro yaqinliklarini yuzaga keltirish, “o‘qituvchi - o‘quvchi - o‘quvchilar guruhi”ning o‘zaro bir-birlarini hurmat qilishlari, tushunishlari va qo‘llab- quvvatlashlari, samimiy munosabatda bo‘lishlari, ruhiy birlikka erishishlar kabilar bilan tavsiflanadi. Interfaol ta’lim mohiyatiga ko‘ra suhbatning “o‘quvchi - axborot-kommunikatsion texnologiyalar” shaklida tashkil etilishi o‘quvchi (talaba)lar tomonidan mustaqil ravishda yoki o‘qituvchi rahbarligida axborot texnologiyalari yordamida bilim, ko‘nikma, malakalaming o‘zlashtirilishini anglatadi.

O‘qituvchi ta’lim jarayonida interfaol ta’lim yordamida o‘quvchilaming qobiliyatlarini rivojlantirish, mustaqillik, o‘z-o‘zini nazorat, o‘z-o‘zini boshqarish, samarali suhbat olib borish, tengdoshlari bilan ishlash, ulaming likrlarini tinglash

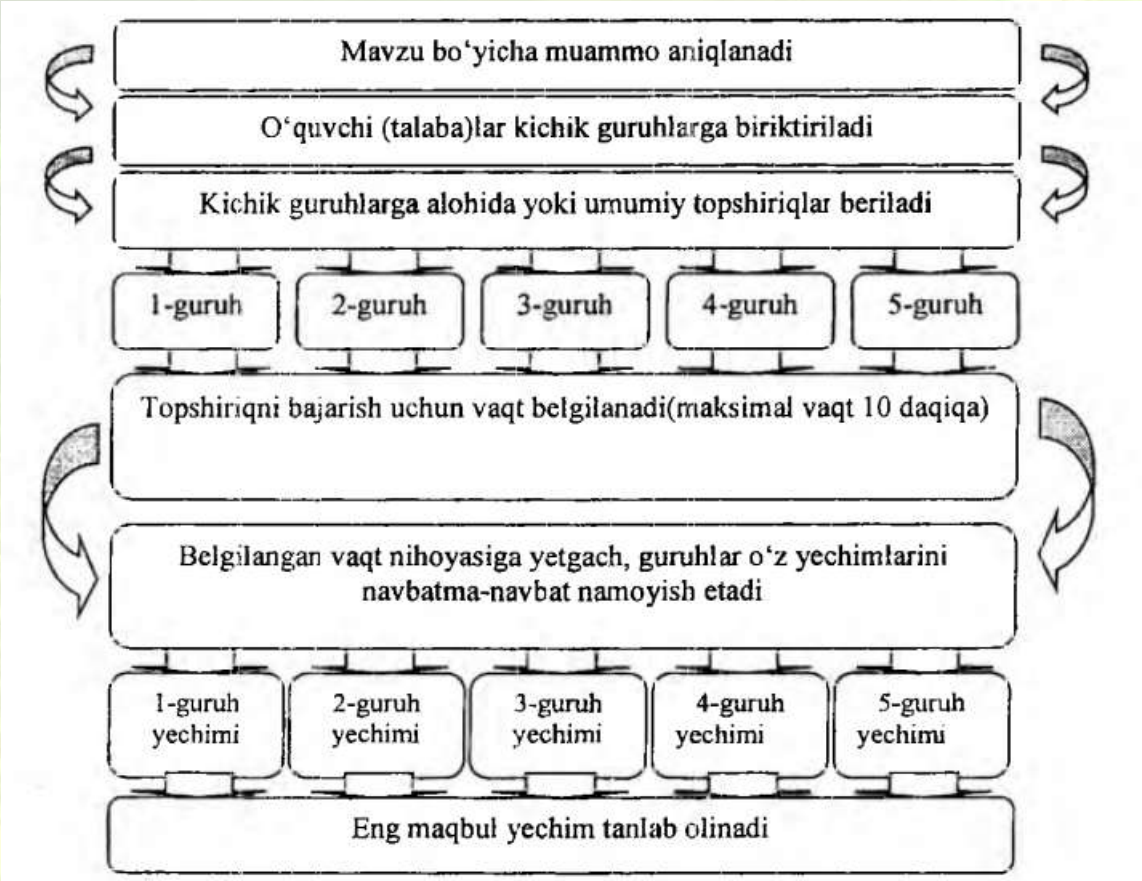
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va tushunish, mustaqil hamda (tanqidiy fikrlash, muqobil takliflami ilgari surish, fikr- mulohazalarini erkin bayon qilish, o‘z nuqtai nazarlarini himoya qilish, muammoning yechimini topishga intilish, murakkab vaziyatlardan chiqa olish kabi sifatlami shakllantirishga muvaffaq bo‘ladi. Eng muhimi, interfaol metodlami qo‘llash orqali o‘qituvchi oquvchilaming aniq ta’limiy maqsadga erishish yo‘lida o‘zaro hamkorlikka fisoslangan harakatlarini tashkil etish, yo‘naltirish, boshqarish, nazorat va tahlil qilish orqali xolis baholash imkoniyatini qo‘lga kiritadi.

“Asalari galasi” metodi o‘rganilayotgan mavzu bo‘yicha tanlangan muammoning auditoriyada umumiy yoki kichik guruhlarda alohida tahlil qilinishiga yordam beradi. Metodni qo‘llashda kichik guruhlarga beriladigan topshiriqlar bir xil yoki turlicha bo‘lishi mumkin. Guruhlarga berilgan topshiriq muayyan muddat ichida muhokama qilinib, natija barchaga ma'lum qilinadi. Mashg‘ulot yakunida masalaning eng maqbul yechimi tanlab olinadi.

Bu metoddan kimyo darslarida foydalanish uchun avval sinf mayda guruhlarga bo‘linadi. Guruhlarga mavzu beriladi, mavzu bo‘yicha yechim aniqlanadi. Misol uchun oksidlanish qaytarilish mavzusida sinfni ikkita guruhga ya’ni oksidlovchilar va qaytaruvchilarga bo‘linadi. Oksidlovchi kichik guruhini yana mayda guruhlarga eng muhim oksidlovchilar, oddiy oksidlovcghilar kabi kichik guruhlarga bo‘linadi. Qaytaruvchilar guruhini o‘zini yana eng muhim qaytaruvchilar va oddiy qaytaruvchilar guruhiga bo‘lib ularning har biriga topshiriq beriladi.

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GALEREYA STRATEGIYASI

Metod o‘quvchi (talaba)larda kichik guriih asosida bir yo‘la bir nechta masalani muhokama qilish qobiliyatini shakllantiradi. Uni qo‘llashda guruhning har bir a’zosi taklif etilgan barcha masalalar yechimini topishga o‘z hissasini qo‘shish imkoniyatiga ega bo‘ladi. Mashg‘ulotlar davrida “Galereya” metodidan foydalanish quyidagi tartibda amalga oshiriladi:

1-bosqich - masalani qo‘yish (o‘qituvchi kichik guruhlarga muayyan muammo (yoki masala)ni hal qilish topshirig‘ini beradi.

2-bosqich - har bir guruh o‘ziga topshirilgan masalaning yechimini topish ustida ishlaydi (bu jarayon 5- 10 daqiqa ichida kechadi)

3-bosqich - har bir guruh navbati bilan 2-, 3- va 4-guruhga topshirilgan muammoning yechimini topishga kirishadi (guruhlar harakati doira tarzida soat strelkasi bo‘yicha amalga oshiriladi; bir guruh boshqa guruhlarning yechimlarini o‘rganadi, ularga nisbatan o ‘z mimosabatini bildiradi; qo‘shimchalar kiritadi)

4-bosqich - guruh o‘z o‘rniga qavtadi.

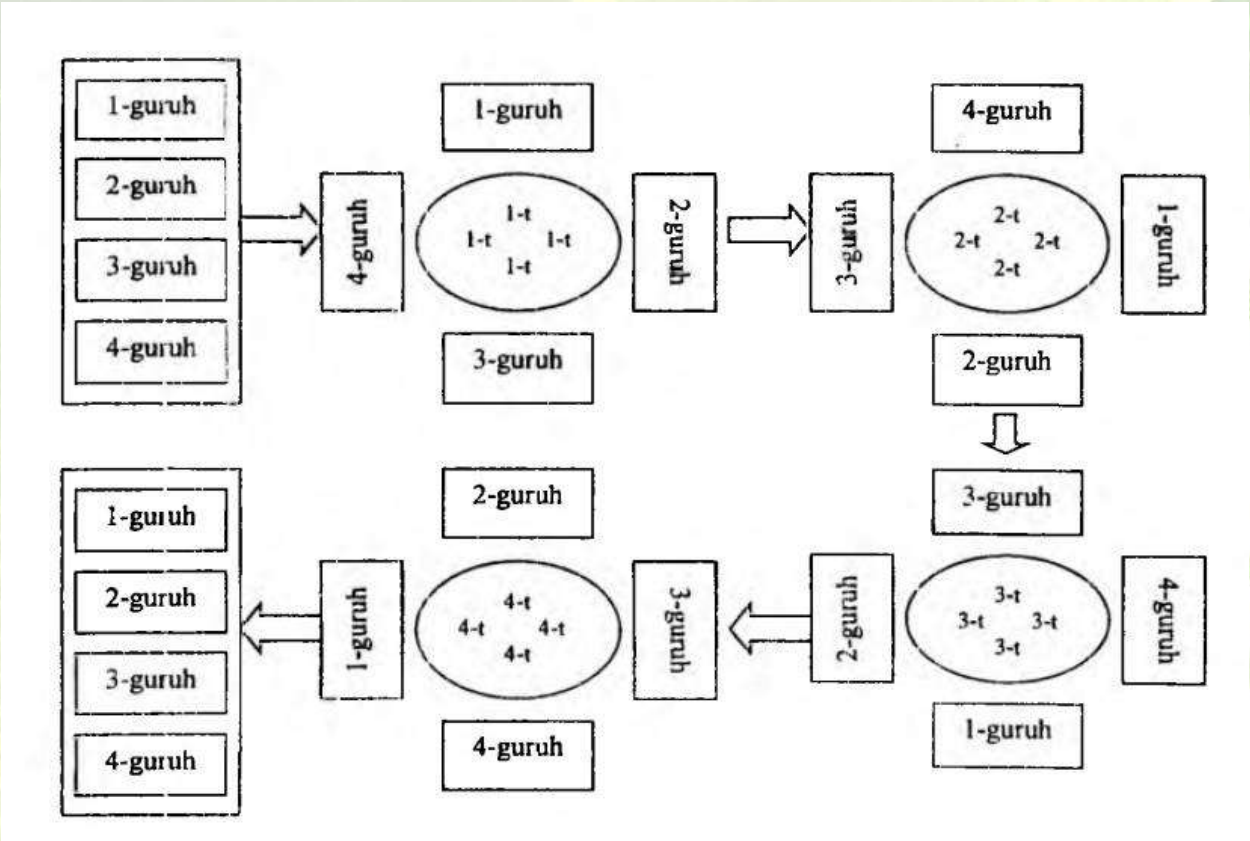
5-bosqich - har bir guruhdan bir nafar o‘quvchi (talaba) guruh ishi bilan jamoani tanishtiradi va ular asosida muhokama tashkil etiladi

6-bosqich - muayyan guruh boshqa guruhlarning yechimlariga nisbatan o‘zlari tomonidan bildirilgan mulohazalarni sharhlaydi

7-bosqich - guruhlarning fikrlariga ko‘ra yakuniy xulosa qilinadi.

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Metodni qo‘llash jarayonini sxema asosida quyidagicha ifodalash mumkin:



“GUGURT DONALARJ” STRATEGIYASI

Gugurt donalari metodi o‘quv materiallarining o‘quvchi (talaba)lar tomonidan 0‘rganilgan qay darajada egallanganligini aniqlash maqsadida qo‘llaniladi. Metod o‘quvchi (talaba)larga o‘quv materialining mavzusidan kelib chiqqan holda turli muammoli masala yoki vaziyatlami yaratish, mavzuning asosiy tayanch tushunchalarini ajratib olish, ulami izohlash, tahlil qilish, ta'riflashda yordam beradi. Shuningdek, metod. mashg‘ulot davomida har bir o‘quvchi (talaba)ga turli topshiriqlami individual bajarish, uning ustida mustaqil ishlash imkonini beradi. Bu metod o‘quvchilarda bir qator tarbiyaviy xarakterdagi, ya'ni: mustaqil ishlay olish; muloqatga kirishuvchanlik; xushfe'llik; o‘zgalar fikrini hurmat qilish; faollik;

faoliyatga ijodiy ycndashish; faoliyatning samarali bo‘lishiga qiziqish va intilish;

o‘zini o‘zi baholash kabi sifatlami shakllantirishga yordam berdi. Metod qo‘llanilgan mashg‘ulot o‘quvchilami o‘rganilgan yoki o‘rganilishi kerak bo‘lgan mavzu bo‘yicha yakka va kichik jamoa bo‘lib fikrlash, o‘zlashtirilgan bilimlami yodga olish, to‘plangan fikrlashni umumlashtirish, ulami yozma ravishda yoki rasm, chizma, tasvir, sxema, model ko‘rinishida ifodalashga o‘rgatadi. Metod juftlik, kichik guruhlar yoki jamoada tashkil etiladi. O‘quvchi (talaba)lar

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tushunchalami yozma ravishda ta'riflaydi va ulami taqdimot asosida jamoaga namoyish qiladi.

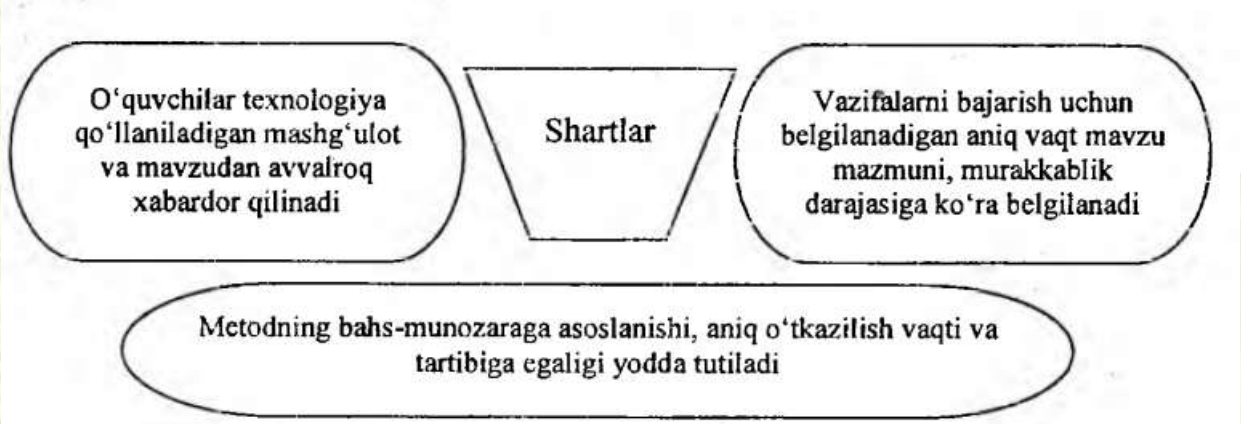
Mashg‘ulotda metodni qo‘llash quyidagi tartibda amalga oshiriladi:

O‘qituvchi o‘quvchi (talaba)larga gugurt donalari yoki oddiy cho‘plardan istagancha tanlab olishni taklif etadi. O‘quvchi o 'z xohishiga ko 'ra gugurt donachalari yoki oddiy cho‘plarni tanlaydi. Har bir o‘quvchi (talaba) tanlangan gugurt donalari yoki oddiy cho‘plarining soniga ko‘ra mavzuga oid tayanch tushunchalami ajratib ko‘rsatib, ularning har biriga izoh berdi yoki qoidalarni aytadi.

KBI(“KUZATISH, BAHSL.ASHISH, ISHONTIRISH”) STRATEGIYASI

Texnologiya 0‘quvchilami hayotda o‘z o‘rinini topish yo‘Iida faollik ko‘rsatishga rag‘batlantirib, ularda yetakchilik, sardorlik sifatlari, jamoada ishlash ko‘nikmalari, o‘zgalar fikrini hurmat qilgan holda o‘z pozitsiyalarini himoyalash, fikrini isbotlay bilish, asoslash, ishontirish, munozara olib borish, murosaga kelish, ijodiy izlanish kabi qobiliyatlarini shakllantirish va rivojlantirishga xizmat qiladi.

Mashg‘ulotda mazkur texnologiyani qo‘llashda quyidagi shartlarga rioya etiladi:



Texnologiyadan foy dalanish tartibi quyidagicha:

1.O‘qituvchi o‘quvchi (talaba)larni m ashg‘ulot o‘tkazish tartibi bilan tanishtiradi.

2.O‘qituvchi o‘quvchi (talaba)lami kichik guruhlarga birilctirib, ularga savollar to‘plamini taklif etadi va topshiriqni bajarish uchun vaqt hajmini belgilaydi.

3. Guruhlar bittadan savo! tanlab olib, so‘zga chiqishga tayyorlanadi.

4. Belgilangan vaqt nihoyasiga etgach, navbat bilan guruhlarning chiqishi tashkil etiladi.

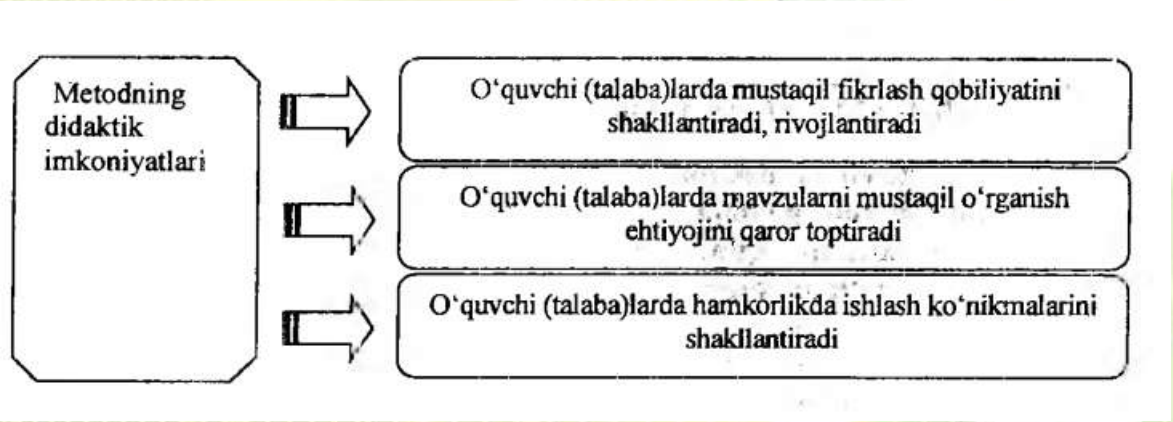
5. O 'qituvchining ko‘rsatm asiga binoan har bir guruh chiqishi jarayonida qolgan guruhlar uning fikri va pozitsiyasiga qarshi fikrlami bildirib, guruh tanlagan yo‘lni rad etish orqali uning a'zolarini bahs-munozaraga undaydi.

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6. So‘zga chiqqan har bir guruh boshqa guruhlarning a'zolarini o 'z fikrlari, tanlagan yo‘li hamda keltirganda. Ullarining to 'g 'ri ekanligiga ishontirish, o 'z tomoniga og‘dirish, imkoni boricha ulami o 'z guruhiga qo‘shishga harakat qiladi.
7. O 'qituvchi bahs-munozaraning natijalari bo‘yicha fikmi bildirib, darsni yakunlaydi.

“O‘QUV LOYIHASI” METODI

Metod o‘quvchi (talaba)lar tomonidan individual, guruh yoki jamoa tarzida aniq belgilangan vaqt oralig‘ida o‘rganilayotgan mavzu bo‘yicha axborotlami yig‘ish va tadqiq qilinishini ta’minlashga xizmat qiladi. Mashg‘ulotlarda metoddan foydalanish o‘quvchi (talaba)larda rejalashtirish, qaror qabul qilish, faoliyatni amalga oshirish, ma’lumotlami qayta teltshirish, mavjud ma’lumotlarga tayangan holda xulosa chiqarish, natijalami baholash ko‘nikmalarining shakllanishiga yordam beradi. Metodni qo‘llashda o‘quvchi (talaba)lar mavzu bo‘yicha yangi loyihalarni yarata olishlari lozim. Loyihalarni yaratishda taklif etilgan jarayonning mohiyati qisqa, aniq fikr, belgi, tasvirlar yordamida ifodalanishi talab etiladi.
Metodning didaktik imkoniyatlari quyidagilar bilan belgilanidi:



Kimyoni o‘qitishda interfaol metodlardan foydalanish o‘quv jarayonining samaradorligini sezilarli darajada oshiradi. Bunday metodlar o‘quvchilarning faolligini kuchaytiradi, mustaqil fikrlash, muammoni tahlil qilish va mantiqiy xulosa chiqarish ko‘nikmalarini rivojlantiradi. Interfaol yondashuv orqali o‘quvchilar faqat tayyor bilimni qabul qilmay, balki bilimni o‘zlari izlab topish, muhokama qilish va amaliyotda qo‘llash imkoniyatiga ega bo‘ladilar. Shuningdek, guruhli ishlar, munozara, aqliy hujum, klaster, konseptual xaritalar kabi interfaol metodlar kimyo fanining murakkab tushunchalarini osonroq va qiziqarli tarzda o‘zlashtirishga yordam beradi. Bu metodlar o‘quvchilarda jamoada ishlash, fikrini erkin ifodalash va ilmiy dunyoqarashni shakllantirishga xizmat qiladi. Umuman olganda, kimyo fanini o‘qitishda interfaol metodlardan samarali foydalanish ta’lim sifatini oshiradi, o‘quvchilarning bilimga bo‘lgan qiziqishini kuchaytiradi hamda

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ularni zamonaviy, mustaqil fikrlaydigan shaxs sifatida shakllanishiga yordam beradi.

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СОРБЦИОННО-СПЕКТРОФОТОМЕТРИЧЕСКОЕ ОПРЕДЕЛЕНИЕ ИНДИЯ И ТЕЛЛУРА В ОТХОДАХ МЕТАЛЛУРГИЧЕСКОГО ПРОИЗВОДСТВА

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Аннотация. В работе представлен аналитический обзор методов определения индия и теллура в отходах металлургического производства, основанных на сочетании сорбционного концентрирования и спектрофотометрических измерений. Рассмотрены традиционные хромогенные реагенты, а также современные варианты твёрдофазной и жидко-жидкостной экстракции. Особое внимание уделено биополимерным сорбентам, включая материалы на основе шелкового фиброина. Показано, что интеграция сорбционных процедур со спектрофотометрией обеспечивает высокую чувствительность и устойчивость анализа в условиях сложных матриц металлургических отходов.

Ключевые слова: индий, теллур, сорбция, спектрофотометрия, экстракция, шелковый фиброин, отходы металлургии.

Annotatsiya. Maqolada metallurgiya chiqindilarida indiy va tellurni aniqlashning sorbsiya va spektrofotometriyaga asoslangan zamonaviy usullari ko‘rib chiqiladi. Klassik xromogen reagentlar, suyuqlik-suyuqlik va qattiq fazali ekstraksiya usullari, shuningdek ipak fibroiniga asoslangan biopolimer sorbentlar tahlil qilindi. Sorbsiya bilan birgalikda spektrofotometriya qo‘llanishi murakkab matritsali sanoat chiqindilarida yuqori sezuvchanlik va selektivlikni ta’minlashi ko‘rsatildi.

Kalit so‘zlar: indiy, tellur, sorbsiya, spektrofotometriya, ekstraksiya, ipak fibroini, metallurgiya chiqindilari.

Abstract. This paper presents an analytical review of methods for determining indium and tellurium in metallurgical waste, based on a combination of sorption concentration and spectrophotometric measurements. Traditional chromogenic reagents are considered, as well as modern variants of solid-phase and liquid-liquid extraction. Particular attention is paid to biopolymer sorbents, including materials based on silk fibroin. It is shown that the integration of sorption procedures with

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spectrophotometry ensures high sensitivity and stability of the analysis under the conditions of complex matrices of metallurgical waste.

Keywords: indium, tellurium, sorption, spectrophotometry, extraction, silk fibroin, metallurgical waste.

ВВЕДЕНИЕ.

Индий и теллур относятся к редким элементам, востребованным в высокотехнологичных отраслях — производстве полупроводников, солнечных элементов, специальных сплавов и функциональных материалов. Металлургические предприятия формируют отходы, содержащие следовые количества этих элементов, что требует применения высокочувствительных аналитических методик.

Промышленное значение индия растет по мере того, как металл, его сплавы и химические вещества используются. Индий и его соединения имеют многочисленные промышленные применения и в настоящее время используются в производстве жидкокристаллических дисплеев, полупроводников, низкотемпературных припоев и инфракрасных фотодетекторов

Спектрофотометрия остаётся одним из наиболее доступных инструментальных методов, однако сложный состав отходов (Fe, Zn, Cu, Pb, Sn, As, Se) делает необходимым предварительное выделение аналитов. Наиболее эффективным решением является использование сорбционных методов концентрирования, совмещённых со спектрофотометрическим детектированием [9–12].

МАТЕРИАЛЫ И МЕТОДЫ

1.1. Спектрофотометрические методы определения индия

Для определения In (III) предложено множество хромогенных реагентов. Наиболее известным является ПАН, образующий интенсивно окрашенные комплексы [1, 2]. Галлион обеспечивает повышенную селективность в присутствии Ga(III) [6]. β-дикетоны, такие как TTA и TTFA, применяются в экстракционно-спектрофотометрических схемах [5]. Полимерные реагенты, например PV·FPAQ, позволяют повысить устойчивость аналитического сигнала [8].

Методы производной спектрофотометрии дают возможность одновременного определения индия и галлия [7].

1.2. Сорбционно-экстракционные методы для индия

Для повышения селективности и чувствительности анализа используются различные сорбенты:

- Chromosorb-108 для SPE [9];

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- магнитные нанотрубки MWCNT-Fe_3O_4 [10];
- функционализированные силикагели [11];
- C18-картриджи, модифицированные азопиримидиновыми реагентами [12];
- композитные сорбенты на основе органических и неорганических материалов [14].

Эти методы позволяют эффективно удалять мешающие ионы и концентрировать индий до уровней, измеримых спектрофотометрически.

2.1. Спектрофотометрические методы определения теллура

Для определения Te(IV) и Te(VI) предложены различные подходы. Классические методы включают образование иодотеллуритного комплекса [16], использование 1,1′-диантримида [17], а также экстракцию комплекса Te(IV) с диантипирилметаном [18]. Ранние работы также описывают прямые спектрофотометрические методики [19].

2.2. Сорбционно-экстракционные методы для теллура

Для повышения селективности применяются:

- ксантогенатные реагенты [20];
- серосодержащие экстрагенты [21];
- комбинированные методы с использованием 4-BPH+NEDA, MBTH+CA и 2,3-DMSO [22];
- дифференциальное определение Te(IV)/Te(VI) с дитиокарбаматами [23];
- SASAC-метод [24];
- каталитические схемы для следовых концентраций [25];
- восстановление Te(IV) до элементарного теллура с последующей спектрофотометрией [26];
- современные высокочувствительные методики [27].
- Биосорбенты на основе шелкового фиброина

Шелковый фиброин представляет собой перспективный природный сорбент благодаря развитой поверхности, наличию функциональных групп и возможности химической модификации. Исследования показывают его высокую эффективность при сорбции различных тяжёлых металлов [28].

Фиброин шелка (silk fibroin, SF) — это основной белковый компонент натурального шелка (из коконов шелкопряда Bombyx mori), который широко используется как биосорбент (biosorbent) благодаря своей экологичности, биосовместимости, доступности и наличию функциональных групп (амино-, карбоксильные, гидроксильные, пептидные связи), способных к хелатированию и ионному обмену с ионами металлов [29-32].

Преимущества фиброина шелка как сорбента в сорбционно-спектрофотометрическом анализе:

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-Экологичность и безопасность: Натуральный биополимер, нетоксичен, биоразлагаем, не вводит дополнительных загрязнителей в пробу (в отличие от синтетических сорбентов).

-Высокая сорбционная ёмкость: Для тяжёлых металлов (Cu, Pb, Cd, Fe, Ni, Cr и др.) достигает 50–200 мг/г в зависимости от формы (порошок, плёнка, волокна, гель, наночастицы). Для индия (In(III)) и теллура (Te(IV)) данных мало, но по аналогии с похожими металлоидами/металлами (Ga, Al, Fe) — сорбция возможна за счёт координации с серосодержащими/азотсодержащими группами.

- Широкий диапазон pH: Сорбция эффективна в кислой (pH 2–6 для In/Te) и нейтральной/слабокислой среде (pH 4–8 для многих тяжёлых металлов), что удобно для проб металлургических отходов.

- Предконцентрирование: Позволяет концентрировать следы металлов (фактор 50–500) из больших объёмов раствора, что критично для низких концентраций In/Te в отходах.

- Совместимость со спектрофотометрией: После сорбции возможны:

1) Прямое измерение на сорбенте (диффузно-отражательная спектрофотометрия, DRS);

2) Десорбция (кислотами, комплексонами, этанолом/щелочью) → измерение в растворе;

3) Иммобилизация реагентов (PAR, Chrome Azurol S, Eriochrome Black T и др.) на фиброине для тест-методов.

- Повторное использование: До 5–10 циклов с минимальной потерей ёмкости (особенно в порошковой или мембранной форме).

- Модификации для улучшения: Можно модифицировать (допамином, магнитными наночастицами Fe_3O_4, биосиликой) для повышения селективности, магнитного разделения или ёмкости.

Материалы на основе фиброина могут быть адаптированы для предварительного концентрирования индия и теллура, что делает их привлекательными для экологически ориентированных аналитических технологий [33-38].

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

Сорбционно-спектрофотометрические методы обладают рядом преимуществ:

- возможность определения аналитов на уровне нг/л [7, 12, 21];
- высокая селективность благодаря сорбционному этапу [9–12];
- устойчивость к сложным матрицам металлургических отходов [20–23];
- низкая стоимость и доступность оборудования;

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• возможность автоматизации анализа.

Использование биосорбентов на основе фиброина открывает перспективы для создания экологически безопасных и экономичных методов концентрирования редких элементов [28–38].

Выбраны реагенты, совместимые с биосорбентом, для повышения селективности и чувствительности (предел обнаружения 0.01–0.1 мкг/мл).

Таблица 1.

Реагенты для комплексообразования теллура

Реагент	**Цвет реагента**	**Цвет комплекса**	**λ_{max} (нм)**	**ε (L моль$^{-1}$ см$^{-1}$)**	**Примечание/среда**
Бриллиантовый зеленый	зелёный	зелёный / сине-зелёный	620 - 640	8-10 × 10^4	Ионная ассоциация с $[TeCl_6]^{2-}$ или $[TeBr_6]^{2-}$; pH 1–3; экстракция в органику, сорбция на фиброине >95%
Лейкометиленовый зеленый	бесцветный	синий	650	4,9 × 10^4	pH 3-5, сорбируется на белке
Родамин Б	розовый / малиновый	фиолетовый / синий-фиолетовый	550 - 590	9-11 × 10^4	С галогенидами; pH 1–4; высокая стабильность, совместим с биосорбентами
Виктория синий	синий	синий	590 - 610	7-9 × 10^4	3-5 М кислота + KBr/LiCl; pH 2–5; селективен в матрице отходов
Хром Азурол С + цетилпиридиний	красный / фиолетовый	розовый	525	2,5 × 10^4	pH 3 + ПАВ

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Бензагрин	зеленый	зеленый	620 - 640	-	Иммобилирован на вискозе

В ходе анализа литературных данных и сравнения характеристик реагентов для комплексообразования индия и теллура установлено, что для разрабатываемого сорбционно-спектрофотометрического метода с использованием фиброина шелка как сорбента наиболее перспективны реагенты, не содержащие серу в структуре лиганда. Это позволяет избежать перекрёстных реакций между определяемыми элементами и обеспечить селективность в сложных матрицах металлургических отходов.

Для теллура оптимальными являются катионные красители, образующие ион-ассоциаты с гексагалогено-анионами $[TeX_6]^{2-}$ ($X = Br^-, Cl^-$), а также некоторые ион-парные и окислительные системы:

- Родамин Б — наиболее чувствительный и контрастный реагент, обеспечивает устойчивую сорбцию на белковой матрице фиброина шелка за счёт электростатического и гидрофобного взаимодействия.
- Бриллиантовый зеленый — даёт максимальную визуальную контрастность на белом сорбенте, рекомендован как один из лучших для твёрдофазной спектрофотометрии.
- Виктория синий — обеспечивает хорошую селективность и высокую степень извлечения на фиброине [39-41].

Таблица 2.

Реагенты для комплексообразования индия

Реагент	**Цвет реагента**	**Цвет комплекса**	**λ_{max} (нм)**	**ε (L моль$^{-1}$ см$^{-1}$)**	**Примечание/среда**
ПАР	оранжево-красный	красный / красно-фиолетовый	500 – 520	8–10 × 10^4	pH 5–6; маскировка ЭДТА/цитратом
ПАН	оранжевый	красный / фиолетово-красный	520 – 550	5–7 × 10^4	pH 5–7; экстракция или прямая сорбция
Арсеназо III	фиолетовый	синий / фиолетово-синий	650 – 675	1–1.5 × 10^5	pH 1–3 (HCl/H_2SO_4); сильнокислый.

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Ксиленовый оранжевый	жёлто-оранжевый	розовый / красно-фиолетовый	550 – 570	4–6 × 10^4	pH 3–5; маскировка фторидом/ЭДТА
Метилтимоловый синий	синий / фиолетовый	синий / сине-фиолетовый	600 – 620	5–8 × 10^4	pH 4–6
Хром Азурол С + цетилпиридиний	красный / фиолетовый	синий / голубой	620 – 650	8–12 × 10^4	pH 4–6 + ПАВ

Для индия приоритетными являются азосоединения и трифенилметановые красители, образующие интенсивно окрашенные комплексы:

- ПАР и ПАН — наиболее чувствительные и гидрофобные комплексы, отлично сорбируются на фиброине шелка.
- Ксиленовый оранжевый и Метилтимоловый синий — дают высокую контрастность и устойчивость окраски на сорбенте.
- Хром Азурол С + цетилпиридиний — ион-парный комплекс с ПАВ, обеспечивает максимальную чувствительность и сорбционную способность.

Общие преимущества выбранных реагентов:

- Высокие значения молярных коэффициентов поглощения ($\varepsilon > 5\times10^4$ в большинстве случаев) позволяют определять микро- и нанограммовые количества элементов.
- Гидрофобные и ионные комплексы эффективно удерживаются на белковой матрице фиброина шелка без значительной десорбции в течение 24–48 ч.
- Возможность твёрдофазного измерения (диффузное отражение) или десорбции с последующей спектрофотометрией в растворе.
- Селективность в присутствии типичных мешающих ионов (Fe, Cu, Se, Al, Ga) достигается с помощью маскирующих агентов (ЭДТА, фторид-ионы, аскорбиновая кислота, тартраты) [42-43].

ЗАКЛЮЧЕНИЕ

Сорбционно-спектрофотометрические методы являются эффективным инструментом для определения индия и теллура в отходах металлургического производства. Применение современных сорбентов — от наноструктурированных материалов до биополимеров — обеспечивает высокую чувствительность и селективность анализа. Перспективным

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направлением является разработка гибридных сорбентов и миниатюризация аналитических процедур.

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СОВРЕМЕННЫЕ ПОДХОДЫ И ТЕХНОЛОГИИ ИЗМЕРЕНИЯ ВЯЗКОСТИ И ПЛОТНОСТИ ЖИДКОСТЕЙ: АНАЛИТИЧЕСКИЙ ОБЗОР

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Аннотация. В статье представлен аналитический обзор современных методов и технологий измерения вязкости и плотности жидких сред. Рассмотрены классические и инновационные подходы, включая капиллярные, вибрационные, ультразвуковые, оптические и комбинированные методы. Особое внимание уделено высокочастотным акустическим системам и интеллектуальным алгоритмам обработки данных, основанным на вейвлет-анализе и нейросетевых моделях. Проанализированы принципы работы приборов нового поколения, обеспечивающих высокую точность измерений в режиме in situ. Отмечено, что интеграция сенсорных систем с цифровыми платформами и технологиями Индустрии 4.0 позволяет существенно повысить эффективность контроля физических свойств жидкостей. Представлены сравнительные данные по чувствительности, диапазону измерений и метрологическим характеристикам существующих приборов.

Ключевые слова: вязкость, плотность, ультразвуковые методы, вибрационные сенсоры, вейвлет-анализ, нейросетевые алгоритмы, измерительные системы.

Abstract. The article provides an analytical review of modern approaches and technologies for measuring the viscosity and density of liquid media. Classical and innovative techniques are analyzed, including capillary, vibrational, ultrasonic, optical, and hybrid methods. Special attention is paid to high-frequency acoustic systems and intelligent data-processing algorithms based on wavelet analysis and neural networks. The study highlights the principles of next-generation instruments that ensure high-accuracy measurements in in situ mode. Integration of sensor networks with digital platforms and Industry 4.0 technologies significantly enhances the effectiveness of liquid property monitoring. Comparative characteristics of sensitivity, measurement range, and metrological performance of existing instruments are presented.

Keywords: viscosity, density, ultrasonic measurement, vibrational sensors, wavelet analysis, neural networks, measurement systems.

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Annotatsiya. Ushbu maqolada suyuqliklarning yopishqoqligi va zichligini o‘lchashning zamonaviy usullari va texnologiyalarining analitik sharhi keltirilgan. Klassik va innovatsion yondashuvlar, jumladan, kapillyar, tebranish, ultratovush, optik va kombinatsiyalangan usullar ko‘rib chiqiladi. Yuqori chastotali akustik tizimlar va veyvlet tahlili va neyron tarmoq modellariga asoslangan aqlli ma’lumotlarni qayta ishlash algoritmlariga alohida e’tibor qaratiladi. Yuqori aniqlikdagi joyida o‘lchovlarni ta’minlaydigan yangi avlod qurilmalarining ishlash tamoyillari tahlil qilinadi. Sensor tizimlarini raqamli platformalar va Sanoat 4.0 texnologiyalari bilan integratsiyalash suyuqliklarning fizik xususiyatlarini kuzatish samaradorligini sezilarli darajada oshirishi ta’kidlangan. Mavjud qurilmalarning sezgirligi, o‘lchash diapazoni va metrologik xususiyatlari bo‘yicha qiyosiy ma’lumotlar keltirilgan.

Kalit so‘zlar: yopishqoqlik, zichlik, ultratovush usullari, tebranish sensorlari, veyvlet tahlili, neyron tarmoq algoritmlari, o‘lchash tizimlari.

ВВЕДЕНИЕ

Измерение вязкости и плотности жидких сред является одной из ключевых задач современной физико-технической метрологии. От точности определения этих параметров зависят процессы тепло- и массообмена, гидродинамическая устойчивость, технологическая безопасность и качество готовой продукции в нефтегазовой, химической, пищевой, фармацевтической и энергетической промышленности.

На протяжении более чем столетия проблема измерения вязкости решалась с применением классических методов — капиллярных, ротационных, осцилляционных. Однако развитие нанотехнологий, биофизики, цифрового машиностроения и индустриальных стандартов «Индустрия 4.0» поставило новые задачи: обеспечить высокую точность, автоматизацию, экспрессность и возможность измерений *in situ*, то есть без отбора проб.

В этих условиях особую значимость приобретают ультразвуковые и вибрационные методы, которые позволяют регистрировать изменения физических свойств жидкости через отклик акустической или механической системы. Эти методы обеспечивают высокую чувствительность к изменению вязкости и плотности, компактность приборов и возможность интеграции с цифровыми интерфейсами и системами машинного обучения.

Ультразвуковые методы основаны на анализе скорости распространения и затухания акустических волн в среде, что позволяет одновременно определять её вязкоупругие характеристики и плотность. Вибрационные методы используют регистрацию частоты и амплитуды

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колебаний погружённого чувствительного элемента (струны, пластины, цилиндра), затухающие пропорционально вязкости и плотности исследуемой среды.

В последние годы на первый план выходят интеллектуальные измерительные комплексы, совмещающие ультразвуковую диагностику, вибрационные сенсоры и цифровые алгоритмы обработки сигналов. В таких системах применяются вейвлет-анализ, спектральная декомпозиция и нейросетевые модели (MLP, CNN, LSTM), позволяющие не только измерять, но и прогнозировать изменение реологических параметров в реальном времени [1-75].

Целью данного исследования является проведение аналитического обзора современных ультразвуковых и вибрационных методов измерения вязкости и плотности жидкостей, определение их физических принципов, метрологических характеристик, а также перспектив развития интеллектуальных систем на их основе.

МАТЕРИАЛЫ И МЕТОДЫ

Современные ультразвуковые и вибрационные методы измерения реологических свойств жидкостей основаны на тесной связи между вязкоупругими параметрами среды и характеристиками колебаний твёрдого или акустического элемента, погружённого в жидкость. Эти методы позволяют регистрировать изменения вязкости (η) и плотности (ρ) через затухание, сдвиг фаз, резонансную частоту и другие динамические параметры.

Физические основы ультразвуковых методов.

Принцип ультразвуковой вискозиметрии заключается в распространении акустических волн высокой частоты (1–20 МГц) в жидкости, где их скорость (c) и коэффициент затухания (α) зависят от вязкоупругих свойств среды.

Для ньютоновской жидкости зависимость между акустическим затуханием и частотой описывается уравнением [1–3]:

$$\alpha = \frac{2\pi^2 f^2 \eta}{\rho c^3},$$

где α — коэффициент затухания (см$^{-1}$), f — частота колебаний (Гц), η — динамическая вязкость (Па·с), ρ — плотность жидкости (кг/м^3), c — скорость звука в жидкости (м/с).

В более общем виде затухание акустических волн определяется комплексным волновым числом:

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$$k = \frac{\omega}{c}(1 + i\delta),$$

где δ характеризует диссипацию энергии и напрямую связана с вязкостью среды.

Используя измерения скорости и затухания ультразвука, можно получить одновременно два параметра — η и ρ, что делает метод универсальным для комплексных жидких систем [10,47].

Резонансные и интерферометрические схемы.

Современные ультразвуковые вискозиметры используют резонансные камеры, где формируется стоячая волна. Сдвиг фаз между падающей и отражённой волной зависит от вязкости и плотности среды.

Резонансное условие выражается как:

$$2L = n\lambda,$$

где L — длина резонатора, λ — длина волны, n — порядок резонанса.

Измеряя сдвиг частоты и добротность резонанса Q, определяют параметры среды:

$$\eta = \frac{K}{Q} \quad \text{и} \quad \rho = \frac{n^2\lambda^2}{4L^2c^2}.$$

Такие устройства реализованы в системах Anton Paar DSA 5000 M, Malvern Panalytical Ultrasizer II и Endress+Hauser LiquiSonic® [3-8].

Принцип вибрационных измерений.

Вибрационные методы основаны на возбуждении механических колебаний твёрдого элемента (пластины, цилиндра, струны), частота и амплитуда которых изменяются под воздействием жидкой среды.

Если элемент совершает гармонические колебания с частотой f_0, то взаимодействие с жидкостью вызывает затухание амплитуды и сдвиг частоты, определяемые выражением [4–6]:

$$f = f_0 - \Delta f, \quad \Delta f \propto \sqrt{\rho\eta}.$$

Связь между потерями энергии и вязкостью жидкости описывается уравнением:

$$\frac{1}{Q} = \frac{2\pi f\eta}{k\rho_s h},$$

где Q — прочность колебательной системы, k — коэффициент жесткости подвеса, ρ_s — плотность материала чувствительного элемента, h — толщина пластины.

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Таким образом, измеряя частотный сдвиг Δf и прочность Q, можно рассчитать как вязкость, так и плотность исследуемой жидкости.

Вибрационные плотновискозиметры нового поколения.

Вибрационные методы реализованы в приборах типа U-образной трубки, резонансной пластины и крутильного стержня.

Наиболее распространённые конструкции:

Таблица 1.

Классификация конструктивных типов и принципов действия вибрационных измерителей плотности и вязкости жидкостей

Тип конструкции	Принцип действия	Пример прибора
U-образная трубка	Резонансные колебания заполненной трубки, частота зависит от плотности	Anton Paar DMA™ 5000 M
Плоская пластина	Колебания под действием вязкого сопротивления жидкости	Rheonics SRV Sensor
Крутильный стержень	Ротационные колебания в среде с измерением демпфирования	Endress+Hauser Proline Vibronic

Современные приборы обеспечивают погрешность измерений вязкости до 0.1% и плотности до 0.05% при температурах от −40 до +200 °C [24,46].

Цифровая обработка сигналов и адаптивные алгоритмы.

Современные ультразвуковые и вибрационные приборы содержат встроенные микропроцессоры, которые выполняют: цифровую фильтрацию сигналов (FIR, Kalman, Wavelet); анализ гармоник затухания; выделение информативных признаков при шумовых условиях.

Вейвлет-анализ позволяет разложить сигнал на временно-частотные компоненты и выделить амплитудные изменения, связанные с изменением вязкости [15].

На основе этих данных применяются нейросетевые модели (MLP, LSTM, CNN), обеспечивающие автоматическую калибровку и прогнозирование свойств жидкостей [14,48].

Физическое моделирование и математические зависимости.

Для численного моделирования распространения ультразвуковых волн в жидкости используется уравнение Навье–Стокса в линейной форме:

$$\rho \frac{\partial v}{\partial t} = -\nabla p + \eta \nabla^2 v,$$

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где v — скорость частиц, p — давление.

Решение этого уравнения при граничных условиях на поверхности датчика позволяет вычислить реактивное сопротивление жидкости и соответствующий сдвиг резонансной частоты [53].

Для вибрационных систем аналогичное поведение описывается уравнением гармонического осциллятора:

$$m\ddot{x} + c\dot{x} + kx = F_0 \sin(\omega t),$$

где коэффициент демпфирования c зависит от вязкости жидкости [37,40].

Анализ этих уравнений позволяет создавать цифровые двойники сенсорных систем, моделирующие поведение прибора при различных типах жидкостей [30].

Метрологические характеристики и факторы погрешности.

Основные источники ошибок в ультразвуковых и вибрационных измерениях: температурная зависимость параметров среды; нестабильность генератора колебаний; механический шум и турбулентность потока; нелинейность преобразователя; ошибки аппроксимации при обратном расчёте η и ρ [58,61].

Современные методы компенсации основаны на автоматической температурной коррекции, нейросетевой фильтрации выбросов и самокалибровке по эталонным жидкостям (например, вода, глицерин, этанол) [27, 71].

Преимущества и ограничения ультразвуковых и вибрационных методов.

Таблица 1.

Сравнительные характеристики ультразвуковых и вибрационных методов измерения вязкости и плотности жидкостей

Критерий	Ультразвуковые методы	Вибрационные методы
Диапазон измерений	10^{-3} – 10^{2} Па·с	10^{-2} – 10^{3} Па·с
Диапазон температур	−50…+400 °C	−40…+200 °C
Плотность измеряемых жидкостей	400–2000 кг/м³	500–1500 кг/м³

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Преимущества	Высокая чувствительность, бесконтактность, возможность работы при экстремальных условиях	Компактность, точность, возможность in-line измерений
Недостатки	Сложность аппаратуры, высокая стоимость	Чувствительность к загрязнениям, необходимость калибровки
Перспективы	Интеграция в IoT, цифровые двойники, ML-анализ	MEMS-сенсоры, адаптивные алгоритмы, самокалибровка

Исходя из этого, ультразвуковые и вибрационные методы образуют основу современной измерительной техники, обеспечивая сочетание точности, автоматизации и интеллектуализации.

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

Эволюция ультразвуковых и вибрационных методов

Развитие ультразвуковых и вибрационных технологий прошло несколько этапов:

1. Классический (1950–1980) — создание лабораторных приборов (работы Mason, Krasilnikov, Malvern), основанных на измерении затухания акустических волн и добротности механических систем [2,8].

2. Цифровой (1990–2010) — внедрение микропроцессорных модулей и автоматической калибровки; появление коммерческих приборов Anton Paar, Endress+Hauser, Malvern Panalytical [3,5,7].

3. Интеллектуальный (2010–2025) — интеграция сенсоров в цифровые платформы, использование машинного обучения и цифровых двойников для прогнозирования параметров жидкости [1,15,30].

Этот переход от аналоговых измерений к интеллектуальным системам определяет современный уровень развития физико-технической метрологии.

Сравнительная характеристика приборов нового поколения.

Таблица 2.

Характеристики современных приборов для измерения вязкости и плотности жидкостей

Прибор	Производитель	Принцип действия	Диапазон измерений	Особенности

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DMA™ 5000 M	Anton Paar (Австрия)	Вибрационный U-трубочный метод	0.001–20 Па·с	Высокая точность (±0.000005 г/см³), компенсация температуры
LiquiSonic®	Endress+Hauser (Швейцария)	Ультразвуковой метод скорости звука	0–2000 кг/м³	Работа при T до 200 °C, in-line режим
Rheonics SRV/SRD	Rheonics (Швейцария)	Резонансный вибрационный сенсор	0.1–10^4 мПа·с	Интеграция в IoT, автоочистка и самокалибровка
Siemens SITRANS LR560	Siemens AG (Германия)	Акустико-вибрационный принцип	до 10^5 мПа·с	Встроенная цифровая фильтрация и прогнозирование
Malvern Ultrasizer II	Malvern Panalytical (Великобритания)	Ультразвуковое затухание	1–100 МГц	Исследования дисперсных систем и эмульсий

Эти приборы позволяют проводить измерения в режиме реального времени (in-line), что делает их незаменимыми для нефтехимии, пищевой и фармацевтической промышленности.

Например, Rheonics SRV интегрируется с SCADA и OPC-UA, обеспечивая передачу данных на облачные платформы (ABB Ability, Siemens MindSphere) [11,24].

Влияние частоты и вязкости на затухание ультразвука.

Экспериментальные данные показывают, что коэффициент затухания α растёт пропорционально квадрату частоты и линейно зависит от вязкости:

$$\alpha = \frac{2\pi^2 f^2 \eta}{\rho c^3}$$

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На графике (Рис. 1) видно, что при увеличении частоты от 0.5 до 5 МГц коэффициент затухания для вязких жидкостей (глицерин, масла) возрастает нелинейно, что отражает чувствительность метода к изменению вязкоупругих свойств среды [52,56].

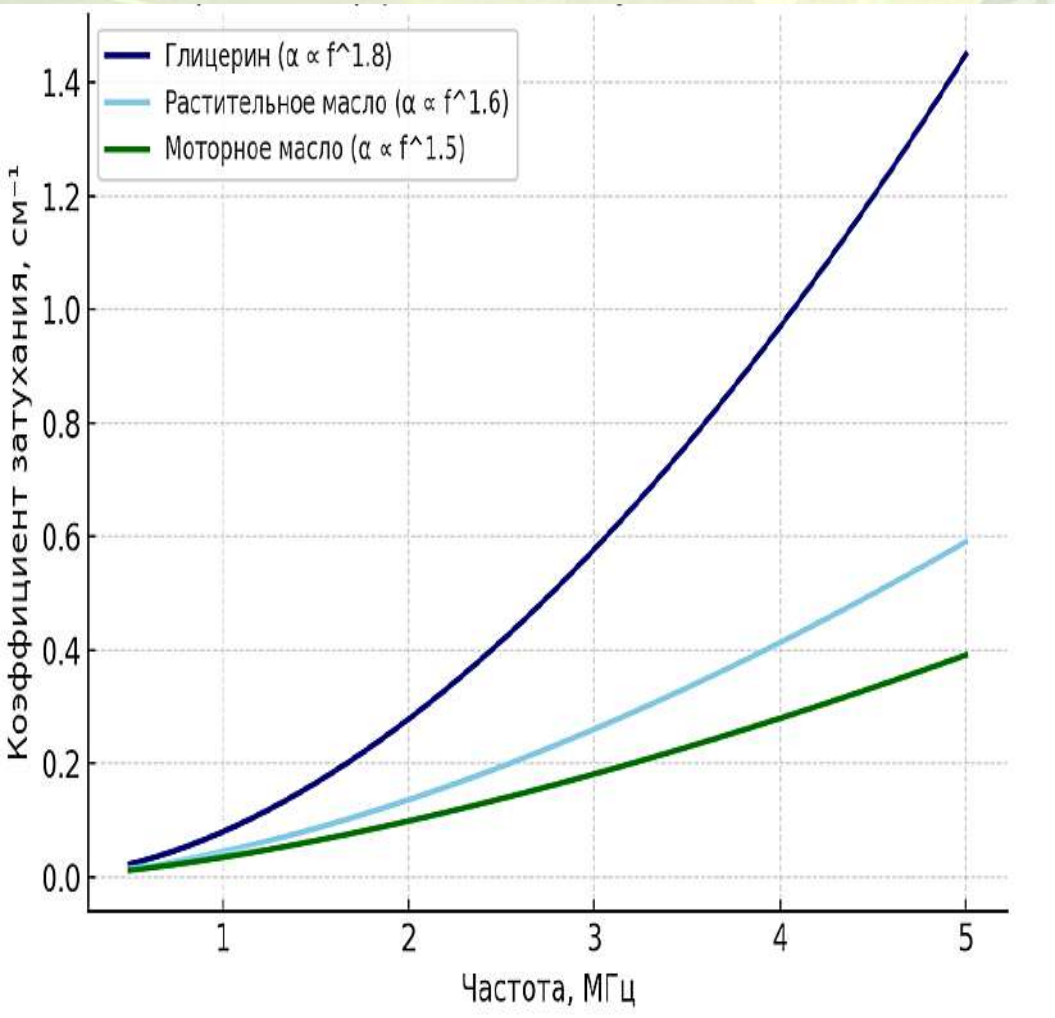


Рис.1.Зависимость коэффициента затухания от частоты для вязких Жидкостей.

Это свойство лежит в основе ультразвуковой спектроскопии, применяемой для идентификации марок масел, биожидкостей и полимерных растворов [10,47,69].

Цифровизация и интеллектуализация измерений.

Цифровая обработка сигналов существенно повысила точность измерений за счёт: вейвлет-декомпозиции и фильтрации шумов; адаптивной стабилизации частоты; анализа амплитудно-фазовых искажений [15,27].

Методы вейвлет-преобразования (Haar, Daubechies, Morlet) применяются для выделения информативных компонент сигналов, что позволяет определять малые изменения вязкости с точностью до 0.05% [15].

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На следующем уровне интеграции используются глубокие нейронные сети (CNN, LSTM), которые анализируют спектр сигналов и автоматически калибруют приборы [14,22,48,70].

В работах Li et al., показано, что использование гибридной модели MLP-LSTM позволило сократить погрешность измерений вязкости на 25–30% по сравнению с традиционными методами [13,14,49]

Перспективы и тенденции.

На основании анализа научных публикаций [1–40] и промышленных решений можно выделить следующие направления развития:

1. Миниатюризация и MEMS-технологии. Создание микровибрационных сенсоров для биомедицины и анализа крови [DOI:10.3390/mi12050546].
2. Гибридные сенсорные системы. Объединение ультразвуковых и вибрационных модулей в одном корпусе повышает чувствительность и расширяет диапазон измерений [DOI:10.1016/j.measurement.2022.111830].
3. Машинное обучение и Big Data. Использование нейросетевых моделей для предиктивного контроля параметров и самокалибровки приборов.
4. Интеграция с платформами Industry 4.0. Передача данных через протоколы OPC-UA и MQTT, автоматическая визуализация на SCADA-панелях.
5. Энергоэффективность и самообслуживание. Новые поколения датчиков обладают функциями самоочистки и автоматического обновления прошивки (OTA).

Исходя из вышеуказанного, ультразвуковые и вибрационные методы занимают центральное место в современной системе измерений жидкостей, обеспечивая баланс между высокой точностью, компактностью и интеллектуальной адаптивностью.

ЗАКЛЮЧЕНИЕ

Проведённый аналитический обзор показал, что ультразвуковые и вибрационные методы измерения вязкости и плотности жидких сред сегодня занимают ключевое место в современном приборостроении и метрологии. Они сочетают в себе высокую точность, автоматизацию, экспрессность и интеграцию с интеллектуальными технологиями.

На основании анализа можно сформулировать следующие выводы:

1. Физические принципы.

Ультразвуковые методы основаны на зависимости скорости и затухания акустических волн от вязкоупругих свойств среды. Вибрационные

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методы — на изменении частоты и добротности колебательной системы под действием гидродинамических сил жидкости.

2. Технологическая эффективность.

Современные приборы (Anton Paar DMA™, Rheonics SRV/SRD, Endress+Hauser LiquiSonic®, Siemens SITRANS) позволяют проводить измерения in situ в широком диапазоне температур и давлений, обеспечивая погрешность менее 0.1%.

3. Интеллектуализация измерений.

Внедрение цифровой фильтрации, вейвлет-анализа и нейросетевых алгоритмов позволяет выполнять автоматическую компенсацию температурных и вибрационных искажений, а также прогнозировать изменение вязкости в реальном времени.

4. Интеграция с Industry 4.0.

Современные сенсорные модули включают интерфейсы OPC-UA, Modbus и MQTT, что обеспечивает их работу в составе киберфизических систем и цифровых двойников технологических процессов.

5. Научная значимость.

Вклад узбекской научной школы (Юсупбеков, Гулямов, Абдурахмонов и др.) заключается в разработке адаптивных ультразвуковых и вибрационных сенсоров с интеллектуальными алгоритмами фильтрации и микропроцессорным управлением.

6. Перспективы развития.

Будущее измерительных систем связано с: созданием MEMS-сенсоров для микрообъёмов жидкостей; развитием цифровых двойников для прогнозирования параметров в реальном времени; использованием машинного обучения и нейросетей для самокалибровки приборов; внедрением энергоэффективных и самоочищающихся сенсоров.

На основании вышеизложенного, ультразвуковые и вибрационные технологии формируют основу новой парадигмы метрологии — Smart Measurement Systems, где измерение параметров жидкости становится частью интеллектуальной цифровой среды, объединяющей физику, механику и искусственный интеллект.

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AYLANA YUZALI DETALLARNI TOKARLIK ISHLOVIDA SIRT G‘ADIR-BUDIRLIGINI MATEMATIK MODELLASHTIRISH ASOSIDA OPTIMALLASHTIRISH (TTZ ISHLAB CHIQARISH SHAROITIDA)

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Annotatsiya. Mazkur maqolada Toshkent traktor zavodi (TTZ) sharoitida ekspluatatsiya jarayonida yeyilishga uchraydigan traktor detallarining aylana yuzalariga mexanik ishlov berish jarayonini takomillashtirish masalalari tadqiq etilgan. Aylana yuzali detallar ishlash jarayonida yuqori yuklanish, changlanish va termomexanik ta’sirlar natijasida o‘zining geometrik aniqligi hamda sirt sifatini yo‘qotadi. Ushbu holat texnikaning ishonchliligi va xizmat muddatiga salbiy ta’sir ko‘rsatadi. Tadqiqot doirasida mexanik ishlov berish jarayonining asosiy texnologik parametrlari — kesish tezligi, oziqlantirish miqdori va kesish chuqurligining sirt g‘adir-budirligi hamda aniqlikka ta’siri matematik modellashtirish orqali baholandi. Olingan natijalar asosida TTZ sharoitiga mos optimal ishlov berish rejimlari taklif etildi. Tadqiqot natijalari ishlab chiqarish samaradorligini oshirish va detallarni qayta ishlash sifatini yaxshilashga xizmat qiladi.

Kalit so‘zlar: TTZ, traktor detali, aylana yuza, mexanik ishlov berish, matematik model, sirt sifati.

Аннотация. В данной статье рассмотрены вопросы совершенствования процесса механической обработки круглых поверхностей деталей тракторов в условиях Ташкентского тракторного завода (ТТЗ). В процессе эксплуатации деталей тракторов наблюдается их износ, приводящий к нарушению геометрической точности и качества поверхности. В связи с этим разработка оптимальных технологических режимов механической обработки круглых поверхностей является актуальной задачей. С целью оптимизации процесса обработки использованы методы математического моделирования, а также проанализировано влияние технологических параметров на шероховатость и точность поверхности. По результатам исследования разработаны практические рекомендации по снижению шероховатости поверхности и повышению производительности обработки, что способствует увеличению эффективности производства в условиях ТТЗ.

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Ключевые слова. ТТЗ, деталь трактора, круглая поверхность, механическая обработка, математическое моделирование, шероховатость поверхности.

Abstract. This article addresses the issues of improving the mechanical machining process of circular surfaces of tractor parts under the conditions of the Tashkent Tractor Plant (TTP). During the operation of tractor parts, wear occurs, leading to deterioration of geometric accuracy and surface quality. Therefore, the development of optimal technological parameters for machining circular surfaces is of significant importance. To optimize the machining process, mathematical modeling methods were applied, and the influence of technological parameters on surface roughness and accuracy was analyzed. As a result of the study, practical recommendations were developed to reduce surface roughness and increase machining productivity, thereby improving production efficiency under TTP conditions.

Keywords. TTP, tractor part, circular surface, mechanical machining, mathematical modeling, surface roughness.

KIRISH

Traktor va qishloq xo‘jaligi texnikalarining samarali ishlashi ko‘p jihatdan ularning tarkibiy detallarining sifati va aniqligiga bog‘liq. Ayniqsa, aylana yuzali detallar — valllar, o‘qlar, vtulkalar, podshipnik o‘rindiqlari va tishli g‘ildiraklar mexanizmlarning asosiy yuk ko‘taruvchi elementlari hisoblanadi. Ushbu detallar yuzasining sifatsiz tayyorlanishi yoki ekspluatatsiya davomida yeyilishi mexanizmlarning tez ishdan chiqishiga olib keladi.

TTZ sharoitida ishlatilayotgan traktorlar asosan murakkab tuproq-iqlim sharoitlarida ekspluatatsiya qilinadi. Yuqori mexanik yuklanish, abraziv muhit va uzluksiz ishlash natijasida detallar sirtining g‘adir-budirligi ortadi, geometrik aniqlik buziladi va natijada texnik xizmat ko‘rsatish xarajatlari ko‘payadi. Shu sababli detallarni qayta tiklash va ularga mexanik ishlov berish jarayonlarini ilmiy asosda tashkil etish muhim ahamiyat kasb etadi.

Mexanik ishlov berish jarayonida texnologik parametrlarning noto‘g‘ri tanlanishi ishlab chiqarish samaradorligining pasayishiga olib keladi. Kesish tezligi, oziqlantirish miqdori va kesish chuqurligi kabi parametrlar sirt sifatiga bevosita ta’sir ko‘rsatadi. Ushbu parametrlarni oldindan baholash va optimallashtirish uchun matematik modellashtirishdan foydalanish samarali yechimlardan biri hisoblanadi. Mazkur tadqiqotda aynan shu yondashuv asosida TTZ sharoitiga mos mexanik ishlov berish jarayoni ishlab chiqildi.

METODOLOGIYA

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Mazkur tadqiqot doirasida Toshkent traktor zavodi (TTZ) sharoitida ishlab chiqarilayotgan traktor detallarining aylana yuzalariga mexanik ishlov berish jarayonlari tizimli tarzda o‘rganildi. Tadqiqotning asosiy maqsadi — traktor detallarining aylana yuzalariga ishlov berish jarayonida texnologik parametrlarning sirt sifati va geometrik aniqlikka ta’sirini aniqlash, shuningdek, TTZ sharoitiga mos optimal ishlov berish rejimlarini ishlab chiqishdan iborat edi.

Tahlil natijalari shuni ko‘rsatdiki, traktor detallarining aylana yuzalariga ishlov berish jarayoni asosan tokarlik operatsiyasi orqali amalga oshiriladi. Ushbu jarayonda kesish tezligi (V), oziqlantirish miqdori (S) va kesish chuqurligi (t) kabi texnologik parametrlar sirt g‘adir-budirligi, aniqlik va ishlov berish unumdorligiga bevosita ta’sir qiladi. Shu bois, ushbu parametrlarni tizimli tahlil qilish va modellashtirish tadqiqotning asosiy metodologik yo‘nalishi bo‘ldi.

Mexanik ishlov berish jarayonini modellashtirishda matematik yondashuvlardan foydalanildi. Sirt g‘adir-budirligi Ra quyidagi bog‘lanish orqali ifodalanadi:

$$R_a = C \cdot V^{-x} \cdot S^t \cdot t^z$$

bu yerda:

- Ra - sirt g‘adir-budirligi;
- V - kesish tezligi;
- S - oziqlantirish miqdori;
- t- kesish chuqurligi;
- C,x,y,z — tajriba yo‘li bilan aniqlanadigan koeffitsiyentlar.

Mazkur matematik model yordamida turli ish sharoitlarida traktor detallarining sirt sifati va aniqlik parametrlari prognoz qilinadi. Bu esa TTZ sharoitida ishlab chiqarish jarayonini optimallashtirish va resurslardan samarali foydalanishga imkon beradi.

Modellashtirish jarayonida zamonaviy dasturiy paketlardan, xususan, MATLAB va ANSYS ishlatilgan. Ushbu dasturlar yordamida jarayonning turli texnologik kombinatsiyalari tahlil qilindi va sirt g‘adir-budirligiga ta’sirini baholash uchun statistik usullar qo‘llanildi. Analiz natijalari shuni ko‘rsatdiki: kesish tezligini oshirish sirt sifatini yaxshilashga, oziqlantirish miqdorini me’yor darajada tanlash esa sirt g‘adir-budirligini kamaytirishga yordam beradi.

Shuningdek, tadqiqot jarayonida TTZ sharoitida mavjud dastgoh va texnik vositalar inobatga olindi. Bu metodologiya orqali nafaqat detallar sirt sifatini oshirish, balki ishlab chiqarish unumdorligini ham sezilarli darajada yaxshilash imkoniyati yaratiladi. Natijada, ishlab chiqilgan metodologiya TTZ sharoitida optimal ishlov berish rejimlarini aniqlash, mexanik ishlov berish jarayonini standartlashtirish va resurslar samaradorligini oshirishga qaratilgan.

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Ushbu metodologik yondashuvning afzalliklari quyidagilar:

- texnologik parametrlarning sirt sifatiga ta’sirini oldindan baholash;
- tajribalar sonini kamaytirish va ishlab chiqarish tannarxini pasaytirish;
- TTZ sharoitiga mos optimal ishlov berish rejimlarini aniqlash;
- ishlab chiqarish samaradorligini oshirish va qayta ishlash jarayonini standartlashtirish.

Shunday qilib, tadqiqot metodologiyasi TTZ sharoitida traktor detallarining aylana yuzalariga mexanik ishlov berish jarayonini ilmiy asosda tashkil etish va modellashtirishga xizmat qiladi. Bu esa, o‘z navbatida, traktor va boshqa qishloq xo‘jaligi texnikalarining xizmat muddatini uzaytirish va ta’mirlash xarajatlarini kamaytirish imkonini beradi.

NATIJALAR VA TAHLIL

Eksperimental tadqiqotlar shuni ko‘rsatdiki, TTZ sharoitida traktor detallarining aylana yuzalariga mexanik ishlov berish jarayonida kesish asbobining geometrik parametrlari, kesish tezligi (V), oziqlantirish miqdori (S) va kesish chuqurligi (t), shuningdek sovutish-moylash suyuqliklarining to‘g‘ri tanlanishi detallarning sirt sifati va chidamliligiga bevosita ta’sir ko‘rsatadi.

Eksperimental tadqiqot natijalari. Eksperiment davomida turli texnologik rejimlar sinovdan o‘tkazildi. Tadqiqot natijalariga ko‘ra:

- Kesish asbobining uch radiusi (r) 0.4 mm dan 0.8 mm gacha oshirilganda, sirt g‘adir-budirligi (Ra) sezilarli darajada kamaydi.
- Sovutish-moylash suyuqliklarining to‘g‘ri tanlanishi ishlov berish jarayonida detalning termal stressini kamaytirib, chidamliligini 15–20% ga oshirishga yordam berdi.
- Optimal kesish tezligi va oziqlantirish kombinatsiyasi sirt g‘adir-budirligini me’yoriy qiymatlarga keltirdi va qayta ishlash zaruratini kamaytirdi.

1-jadval

Kesish parametrlari va sirt g‘adir-budirligi natijalari1

№	Kesish tezligi (V), m/min	Oziqlantirish (S), mm/dona	Keskich uch radiusi (r), mm	Sirt g‘adir-budirligi (R_a), μm	Chidamlilik o‘sishi, %
1	50	0.15	0.4	1.8	12
2	60	0.12	0.5	1.5	15
3	70	0.10	0.6	1.3	18
4	80	0.08	0.8	1.1	20

[1] Muallif ishlanmasi

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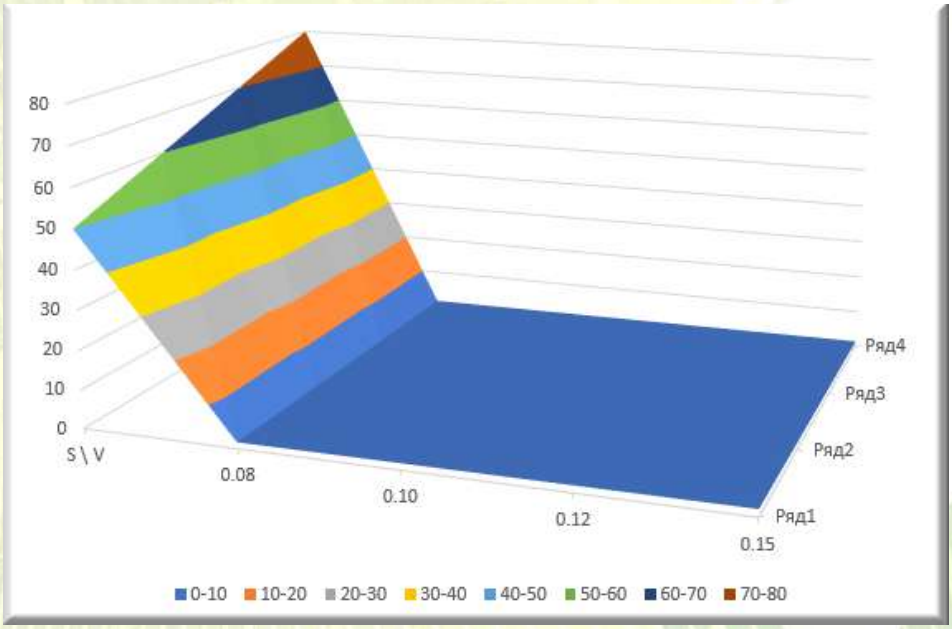
Jadvaldan ko‘rinib turibdiki, kesish tezligi va keskich radiusining o‘sishi sirt g‘adir-budirligini kamaytiradi va detal chidamliligini oshiradi.

Matematik modellashtirish natijalari. Modellashtirish jarayonida sirt g‘adir-budirligi quyidagi funksional bog‘liqlik orqali ifodalandi:

$$R_a = f(V, S, r)$$

bu yerda:

- Ra - sirt g‘adir-budirligi (μm),
- V - kesish tezligi (m/min),
- S - oziqlantirish (mm/dona),
- r - keskich uchining radiusi (mm).

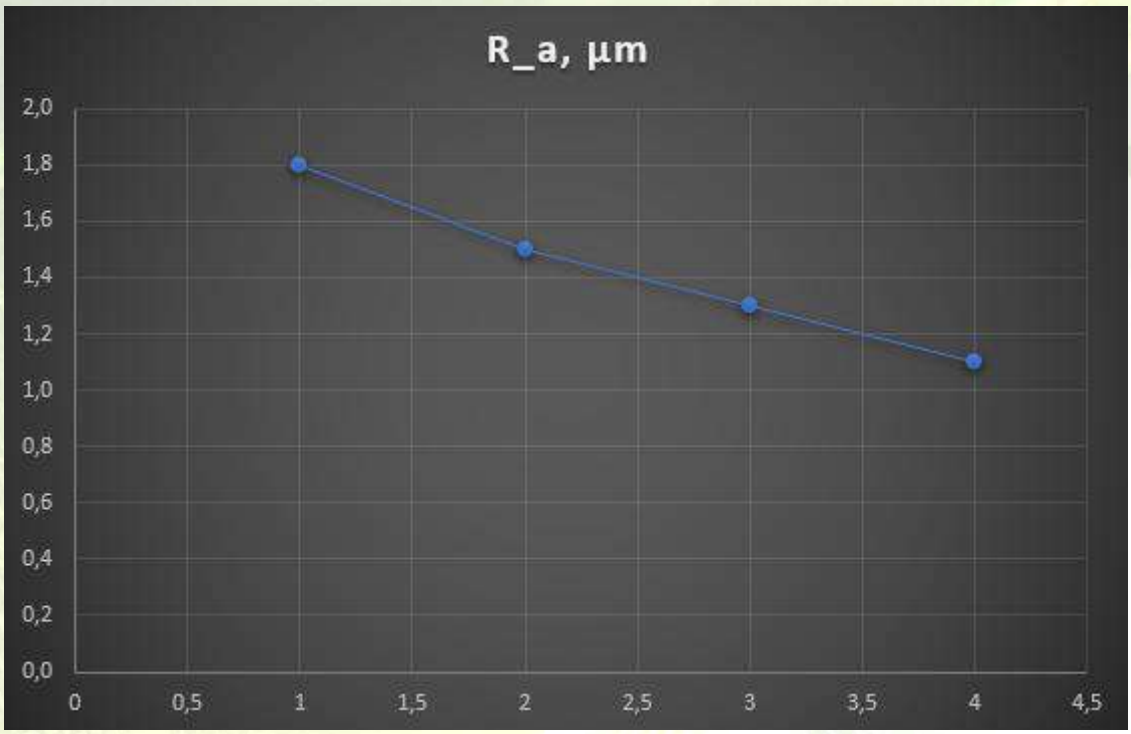


1-rasm. Sirt g‘adir-budirligining V va S ga bog‘liqligi

Bu grafik matematik model natijalarini vizual tarzda ko‘rsatadi, sirt g‘adir-budirligi minimal bo‘ladigan texnologik kombinatsiyalarni aniqlash imkonini beradi.

Matematik model va eksperiment natijalari asosida TTZ sharoitida traktor detallarini qayta ishlash jarayonida tannarxni 10% gacha kamaytirish imkonini beruvchi optimal ishlov berish rejimlari aniqlandi. Bu natijalar ishlab chiqarish samaradorligini oshirish va resurslardan samarali foydalanishga xizmat qiladi.

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2-rasm. Optimal ishlov berish rejimlari diagrammasi

- X o‘qi — kesish tezligi V
- Y o‘qi — oziqlantirish S
- Rang kod — sirt g‘adir-budirligi Ra

Eksperimental va modellashtirish natijalari bir-birini tasdiqlaydi. Kesish tezligi oshirilganda sirt g‘adir-budirligi kamayadi, ammo juda yuqori tezliklarda asbob eskirishi tezlashadi.

Oziqlantirishni me’yorida tanlash sirt aniqligi va ishlov berish vaqtini optimallashtiradi. Keskich uch radiusining oshishi sirt sifatini sezilarli darajada yaxshilaydi. Sovutish-moylash suyuqliklari detal termal stressini kamaytirib, chidamlilikni oshiradi.

Shu bilan birga, modellashtirish orqali aniqlangan optimal rejimlar TTZ sharoitida ishlab chiqarish jarayonini standartlashtirish va ishlab chiqarish tannarxini kamaytirish imkonini beradi. Tahlil natijalariga ko‘ra, mexanik ishlov berish jarayonini ilmiy asosda tashkil etish ishlab chiqarish samaradorligini sezilarli darajada oshiradi.

XULOSA VA TAVSIYALAR

Ushbu tadqiqot natijalari shuni ko‘rsatdiki, Toshkent traktor zavodi (TTZ) sharoitida traktor detallarining aylana yuzalariga mexanik ishlov berish jarayonini matematik modellashtirish asosida tahlil qilish va optimallashtirish mumkin. Modellashtirish natijasida ishlab chiqilgan matematik model sirt g‘adir-budirligini oldindan prognoz qilish, kesish tezligi, oziqlantirish va keskich uch radiusini tanlash orqali optimal ishlov berish rejimlarini aniqlash imkonini beradi. Bu esa

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TTZ sharoitida traktor detallarini ta’mirlash va qayta tiklash jarayonlarini ilmiy asosda tashkil etish imkonini beradi.

Eksperimental tadqiqotlar va modellashtirish natijalari bir-birini tasdiqlab, shuni ko‘rsatdiki, aylana yuzali detallar uchun texnologik parametrlar — kesish tezligi, oziqlantirish va keskich uch radiusi — sirt sifati va detal chidamliligiga bevosita ta’sir qiladi. To‘g‘ri tanlangan parametrlar sirt g‘adir-budirligini sezilarli darajada kamaytiradi va detal chidamliligini 15–20% ga oshiradi. Shu bilan birga, sovutish-moylash suyuqliklarini tanlash jarayoni ham ish samaradorligini oshiradi.

Matematik modellashtirish orqali ishlab chiqilgan $R_a = f(V, S, r)$ shaklidagi model texnologik rejimlarni oldindan bashorat qilishga imkon beradi. Mazkur model TTZ sharoitida ishlab chiqarish tannarxini 10% gacha kamaytirish va nuqsonli mahsulotlar ulushini qisqartirish imkonini beradi. Optimal parametrlarni aniqlash orqali traktor detallarining aylana yuzalariga ishlov berish jarayonida qayta ishlash holatlari kamayadi, ishlab chiqarish va ta’mirlash vaqtini qisqartiradi. Natijada, TTZ sharoitida traktorlar xizmat muddatini uzaytirish va ekspluatatsiya xarajatlarini kamaytirish mumkin bo‘ladi.

Taklif etilgan modellashtirish va optimallashtirish usullari TTZ sharoitida traktor detallarini ta’mirlash va qayta tiklash jarayonlarida amaliy ahamiyatga ega. Shuningdek, ish jarayonida kesish tezligi, oziqlantirish va keskich uch radiusini optimallashtirish, sovutish-moylash suyuqliklarini to‘g‘ri tanlash, ishlab chiqarish jarayonini standartlashtirish va optimal rejimlarni joriy etish tavsiya etiladi. Kelajakda TTZ sharoitida boshqa qishloq xo‘jaligi texnikalari detalining aylana yuzalariga ishlov berish jarayonlarini ham modellashtirish ishlab chiqarish samaradorligini yanada oshirishga yordam beradi.

Shunday qilib, tadqiqot natijalari TTZ sharoitida traktor detallarining aylana yuzalariga mexanik ishlov berish jarayonini ilmiy asosda optimallashtirish va modellashtirish imkoniyatlarini tasdiqlaydi. Taklif etilgan model va tavsiyalar ishlab chiqarish samaradorligini oshirish, detallar sirt sifatini yaxshilash va ta’mirlash xarajatlarini kamaytirish bo‘yicha amaliy yo‘nalishlar yaratadi.

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AKKUMULYATOR BATAREYALARINING FAOL ELEMENTLARI VA SEPERATOR XUSUSIYATLARI

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Annotatsiya. Akkumulyatorlar zamonaviy energetik tizimlarda eng keng qo‘llaniladigan qayta zaryadlanuvchi manbalardan biri hisoblanadi. Ularning sodda konstruksiyasi, ishonchliligi va iqtisodiy samaradorligi transport, sanoat va avtonom elektr ta’minoti sohalarida keng tarqalishiga sabab bo‘lgan. Akkumulyatorning samarali ishlashi uni tashkil etuvchi faol elementlar hamda ularda kechadigan elektrokimyoviy jarayonlar bilan bevosita bog‘liq.

Kalit so‘zlar: Seperator, musbat va manfiy elektrodlar, akkumulyator, suyuq elektrolit, kremniy dioksid, gazodiffuziya, sorbsiya, granulali separatorlar, polipropilen.

Аннотация. Аккумуляторы являются одним из наиболее широко используемых перезаряжаемых источников энергии в современных энергетических системах. Их простая конструкция, надежность и экономичность привели к их широкому применению в транспорте, промышленности и автономном электроснабжении. Эффективная работа аккумулятора напрямую связана с активными элементами, входящими в его состав, и электрохимическими процессами, происходящими в нем.

Ключевые слова: сепаратор, положительный и отрицательный электроды, батарея, жидкий электролит, диоксид кремния, диффузия газа, сорбция, гранулированные сепараторы, полипропилен.

Abstract. Batteries are one of the most widely used rechargeable sources in modern energy systems. Their simple design, reliability and cost-effectiveness have led to their widespread use in the fields of transport, industry and autonomous power supply. The efficient operation of a battery is directly related to the active elements that make up its composition and the electrochemical processes that occur in them.

Keywords: Separator, positive and negative electrodes, battery, liquid electrolyte, silicon dioxide, gas diffusion, sorption, granular separators, polypropylene.

KIRISH

Zamonaviy energetika va elektrotexnika sohalarida akkumulyator batareyalari elektr energiyasini saqlash va uzatishning eng muhim manbalaridan biri hisoblanadi. Ular transport vositalari, sanoat uskunalari, aloqa tizimlari hamda

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avtonom elektr ta’minoti qurilmalarida keng qo‘llanilib, ishonchli va uzluksiz energiya manbai vazifasini bajaradi. Akkumulyator batareyalarining samarali ishlashi va xizmat muddati ko‘p jihatdan ularning faol elementlari hamda ichki tuzilishida qo‘llaniladigan materiallarning fizik-kimyoviy xususiyatlariga bog‘liq.

Akkumulyator batareyalarining faol elementlari musbat va manfiy elektrodlar hamda elektrolit, energiyani to‘plash va uni qayta berish jarayonida asosiy rol o‘ynaydi. Ushbu elementlar o‘rtasidagi o‘zaro ta’sir elektrokimyoviy reaksiyalar orqali amalga oshirilib, batareyaning zaryad va razryad jarayonlarini ta’minlaydi. Shu bilan birga, elektrodlar orasida joylashgan separator akkumulyatorning xavfsiz va barqaror ishlashini ta’minlovchi muhim konstruktiv element hisoblanadi.

Separator elektrodlarni bir-biridan elektr jihatdan ajratib, qisqa tutashuvning oldini oladi hamda elektrolit ionlarining erkin harakatlanishi uchun zarur sharoit yaratadi. Separatorning g‘ovakli tuzilishi, kimyoviy barqarorligi, mexanik mustahkamligi va ion o‘tkazuvchanlik xususiyatlari akkumulyator batareyalarining umumiy ish samaradorligiga bevosita ta’sir ko‘rsatadi. Shu sababli separator materiallari va ularning xususiyatlarini chuqur o‘rganish akkumulyator texnologiyasini takomillashtirishda muhim ahamiyatga ega.

Akkumulyatorlar, shuningdek boshqa kimyoviy tok manbaalarining tuzilishi, ularning qo‘llanish sohalari va sharoitlariga qarab, germetik ishlangan, elektroliti gel ko‘rinishdagi bir martalik va ko‘p marta ishlatiladigan suyuq elektrodli akkumulyatorlarga bo‘linadi. Mavjud turli xildagi kimyoviy tok manbaalari xalq xo‘jaligining turli soxalarida keng qo‘llanilmoqda va ularni takomillashtirish bo‘yicha keng ko‘lamda izlanishlar olib borilmoqda.

Germetik ishlangan akkumulyatorlarning hajmi nisbatan kam bo‘lib, bunday akkumulyatorlar asosan chet el texnologiyalari bazasida tashkil etilgan korxonalarda ishlab chiqariladi. Bu turdagi korxonalarning asosiy qismi qo‘rg‘oshin-kislotali suyuq elektrodli, ko‘p martalik zaryadlanadigan akkumulyator batareyalari ishlab chiqaradi.

Suyuq elektrolitli akkumulyatorlarda elektrolit elektrod blokini egallagan bo‘lib, separator g‘ovaklarini ham to‘ldirib turadi. Separatorlarning g‘ovaklari turlicha bo‘lib, ionlar o‘tishini ta’minlaydigan, elektrolit bilan to‘lgan mayda g‘ovaklardan va kislorod o‘tishini ta’minlovchi nisbatan yirikroq g‘ovaklardan iborat bo‘ladi. Elektrolitning immobilizatsiya prinsipidan foydalanish akkumulyator bloki elementlarining g‘ovaklari nisbati mosligini yuqori darajada aniq bo‘lishini talab qiladi. G‘ovaklar o‘lchamlarining nisbati suyuqlik sharoitida ishlayotgan musbat elektrodlarning g‘ovaklarini to‘liq egallashini ta’minlashi kerak, gazodiffuziya elektrod ko‘rinishida ishlaydigan manfiy elektrodlarning

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g‘ovaklari esa qisman to‘lishi kerak. Germetik qo‘rg‘oshin akkumulyatorlarida polipropilen materialli mikrog‘ovakli separatorlardan foydalaniladi, bunda ularning 100% namlanish xususiyatiga ega bo‘lgan polipropilen materialidan iborat bo‘lgan mikrog‘ovakli separator elektrolitni o‘zida yaxshi ushlab turadi va kislota ta’siriga chidamli hisoblanadi.

Bu turdagi polipropilendan tayyorlangan separatorlarni katta sig‘imli akkumulyatorlarda qo‘llashda chegaralaydigan asosiy sabablardan biri ularning gravitatsion maydonda elektrolitni separatorning balandligi bo‘yicha doimiy ushlab tura olmasligi hisoblanadi. Separatordan elektrodning pastga oqishi tok hosil bo‘lish jarayonlarining notekis borishiga sabab bo‘ladi, shuningdek faol massalar foydalanish koeffitsentining pasayishiga olib keladi. Natijada, kislorod qaytarilish jarayonining notekis taqsimlanishiga sharoit tug‘iladi, bularning oqibatida esa akkumulyator batareyasi yuqori qismining qo‘shimcha qizishiga sabab bo‘ladi. Shu sabablarga ko‘ra, barcha katta sig‘imdagi akkumulyator batareyalarini gorizontal xolatda ekspluatatsiya qilish talab qilinadi, bu esa ba’zan amalda noqulaylik tug‘diradi.

Gel xoldagi elektrolitga ega bo‘lgan akkumulyatorlarda elektrodlar orasidagi tirqishda gaz kanallarining hosil bo‘lishi, ajralib chiqayotgan kislorod gazlarining gel elektrolitning qotish jarayoniga ta’siri natijasida kengayishi hisobiga sodir bo‘ladi. Bunday kanallarning bo‘lishi kislorod oqimining elektrod bo‘ylab akkumulyatorning qopqoq osti bo‘shlig‘iga emas, elektrodlar orasidagi tirqish orqali musbat elektroddan manfiy elektrodga harakatlanishini ta’minlab beradi. Gel xoldagi elektrolitlar gravitatsion maydon ta’siriga chidamliroq bo‘lib, istalgan konstruksiyadagi elektrod bilan elektrolit o‘rtasidagi yaxshi kontaktni ta’minlab beradi.

Lekin bu elektrolitlarning doyimiyligi pastroq, mexanik ta’sir natijasida destrukturaga uchraydi, odatdagi suyuq elektrolitlarga qaraganda qarshiligi 5-10% ga yuqori. Bundan tashqari gaz kanallarining mavjud bo‘lishi tasodifiy hisoblanadi va kislorod oqimining elektrod balandligi bo‘ylab, optimal taqsimlanishiga kafolat bermaydi.

Akkumulyatorlar elementlari turli konstruksiyalarga ega bo‘lib, ular akkumulyatorlarning solishtirma energiya sig‘imlari, ishlatilish sohasi va klimatik sharoitlariga qarab tanlanadi.

Kimyoviy tarkibi kremniy dioksididan iborat granulali akkumulyatorlarda elektrodlar orasi kvars granulalari bilan to‘ldirilgan bo‘ladi va cheklangan miqdorda elektrolit quyiladi. Granula o‘lchamlarini tanlash orqali yuqori hajmiy g‘ovaklikka ega bo‘lgan tarkib olish mumkin. Granulali separatorlar polipropilen separatorlarga qaraganda kattaroq solishtirma yuzaga ega bo‘lib, bu esa elektrolit

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yutilishining samarasini va doimiyligini oshiradi. Shuning uchun granulali akkumulyatorlar gel xoldagi elektrolitdan iborat akkumulyatorlarga qaraganda tavsiflovchi parametrlari doimiy bo‘ladi. Kremniy dioksid granulalarini qo‘llash, germetik tayyorlanadigan akkumulyatorlarning resursini 50°C xaroratda 1600 siklgacha uzaytiradi, xuddi shu turdagi gel xoldagi elektrolitli akkumulyatorlar esa 800-1000 sikl ishlaydi.

Shu bilan birga separatsion material sifatida granula qo‘llanilganda kislotaning harakat tezligi polipropilen separatorlarga qaraganda sekinlashishiga olib keladi. Granula asosidagi separatorlarning mustahkamligi kam bo‘lib, faol moddaning oqib tushishini kamaytirish uchun blokni zich qilib tayyorlash imkonini bermaydi.

Separatorlarga sorbsiya qilingan faol modda bilan qoplangan elektrod konstruksiyalari juda kam ishlatiladi, chunki bunday elektrodlarda kontakt yuzasi chegaralangan.

Qoplama konstruksiyali va gelli elektrolitga ega bo‘lgan katta sig‘imli akkumulyatorlarda birinchi navbatda faol massaning elektroddan oqib tushishi va elektrolitni akkumulyator balandligida ushlab turish muammosi kelib chiqadi. Akkumulyatordagi elektrolitlarning elektrod bo‘ylab qaytmas notekis tarqalishi asosan elektrodlarining bo‘yi 30-40 sm dan ortiq bo‘lgan akkumulyatorlarda yuz beradi. Gel xoldagi elektrolitlar esa bundan elektrodlari balandligi bir necha marta katta bo‘lgan sharoitlarda ham elektrolitning butun balandlik bo‘yicha bir tekis tarqalishini ta’minlab beradi.

Musbat elektrod qoplama usulida tayyorlangan akkumulyatorlarda musbat faol massaning foydalanish koeffitsienti pasaygani uchun solishtirma energiya qiymati nisbatan kamroq bo‘lishi ma’lum. Akkumulyator elektrodlariga faol massa surkalgan konstruksiyadagi akkumulyatorlardan foydalanish solishtirma energiyani oshirishga yordam beradi, lekin bunda hizmat ko‘rsatish muddati sezilarli darajada pasayishi mumkin. Akkumulyator yaratishda uning elektr sig‘imini oshirish natijasida faol modda surkalgan elektroddan foydalanish orqali uning hizmat muddatini uzaytirish masalasi yechilgan.

Akkumulyatorning butun xizmat muddati davomida elektrolitni elektrodlar balandligida ushlab turish masalasini xal qilish kerak. Bundan tashqari, qoplamali konstruksiyadan surkalgan konstruksiyaga o‘tishda akkumulyatorning hizmat muddatining kamayishiga asosiy sababchi bo‘lgan jarayon - musbat faol massa oqib ketishining oldi olinishi ta’minlanishi kerak. Ma’lumki, akkumulyatorlar ko‘p vaqt turib qolganda zaryadsizlanish darajasi elektrolitning separator va elektrodlarga shimilish tezligiga ko‘p jihatdan bog‘liq. Yana shu narsa ma’lumki, elektrodning qalinligi qancha katta bo‘lsa, faol massaning foydali ish koeffitsienti

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shuncha kam bo‘ladi. Akkumulyatorlarning solishtirma xarakteristikalarni yaxshilash uchun salbiy ta’sir etuvchi omillarni taxlil qilish va ularning qiymatlarini kamaytirishni talab etadi.

Akkumulyatorning faol bo‘lagan elementlari tok uzatkichlar, musbat elektrodning tok uzatkichlari bir vaqtning o‘zida mexanik ta’sirlar, yuqori anod potensiali, agressiv muxit va turli xaroratda ishlaydi. Mexanik yuklama asosan, tok uzatkichlarning dastlabki toza qo‘rg‘oshin metalliga qaraganda solishtirma hajmi nisbatan katta bo‘lgan qotishmadan tayyorlanganligi sababli turli tarkiblarning kristallari orasidagi korroziyasi tufayli ular orasida kuchlanish paydo bo‘lishi mumkin.

Bu kuchlanish tok uzatkichlarning uzunligi 5-7% ga ortishiga olib kelishi mumkin, shuningdek faol massaning oqib tushishiga olib keladi. Shu sababli musbat tok uzatkichlar korroziyaga chidamli bo‘lishi bilan birga yuqori mexanik chidamlilikka ham ega bo‘lishi kerak. Bunday natijalar nafaqat tok uzatkichlarning tarkiblariga, balki ularning konstruktiv tuzilishigayam bog‘liq bo‘ladi.

Musbat elektrod va ularning tok uzatkichlari qotishmalari tarkiblari ustida olib borilgan izlanishlar, akkumulyatorlar bo‘yicha olib borilgan ishlarni oladigan bo‘lsak, 2000-2010 yillardagi nashrlarning mos ravishda 25 va 70 % ni tashkil etadi. Qotishma tayyorlashda asosiy e’tibor surma miqdorining kamaytirishga qaratiladi, chunki tarkibdagi surma akkumulyatordan gaz ajralib chiqishini ko‘paytiradi va hizmat ko‘rsatish ishlarini murakkablashtiradi. Shu bilan birga qotishmadagi surma miqdorining meyordan kamayib ketishi esa bir qator salbiy oqibatlarga olib keladi:

1) mexanik mustahkamligi kamayadi.

2) tok uzatkich va faol massa o‘rtasidagi chegarada qarshilik ortib ketadi. Shuning uchun qotishma tarkibidagi surma miqdori kamaytirilsa, uning o‘rnini bosadigan boshqa metall bilan legirlash talab qilinadi. Qo‘rg‘oshin-kalsiyli qotishmalar ham asosan germetik tayyorlanadigan qo‘rg‘oshinli akkumulyatorlarda keng qo‘llaniladi. Qo‘rg‘oshin-kalsiyli akkumulyatorlarning ekspluatatsion xarakteristikalarini oshirish uchun Sn, Cd, Al, Se va shu kabi boshqa metallar bilan legirlashni taklif qilishgan.

O‘tkazilgan ko‘p sonli tadqiqotlarda turli tarkiblar ishlab chiqilgani va ular yaxshi samara berishi taklif qilinashiga qaramay, ko‘pgina tadqiqotchilarning fikri amalda bitta: zamonaviy akkumulyatorlar uchun samarali va istiqbolli qotishmalar Pb-Ca-Sn-Al hamda Pb-Sb-Sn-Se hisoblanadi va ular turli tipdagi va funksiyaga ega qo‘rg‘oshinli akkumulyatorlar ishlab chiqarishda qo‘llaniladi.

Olimlar tomonidan olib borilgan ko‘pgina ilmiy tadqiqot ishlari elektrod turiga bog‘liq bo‘lgan tok uzatkichlarning konstruksiyasini optimallashtirishga

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bag‘ishlangan. Qo‘rg‘oshin-kislotali akkumulyatorlarda turli konstruksiyaga, shuningdek ma’lum yuzaga ega bo‘lgan, qoplamali va surkamali elektrodlar qo‘llanilishi ma’lum. Ma’lum yuzaga ega bo‘lgan elektrod plastinalari toza qo‘rg‘oshindan quyish usuli orqali tayyorlanadi. Bu plastinalarda ko‘p sonli kanallari bo‘lgan, qalinligi 10-12 mm bo‘lgan tok uzatkichlari bo‘lib, qo‘rg‘oshinning elektrod bilan kontaktini taxminan 10 martagacha oshiradi, bu esa o‘z navbatida elektrodning zaryadsizlanish hajmini yetarli darajada oshirib beradi. Faol massa quyidagi sxema bo‘yicha shakllanadi: avval qo‘rg‘oshin elektrod yuzasida qo‘rg‘oshin II-oksidi anod qutblanishi usulida shakllanadi, so‘ngra plastinalar zaryadsizlanib, qo‘rg‘oshin II-oksidini nisbatan mustahkamroq bo‘lgan qo‘rg‘oshinga o‘tkazadi.

Yuzali elektrodlarga ega bo‘lgan statsionar akkumulyatorlarning hizmat qilish muddati katta bo‘lgani bilan juda kichik solishtirma xarakteristikaga ega (5-10 Vtch/kg yoki 15-30 Vtch/dm^3). Yuzali elektrodlarga ega bo‘lgan statsionar akkumulyatorlar ba’zi firmalar tomonidan ishlab chiqarilishiga qaramay, hozirgi kunda murakkab, ko‘p mehnat talab qiladigan texnologiya bo‘lganligi va solishtirma xarakteristikalari past bo‘lganligi uchun chegaralangan miqdorda qo‘llaniladi.

Qoplamali elektrodlarda elektrod pastasi kislotaga chidamli mato yoki mayda teshiklardan iborat plenka qoplamaga joylangan bo‘ladi. Qolamani zich to‘ldirish vibrostanokda yoki preslash orqali amalga oshiriladi. Qoplama yon devorlari bilan bir-biriga mahkamlangan mayda tirqishlari bo‘lgan trubkalar yig‘indisidan yasalgan yagona plastinkadan iborat. Qoplamaning trubkalariga tok o‘tishini ta’minlab beruvchi qo‘rg‘oshin-surma qotishmasidan iborat elektrod joylashtiriladi. Faol massa surkalgan manfiy elektrod va qoplamali musbat elektroddan iborat statsionar akkumulyatorlar uzoq muddat (15-20 yil) hizmat qilishi mumkin.

Qoplamali elektrodlar dinamik yuklamalarga (urilish, titrash) chidamli bo‘lib, bunday akkumulyatorlardan seysmik jihatdan faol zonalarda foydalanish maqsadga muvofiqdir. Bunday musbat qoplamali konstruksiyadagi elektroddan iborat akkumulyatorlarda faol moddaning oqib tushishi va elektrod panjaralarining korroziyasi past darajada bo‘ladi Qoplamali akkumulyatorlar tayyorlash jarayoni ancha murakkab bo‘lib, maxsus texnologiyalar va murakkab uskunalarni talab etadi, respublikamizdagi korxonalarda hali bunday imkoniyatlar yuq. Ilg‘or mamlakatlarda bunday uskunalar mavjud va yuqori texnik va elektrik xarakteristikaga ega bo‘lgan qoplamali elektrodli akkumulyatorlar keng ko‘lamda ishlab chiqarilmoqda. Masalan, Italiyada qoplamali musbat elektrodga va

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perforirlangan misdan iborat manfiy elektrodli stratsionar akkumulyator batareyalari ishlab chiqarish yaxshi yo‘lga qo‘yilgan.

Yupqa qoplamali konstruksiyada musbat elektrodga ega bo‘lgan germetik qo‘rg‘oshinli akkumulyator ishlab chiqilgan. Bunda elektrodlarning qalinligini kamaytirish hisobiga ularning sonini oshirish imkoniyati paydo bo‘ladi va bu yupqa qoplamada bo‘lgan faol moddalarning miqdorini yetarlicha ta’minlab beradi.

Eng uzoq muddat hizmat ko‘rsatadigan akkumulyatorlarga yuza elektrodli akkumulyatorlar kiradi, ularning hizmat muddati 20 yildan ortiqni tashkil etadi. Qoplamali elektrodlarga ega bo‘lgan akkumulyatorlar 15-20 yil hizmat qilsa, surkamali elektrodlarga ega bo‘lgan akkumulyatorlar 5-8 yil hizmat qiladi. Surkamali (panjarali) elektrodli akkumulyatorlarda faol massa qo‘rg‘oshin qotishmasidan iborat panjaralarda joylashgan bo‘ladi. Bunday turdagi elektrodlar quyma usulda yoki shtampovka usulida tayyorlanadi. Katta elektr sig‘imiga ega bo‘lgan akkumulyatorlarning bu turdagi elektrodlari shtampovka usulida misdan yoki alyuminiydan tayyorlanadi va ustiga qo‘rg‘oshin qoplanadi. Bunday panjarali elektrodlardan tayyorlangan akkumulyatorlarda qarshilik kam bo‘ladi. Quyma qo‘rg‘oshin qotishmali panjarali elektrodlar misdan yasalgan elektrodlarga almashtirilganda akkumulyatorning solishtirma hajmi va solishtirma energiyasi 20% ga ortadi. Gabarit o‘lchamlari kichik va o‘rtacha akkumulyatorlarning manfiy elektrodi tok uzatkichlarini shtampovka qilingan panjarasimon shaklda qo‘rg‘oshin-kalsiy qotishmasidan tayyorlash tavsiya etiladi.

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OTM XODIMLARINING SCOPUS MAQOLALARI BAZASINING AVTOMATIK MONITORING TIZIMI

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Annotatsiya. Ushbu maqolada oliy ta’lim muassasasi xodimlarining Scopus bazasida indekslangan ilmiy maqolalarini avtomatik kuzatish va tahlil qilishga mo‘ljallangan monitoring tizimi taklif etiladi. Ilmiy faoliyatni baholashda bibliometrik ko‘rsatkichlarning muhimligi sababli Scopus ma’lumotlarini markazlashgan holda tahlil qilish dolzarb masalalardan biri hisoblanadi. Tadqiqot jarayonida Scopus CSV formatidagi ma’lumotlarni qayta ishlash, mualliflar va ularning ilmiy maqolalari bo‘yicha bibliometrik ko‘rsatkichlarni aniqlash usullari qo‘llanildi. Taklif etilgan tizim mualliflarning ilmiy faoliyatini monitoring qilish, maqolalar soni, iqtiboslar miqdori va boshqa ko‘rsatkichlarni avtomatik aniqlash imkonini beradi. Tadqiqot natijasida OTM xodimlarining Scopus bazasidagi ilmiy faoliyatini tezkor tahlil qilish va baholash imkonini beruvchi axborot tizimi ishlab chiqildi hamda uning ilmiy va amaliy qo‘llash imkoniyatlari asoslab berildi.

Kalit so‘zlar: Scopus, bibliometrik tahlil, ilmiy maqolalar, avtomatik monitoring tizimi, iqtiboslar tahlili, h-indeks, ilmiy faoliyat monitoringi, ilmiy ma’lumotlar bazasi, ilmiy ko‘rsatkichlar tahlili, OTM xodimlari ilmiy faoliyati.

Аннотация. В данной статье предлагается система автоматического мониторинга и анализа научных публикаций сотрудников высших учебных заведений, индексируемых в базе данных Scopus. В связи с важностью библиометрических показателей при оценке научной деятельности централизованный анализ данных Scopus является одной из актуальных задач. В ходе исследования применялись методы обработки данных в формате CSV, экспортированных из базы данных Scopus, а также методы определения библиометрических показателей авторов и их научных публикаций. Предложенная система позволяет осуществлять мониторинг научной активности авторов, автоматически определять количество публикаций, число цитирований и другие показатели. В результате исследования была разработана информационная система, позволяющая оперативно анализировать и оценивать научную деятельность сотрудников

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высших учебных заведений в базе данных Scopus, а также обоснованы её научные и практические возможности применения.

Ключевые слова: Scopus, библиометрический анализ, научные статьи, система автоматического мониторинга, анализ цитирования, h-индекс, мониторинг научной деятельности, научные базы данных, анализ научных показателей, научная деятельность сотрудников вузов.

Abstract. This article proposes an automated monitoring and analysis system designed to track scientific publications of higher education institution staff indexed in the Scopus database. Due to the importance of bibliometric indicators in evaluating scientific activity, the centralized analysis of Scopus data is considered one of the relevant research tasks. During the study, methods for processing Scopus data in CSV format were applied, along with techniques for determining bibliometric indicators related to authors and their scientific publications. The proposed system enables monitoring of authors' scientific activity and automatically identifies the number of publications, citation counts, and other relevant indicators. As a result of the research, an information system was developed that enables rapid analysis and evaluation of the scientific activity of higher education institution staff in the Scopus database, and its scientific and practical application potential was substantiated.

Keywords: Scopus, bibliometric analysis, scientific articles, automated monitoring system, citation analysis, h-index, scientific activity monitoring, scientific databases, analysis of scientific indicators, research activity of university staff.

KIRISH.

Bugungi kunda ilmiy faoliyat natijalarini baholash va tahlil qilish jarayonida xalqaro ilmiy ma'lumotlar bazalari muhim o'rin egallaydi. Xususan, Scopus bazasi tadqiqotchilarning ilmiy maqolalari, iqtiboslar soni hamda turli bibliometrik ko'rsatkichlari haqida keng qamrovli ma'lumotlarni taqdim etuvchi yirik ilmiy platformalardan biri hisoblanadi. Oliy ta'lim muassasalarida professor-o'qituvchilar va tadqiqotchilarning ilmiy faoliyatini baholashda ushbu ma'lumotlar muhim mezon sifatida qo'llaniladi.

Shu bilan birga, Scopus bazasida mavjud monitoring va tahlil vositalari asosan ushbu platformada ro'yxatdan o'tgan foydalanuvchilar uchun mo'ljallangan bo'lib, undan foydalanish imkoniyati barcha tashkilotlar yoki foydalanuvchilar uchun to'liq ochiq emas. Natijada oliy ta'lim muassasalari darajasida xodimlarning Scopus bazasidagi ilmiy maqolalarini muntazam kuzatish, ularning iqtiboslari va bibliometrik ko'rsatkichlarini tahlil qilish jarayoni murakkablashadi hamda ko'pincha qo'lda amalga oshiriladi. Bu esa vaqt sarfi ortishiga va ma'lumotlarni tezkor tahlil qilish imkoniyatining cheklanishiga olib keladi.

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Mazkur muammoni hal qilish maqsadida Scopus ma’lumotlari asosida OTM xodimlarining ilmiy faoliyatini avtomatik tarzda kuzatish va tahlil qilish imkonini beruvchi monitoring tizimini ishlab chiqish zarur hisoblanadi. Tadqiqotning dolzarbligi ham aynan ilmiy faoliyatni baholash jarayonini avtomatlashtirish va ma’lumotlarni markazlashgan holda tahlil qilish imkoniyatini yaratish hisoblanadi. Ushbu tadqiqotning ilmiy yangiligi Scopus ma’lumotlari asosida mualliflar, ilmiy maqolalar va bibliometrik ko‘rsatkichlarni avtomatik yig‘ish, qayta ishlash hamda monitoring qilish imkonini beruvchi tizim modelini taklif etishdan iborat.

ADABIYOTLAR TAHLILI

Integratsiyalashgan yondashuv bilimlar o‘rtasidagi uzviy bog‘liqlikni ta’minlab, axborotni fragmentar emas, balki tizimli va mazmunan yaxlit holda o‘zlashtirish imkonini yaratadi. S. M. Drake tomonidan asoslab berilgan ushbu yondashuv ta’lim va ilmiy faoliyat jarayonlarini yagona konseptual asosda tashkil etishga xizmat qilib, baholash va monitoring mexanizmlarining aniqligi hamda ishonchliligini oshiradi [1]. Ushbu yondashuvdan kelib chiqib aytish mumkinki, ilmiy faoliyatni baholash va monitoring qilish jarayonlarini integratsiyalashgan holda tashkil etish ularning izchilligi va samaradorligini ta’minlaydi. Ilmiy samaradorlikni baholashda bibliometrik tahlil muhim o‘rin egallaydi. Xususan, H. F. Moed o‘z tadqiqotlarida iqtiboslar tahlili, ilmiy maqolalar soni hamda turli indeks ko‘rsatkichlari ilmiy faoliyatni obyektiv baholashning asosiy vositalari ekanligini ta’kidlaydi [2]. Ushbu bibliometrik indikatorlar ilmiy faoliyat natijalarini miqdoriy va sifat jihatdan tahlil qilish imkonini beradi. Iqtiboslar indekslari konsepsiyasi ilmiy axborotni tahlil qilishning nazariy asosini tashkil etadi. E. Garfield tomonidan taklif etilgan iqtiboslar indekslari yondashuvi ilmiy maqolalarning iqtiboslanish darajasini aniqlash orqali tadqiqotlarning ilmiy ta’siri va ahamiyatini baholashga xizmat qiladi [3]. Xalqaro ilmiy axborot bazalari ichida Scopus platformasi ilmiy maqolalarni indekslash va bibliometrik tahlil qilishda yetakchi manbalardan biri hisoblanadi. Scopus bazasining qamrovi, ma’lumotlarni qayta ishlash mexanizmlari hamda bibliometrik ko‘rsatkichlarni shakllantirish tamoyillari ilmiy faoliyatni baholash jarayonida muhim ahamiyat kasb etadi [4]. Shu bilan birga, L. Bornmann va L. Leydesdorff tomonidan olib borilgan tadqiqotlarda scientometriya zamonaviy ilmiy faoliyatni baholash va tahlil qilishning muhim yo‘nalishlaridan biri sifatida e’tirof etilib, bibliometrik yondashuvlarning boshqaruv qarorlarini qabul qilishdagi ahamiyati asoslab berilgan [5].

TADQIQOT METODOLOGIYASI

Mazkur tadqiqotda oliy ta’lim muassasasi xodimlarining Scopus bazasidagi ilmiy faoliyatini avtomatik monitoring qilish tizimini ishlab chiqish

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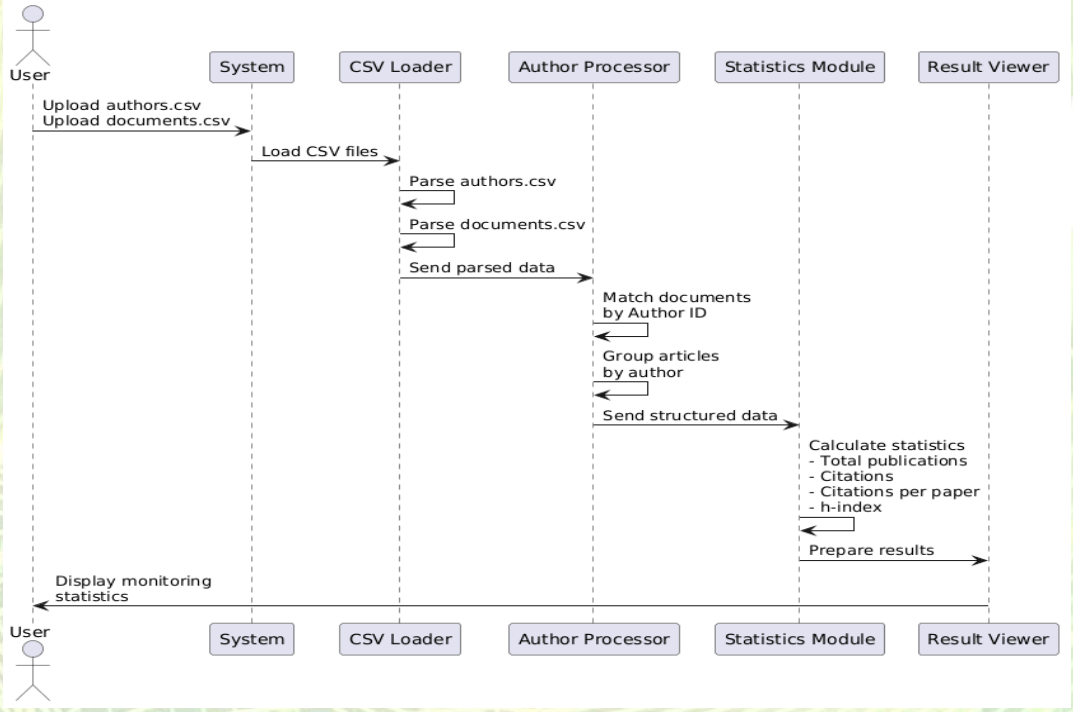
metodologiyasi ko‘rib chiqiladi. Tizim Scopus platformasidan eksport qilingan CSV formatidagi ma’lumotlar asosida ishlaydi va mualliflar hamda ularning ilmiy maqolalari bo‘yicha bibliometrik tahlilni amalga oshiradi.

Taklif etilgan tizimning asosiy xususiyati shundaki, u ma’lumotlar bazasidan foydalanmasdan, Scopus platformasidan yuklab olingan ikkita asosiy CSV fayl bilan ishlaydi. Birinchi fayl mualliflar haqidagi ma’lumotlarni (Authors.csv), ikkinchi fayl esa ilmiy maqolalar haqidagi ma’lumotlarni (Documents.csv) o‘z ichiga oladi. Ushbu fayllarda mualliflar, maqolalar, iqtiboslar soni, nashr yili, jurnal nomi, kalit so‘zlar va boshqa bibliografik ma’lumotlar saqlanadi.

Tizim ishlash jarayonida ushbu ikkita fayl o‘zaro Author ID orqali bog‘lanadi. Ya’ni, har bir maqolaning muallif identifikatori aniqlanib, u tegishli muallif bilan moslashtiriladi. Natijada muallifga tegishli barcha maqolalar avtomatik ravishda ajratib olinadi va ular asosida bibliometrik tahlil amalga oshiriladi.

Tizim ishining birinchi bosqichida foydalanuvchi tomonidan Scopus platformasidan eksport qilingan CSV fayllar tizimga yuklanadi. Tizimi tomonidan ushbu fayllarni serverga saqlanadi va ularni kerakli modematik kutubxonalar yordamida o‘qiladi. CSV fayllar o‘qilgandan so‘ng ma’lumotlar tozalanadi, bo‘sh qiymatlar aniqlanadi va kerakli ustunlar ajratib olinadi.

Tizimning ishlash jarayonini tushunarli tasvirlash maqsadida Sequence diagram yordamida jarayonlar ketma-ketligi modellashtirildi [1].



1-rasm. Sequence diagram [1]

Ma’lumotlarni qayta ishlash bosqichlari

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Ma’lumotlarni yuklash bosqichi (Upload stage). Tizim ishlashi foydalanuvchi tomonidan Scopus platformasidan eksport qilingan authors.csv va documents.csv fayllarini yuklash bilan boshlanadi. Ushbu fayllar mualliflar va ilmiy maqolalar haqidagi barcha zarur bibliografik ma’lumotlarni o‘z ichiga oladi.

Ma’lumotlarni o‘qish va ajratish bosqichi (Parsing stage). Yuklangan CSV fayllar tizim tomonidan avtomatik tarzda o‘qiladi va ularning tarkibidagi ustunlar ajratib olinadi. Bu bosqichda muallif identifikatori, maqola nomi, nashr yili, manba nomi va iqtiboslar soni kabi asosiy atributlar aniqlanadi.

Ma’lumotlarni bog‘lash bosqichi (Linking stage). Tizim maqolalar haqidagi ma’lumotlarni Author ID orqali mualliflar bilan bog‘laydi. Natijada har bir muallifga tegishli barcha maqolalar avtomatik ravishda guruhlanadi va muallif profili shakllantiriladi.

Statistik ko‘rsatkichlarni hisoblash bosqichi (Statistics calculation stage). Ushbu bosqichda tizim mualliflarning ilmiy faoliyatini baholash uchun turli bibliometrik ko‘rsatkichlarni hisoblaydi. Jumladan, muallifning umumiy maqolalar soni, iqtiboslar soni, maqolaga to‘g‘ri keladigan o‘rtacha iqtiboslar hamda h-index kabi ko‘rsatkichlar aniqlanadi.

Monitoring va tahlil bosqichi (Monitoring and analysis stage). Hisoblangan ma’lumotlar asosida tizim mualliflarning ilmiy faoliyati bo‘yicha umumiy tahlilni amalga oshiradi. Bu orqali oliy ta’lim muassasasi xodimlarining Scopus bazasidagi ilmiy natijalari monitoring qilinadi.

Natijalarni taqdim etish bosqichi (Result presentation stage). Jarayon yakunida tizim foydalanuvchiga shakllantirilgan statistik natijalarni taqdim etadi. Natijalar jadval va grafik ko‘rinishida chiqarilib, foydalanuvchiga mualliflar va ularning ilmiy faoliyati haqida to‘liq tasavvur beradi.

1. h-indeksni hisoblash formulasi

Muallifning ilmiy faoliyatini baholashda eng ko‘p qo‘llaniladigan ko‘rsatkichlardan biri h-index hisoblanadi. h-index muallifning nechta maqolasi kamida shu miqdorda iqtibos olinganini ko‘rsatadi.

Hirsch index formula:

$$h = \max\{i : C_i \geq i\}$$

h — muallifning h-indeksi

i — maqolalar tartib raqami (iqtiboslar soni kamayish tartibida saralangan)

C_i — i-chi maqolaning iqtiboslar soni

Agar muallifning kamida h ta maqolasi kamida h marta iqtibos olingan bo‘lsa, u holda muallifning h-indeksi h ga teng bo‘ladi. Ushbu ko‘rsatkich muallifning ilmiy faoliyati barqarorligi va ta’sir darajasini baholashda keng qo‘llaniladi.

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2. O‘rtacha iqtiboslar soni formulasi

Muallifning maqolalari qanchalik darajada iqtibos olayotganini aniqlash uchun o‘rtacha iqtiboslar soni ko‘rsatkichi hisoblanadi.

Average Citations per Publication (ACP) formula:

$$ACP = \frac{\sum_{i=1}^{n} C_i}{n}$$

ACP — bir maqolaga to‘g‘ri keladigan o‘rtacha iqtiboslar soni (Average Citations per Publication)

C_i — i-chi maqolaning iqtiboslar soni

n — muallifning umumiy maqolalar soni

Ushbu formula muallifning ilmiy maqolalari qanchalik darajada ilmiy hamjamiyat tomonidan foydalanilayotganini ko‘rsatadi. Ko‘rsatkich qanchalik yuqori bo‘lsa, muallifning ilmiy ishlari shunchalik ko‘p iqtibos olinayotganini bildiradi.

3. Ilmiy mahsuldorlik ko‘rsatkichi (Publication Productivity)

Muallifning ma’lum vaqt oralig‘ida qancha ilmiy maqola chop etganini aniqlash uchun ilmiy mahsuldorlik ko‘rsatkichi ishlatiladi.

Publication Productivity formula:

$$PP = \frac{P}{T}$$

PP — ilmiy mahsuldorlik ko‘rsatkichi

P — muallif tomonidan chop etilgan maqolalar soni

T — kuzatilayotgan vaqt oralig‘i (yillar soni)

Ushbu ko‘rsatkich muallifning ilmiy faoliyati intensivligini baholash imkonini beradi. Agar ko‘rsatkich yuqori bo‘lsa, muallifning ilmiy faoliyati faol ekanligini ko‘rsatadi.

4. Iqtiboslar o‘sish koeffitsienti (Citation Growth Rate)

Muallifning ilmiy ishlari vaqt o‘tishi bilan qanchalik ko‘p iqtibos olinayotganini aniqlash uchun iqtiboslar o‘sish koeffitsienti hisoblanadi.

Citation Growth Rate formular:

$$CGR = \frac{C_t - C_{t-1}}{C_{t-1}} \times 100\%$$

CGR — iqtiboslar o‘sish koeffitsienti

C_t — joriy davrdagi iqtiboslar soni

C_{t-1} — oldingi davrdagi iqtiboslar soni

Ushbu ko‘rsatkich muallifning ilmiy ishlari ilmiy hamjamiyatda qanchalik tez ommalashayotganini aniqlash imkonini beradi. Agar qiymat musbat bo‘lsa, iqtiboslar soni ortib borayotganini bildiradi.

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MUHOKAMA VA NATIJALAR

Taklif etilayotgan tizim ilmiy faoliyatni raqamli muhitda tizimli ravishda tahlil qilish va boshqarish uchun mo‘ljallangan bo‘lib, u ilmiy nashrlar haqidagi ma’lumotlarni markazlashtirilgan holda qayta ishlash imkonini yaratadi. Mazkur tizim orqali oliy ta’lim muassasasi xodimlarining ilmiy faoliyati haqidagi ma’lumotlar yagona platformada jamlanadi va ular asosida turli analitik hisobotlar shakllantiriladi.

Tizimning muhim jihatlaridan biri shundaki, u katta hajmdagi bibliografik ma’lumotlarni avtomatik tarzda qayta ishlash imkoniyatini beradi. Natijada mualliflarning ilmiy faoliyati, nashrlar soni, iqtiboslar dinamikasi hamda ilmiy hamkorlik darajasi haqida aniq va tizimli ma’lumotlar olish mumkin bo‘ladi

Shuningdek, tizim ilmiy ma’lumotlarni turli kesimlarda tahlil qilish imkonini beradi. Masalan, mualliflar faoliyati bo‘yicha vaqt oralig‘i kesimida tahlil qilish, ilmiy yo‘nalishlar bo‘yicha nashrlar taqsimotini aniqlash hamda ilmiy hamkorlik tarmoqlarini ko‘rib chiqish mumkin. Oliy ta’lim muassasasi rahbariyati ushbu ma’lumotlar asosida ilmiy faoliyat samaradorligini baholash, istiqbolli tadqiqot yo‘nalishlarini aniqlash hamda ilmiy salohiyatni rivojlantirish bo‘yicha qarorlar qabul qilishi mumkin. Shu sababli taklif etilayotgan tizim ilmiy faoliyat monitoringi va tahlilini avtomatlashtirishda muhim amaliy ahamiyat kasb etadi.

Taklif etilgan tizimning ishlash samaradorligini baholash maqsadida eksperimental tadqiqotlar o‘tkazildi. Tajribada Scopus platformasidan eksport qilingan 1140 ta ilmiy maqoladan iborat ma’lumotlar to‘plami ishlatildi. Ma’lumotlar tizimga ikki asosiy CSV fayl ko‘rinishida yuklandi: authors.csv (mualliflar haqidagi ma’lumotlar) va documents.csv (ilmiy maqolalar haqidagi bibliografik ma’lumotlar).

Tajriba jarayonida tizim quyidagi asosiy bosqichlarni amalga oshirdi:

1.CSV fayllarni yuklash va o‘qish

2.ma’lumotlarni tozalash va ustunlarni aniqlash

3.maqolalarni mualliflar bilan Author ID orqali bog‘lash

4.bibliometrik ko‘rsatkichlarni hisoblash

5.statistik natijalarni shakllantirish

Tizimning ishlash samaradorligini baholash maqsadida turli hajmdagi ma’lumotlar to‘plamlarida tajriba o‘tkazildi. Eksperiment davomida maqolalar soni oshib borganda tizimning umumiy qayta ishlash vaqti o‘lchandi.

1-jadval.

Ma’lumotlar hajmiga qarab qayta ishlash vaqti [1]

Maqolalar soni (N)	**Umumiy vaqt $T_{total}(s)$**	**1 taqola uchun o‘rtacha vaqt $T_{avg}(s)$**

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500	2.5	0.005
1000	4	0.004
2000	7	0.0035

Eksperimentdan olingan natijalar asosida qayta ishlash o‘rtacha vaqtini quyidagicha formula yordamida aniqlaymiz.

Average Execution Time formula:

$$T_{avg} = \frac{T_{total}}{N}$$

T_{avg} — bitta maqola qayta ishlash uchun o‘rtacha vaqt

T_{total} — umumiy qayta ishlash vaqti

N — maqolalar soni

$$T_{avg} = \frac{2.5 + 4 + 7}{500 + 1000 + 2000}$$

$$T_{avg} = \frac{13.5}{3500} = 0.0038\ s$$

Natijalarga ko‘ra tizim bitta maqolani qayta ishlash uchun o‘rtacha 0.0038 soniya vaqt sarflaydi. Bu ko‘rsatkich tizimning katta hajmdagi Scopus ma’lumotlarini tezkor qayta ishlash imkoniyatiga ega ekanligini ko‘rsatadi.

Maqolalar soni oshishi bilan vaqt deyarli chiziqli o‘sayotganini hisobga olib quyidagi formuladan foydalanamiz.

Linear Interpolation formula:

$$T = T_1 + \frac{(N - N_1)}{(N_2 - N_1)} \times (T_2 - T_1)$$

T — umumiy vaqt

N — maqolalar soni

N_1, N_2 — tajribadagi qiymatlar

T_1, T_2 — qiymatlarga mos vaqtlar

$$N = 1140;\ N_1 = 1000;\ T_1 = 4s;\ N_2 = 2000;\ T_2 = 7s$$

$$T = 4 + \frac{(1140 - 1000)}{(2000 - 1000)} \times (7 - 4)$$

$$T = 4 + \frac{140}{1000} \times 3$$

$$T \approx 4.42\ s$$

Demak, eksperimental natijalarga ko‘ra 1140 ta maqolani qayta ishlash uchun taxminan 4.4 soniya vaqt talab etiladi.

XULOSA VA TAKLIFLAR

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Olib borilgan tadqiqot natijasida ilmiy nashrlar haqidagi ma’lumotlarni avtomatik tarzda qayta ishlash va tahlil qilishga mo‘ljallangan dasturiy yechim ishlab chiqildi. Ushbu yechim bibliometrik ma’lumotlarni tizimli ravishda qayta ishlash, ularni tartiblash hamda ilmiy faoliyat ko‘rsatkichlarini aniqlash imkonini beradi. Natijada katta hajmdagi ilmiy ma’lumotlar bilan ishlash jarayoni ancha samarali va tezkor amalga oshirilishi ta’minlandi.

Ishlab chiqilgan tizim ilmiy faoliyat bo‘yicha turli analitik hisobotlarni shakllantirishga xizmat qiladi. Tahlil jarayonida mualliflar o‘rtasidagi ilmiy faollik darajasi, nashrlar taqsimoti hamda iqtiboslar asosidagi ilmiy ta’sir ko‘rsatkichlarini aniqlash imkoniyati yaratildi. Bu esa ilmiy faoliyatni baholash va tahlil qilish jarayonining aniqligini oshirishga yordam beradi.

Mazkur tizimdan foydalanish ilmiy faoliyatni boshqarish jarayonini takomillashtirishga xizmat qiladi. Xususan, u ilmiy natijalarni tezkor baholash, samaradorlikni aniqlash hamda mavjud ilmiy salohiyatdan yanada oqilona foydalanish imkonini yaratadi. Shuningdek, tizim orqali shakllantirilgan ma’lumotlar asosida ilmiy faoliyatni rivojlantirishga qaratilgan strategik qarorlar qabul qilish mumkin.

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MASHINA VA MEXANIZMLARNI TA’MIRLASH VA ULARGA TEXNIK XIZMAT KO‘RSATISHDA TEXNIKA XAVFSIZLIGI

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Annotatsiya. Maqolada mashina va mexanizmlar mavjud korxonalardagi ishchilarni turli xavflardan saqlash bo‘yicha tayyorlangan bo‘lib, unda mexanizmlarga texnik xizmat ko‘rsatishda xavfsizlik choralarini ishlab chiqish bo‘yicha ma’lumotlar, mexanizmlarning turlari, ularning tayyorlashdagi aniqliklar, ishlatish sohalari, shu bilan birgalikda ularni ta’mirlash, ularga texnik xizmat ko‘rsatishda texnika xavfsizligi bo‘yicha ma’lumotlarni o‘z ichiga olgan. Mashina va mexanizmlarni ta’mirlash va ularga texnik xizmat ko‘rsatishda texnika xavfsizligi avtomatik tizimi bo`yicha ham ma`lumotlar keltirilgan.

Kalit so‘zlar: mashina va mexanizmlar, ta’mirlash, texnik xizmat ko‘rsatish, texnika xavfsizligi, mehnatni muhofaza qilish, sanoat xavfsizligi, uskunalarni ekspluatatsiya qilish, avtomatlashtirilgan xavfsizlik tizimlari, ishlab chiqarish xavflari, ishchilarni himoya qilish.

Аннотация. В статье рассматриваются вопросы защиты работников на предприятиях, где используются машины и механизмы, от различных видов опасностей. В ней представлены сведения по разработке мер безопасности при техническом обслуживании механизмов, их видам, точности изготовления и областям применения. Наряду с этим, освещены вопросы ремонта и технического обслуживания механизмов с точки зрения техники безопасности. Также приведены данные об автоматизированной системе обеспечения техники безопасности при ремонте и техническом обслуживании машин и механизмов.

Ключевые слова: машины и механизмы, ремонт, техническое обслуживание, техника безопасности, охрана труда, промышленная безопасность, эксплуатация оборудования, автоматизированные системы безопасности, производственные риски, защита работников.

Abstract. This article addresses the issues of protecting workers at enterprises where machines and mechanisms are used from various types of hazards. It provides information on the development of safety measures during the maintenance of mechanisms, their types, manufacturing accuracy, and fields of application. In addition, issues related to the repair and maintenance of mechanisms

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from the perspective of occupational safety are discussed. The article also presents data on automated safety systems used during the repair and maintenance of machines and mechanisms.

Keywords: machines and mechanisms, repair, maintenance, occupational safety, labor protection, industrial safety, equipment operation, automated safety systems, production risks, worker protection.

KIRISH.

Jamiyatni asosiy rivojlantiruvchi va ishlab chiqarish tizimini boshqaruvchi kuch inson ekanligini e'tiborga olib, uning ishlab chiqarish faoliyatini va sog'lig'ini saqlash ijtimoiy sotsial taraqqiyot yo'lidagi muhim omil bo'lib hisoblanadi. Shuning uchun ham sanoat korxonalarining muhim talabi, faqat sifatli mahsulot ishlab chiqarish bo'lib qolmasdan, balki ishlab chiqarish sharoitini yaxshilash, ishlab chiqarishda jarohatlanish va kasb kasalliklari kelib chiqishiga sabab bo'lgan manbalarni yo'qotish, ish faoliyati uchun charchash, toliqish va kasalliklar manbai bo'lmasdan, quvonch va baxt keltiruvchi faoliyat bo'lishini ta'minlashga harakat qilish zarur. Yuqorida tavsiflangan talablarga rioya qilish muhim shart bo'lib, uni bajarmaslik uchun xodimlar javobgarlikka tortiladi. Ammo ishlab chiqarishda xavfsiz ishlash uchun sharoit yaratilmagan bo'lsa, menejer javob beradi. Qanday bo'lmasin, agar ishchilarning hayoti uchun xavf tug'ilsa yoki ular mehnatni muhofaza qilish talablariga rioya qilmasa, har qanday faoliyat to'xtatilishi kerak.

So'nggi paytda ishlab chiqarish korxonalarida mavjud ish sharoiti nisbatan yaxshilangan bo'lsada, ko'p joylarda bu sharoit oxiriga yetmagan. Bunga ishlab chiqarishdagi asbob-uskunalarning eskirib, ishdan chiqqanligi, ish joyining yetarli darajada yoritilmaganligi, havo harorati normasi buzilganligi, havo almashtirish tizimlari va shaxsiy himoya vositalarining kamligi yoki umuman yo'qligi sabab bo'lmoqda. Qoida tariqasida, mexanizm-bu qismlar to'plami bir-biriga bog'langan harakatni uzatish yoki o'zgartirish uchun. Har qanday mexanizmning murakkabligi uning tarkibiy qismlari soni va ularning o'lchamlari bilan belgilanadi.

Mexanizmning eng keng tarqalgan vazifasi - bu aylanish tezligini o'zgartirish yoki tarjima harakatini aylanishga aylantirish yoki aksincha. Qoida tariqasida, ular darhol asosiy haydovchidan kerakli harakat yoki kuchni olishning iloji bo'lmaganda ishlatiladi. Mexanizmni ta'mirlash, ular uchun zarur bo'lgan xavfsizlik choralarini ko'rish, qoida tariqasida, asosan tavsiflangan barcha asosiy bosqichlarni o'z ichiga oladi: nuqson, demontaj, to'g'ridan-to'g'ri ta'mirlash, yig'ish va boshqarish. Ushbu bosqichlarning har biriga ta'mirchi alohida e'tibor bilan munosabatda bo'lish kerak.

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Mashina va mexanizmlarni ta’mirlash va ularga texnik xizmat ko‘rsatishda xavfsizligini ta’minlashda umumiy masalalar.

Mashina (lot. machina - qurol, qurilma) - bir turdagi harakat energiyasini ikkinchi turdagi harakat energiyasiga aylantirish, materiallar yoki axborotlarni o‘zgartirish, aloqa o‘rnatish, yuk va odamlarni tashish uchun mo‘ljallangan mexanizm yoki mexanizmlar majmui.

Jamiyatdagi ishlab chiqarish kuchlarining eng muhim tarkibiy qismi, yirik mashinali ishlab chiqarishning moddiy negizi, aloqa va transportning asosiy vositasi hisoblanadi. Mashina fan-texnika inqilobining asosi. Mashina ayni paytda ham mehnat quroli, ham mehnat mahsuloti hisoblanadi. Insoniyat qadimdan o‘z mehnatini yengillashtirish uchun turli-tuman qurol va qurilmalarni yaratishga urinib kelgan. Mola, omoch, charxpalak, urchuq, charh, dug, to‘quvchilik dastgohlari (do‘konlari), cho‘t, palaxmon, piltato‘p, shamol tegirmoni va boshqa vositalar mashina yaratish borasidagi urinishlar edi. Shuning uchun ilgari mashina inson mehnatini osonlashtiradigan mexanik tizim deb tushunilgan. Bora-bora u insonning aqliy mehnatini va fiziologik vazifasini ham bajaradigan murakkab tizimga aylandi.

Mexanizm - bu ma’lum mexanik harakatlarni bajarish orqali ish jarayoni amalga oshiriladigan mashinaning bir qismi (1-rasm). Mexanizm-bu bir yoki bir nechta jismlarning harakatini boshqa jismlarning kerakli harakatlariga aylantirish uchun mo‘ljallangan o‘zaro bog‘liq detallar tizimi.



1-rasm. Ishlab chiqarishda mavjud mexanizm turlari

Mashinalar va mexanizmlarga qo‘yiladigan asosiy xususiyatlar va talablar.

Mashinalarning asosiy xususiyatlariga: qo‘llanilish sohasi, maqsadi, boshqarish usuli, quvvati ,ishlash tizimi, samaradorligi, vazni, umumiy o‘lchamlari va boshqa parametrlar kiradi.

Mashinalarning ishlashi ishlov beriladigan material uchun eng mos bo‘lgan birliklarda o‘lchanadi. Samaradorlik - bu mashinalar samaradorligining o‘ziga xos xususiyati. Bu foydali amalga oshiriladigan energiyaning ulushini va undan foydalanish samaradorligini ko‘rsatadi. Mashinalarni tashish va ularni ishlab chiqarish maydonlariga joylashtirish uchun massa va umumiy o‘lchamlarni bilish

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kerak. Mashinalarning asosiy xususiyatlari ularning texnik pasportida ko‘rsatilgan bo‘ladi.

Mashinalar va mexanizmlarga quyidagi talablar qo‘yiladi:

Ishlash qobilyati – ma’lum bir vaqtda uning asosiy parametrlari me’yoriy-texnik hujjatlar talablarida belgilangan chegaralar ichida bo‘lgan mashinalar va mexanizmlarning texnik holati va xususiyatidir.

Ishonchlilik-belgilangan funktsiyalarni bajarish qobiliyati, o‘z vaqtida asosiy xususiyatlarini belgilangan chegaralarda saqlash. Ishonchlilik ishonchlilik, chidamlilik, texnik xizmat ko‘rsatish va barqarorlikni o‘z ichiga oladi. Ishonchlilik ko‘rsatkichlari-ish vaqti, xizmat muddati va boshqalarga asoslangan bo‘ladi.

Texnologik. Ishlab chiqarish, ishlatish va ta‘mirlashda minimal xarajatlar, vaqt va mehnatni talab qiladigan mashinalarni o‘zaro bog‘lash xususiyatidir.

Iqtisodiy samaradorlik. Iqtisodiyotni baholashda konstruksiya, ishlab chiqarish, ishlatish va ta‘mirlash xarajatlari o‘z hisobiga olinadi. Mashinalarning samaradorligi yuqori ishonchliligi bilan ishlashda maksimal samaradorlik tufayli ishlab chiqarishning moddiy iste‘moli, energiya sarfi va mehnat zichligini kamaytirish orqali erishiladi. Mexanizmlar va mashinalar va shunga o‘xshash texnik vositalarning ergonomik xususiyatlari mexanikning psixofizik energiyasining xarajatlar darajasini, uning charchoq darajasini va xizmat paytida xavfsizligini tavsiflaydi (2-rasm). Bularga quyidagilar kiradi: mexanikning qulayligi, boshqarish qulayligi, mexanik xavfsizligi va xizmat qilish qulayligi.



2-rasm. Ergonomika-ishlab chiqarish sharoitida mashinaning inson faoliyatiga moslashishi.

Mashina va mexanizmlarni ta’mirlash va ularga texnik xizmat ko‘rsatish jihozlari, uskunalar va qurilmalarni loyihalash, o‘rnatish va foydalanishda xavfsizlik talablari.

1. Mashina va mexanizmlarni ta’mirlash tizimini ishlab ishlab chiqishda (loyihalashda) hayot siklining barcha bosqichlarida yuzaga kelishi mumkin bo‘lgan xavf turlari aniqlanishi kerak.

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3-rasm. Mashina va mexanizmlarni ta’mirlashda xavf turlarini uchun ularni hisoblash.

2. Aniqlangan xavf turlari uchun xavfni hisoblash, eksperimental yoki shunga o‘xshash mashinalar va uskunalarning ishlash ma‘lumotlari bo‘yicha baholash kerak. Xavfni baholash usullari ushbu texnik reglamentning tegishli bandida ko‘rsatilgan standartlarda belgilanishi mumkin.

3. Ishlab chiqishda (loyihalashda) mashina va (yoki) uskunalar uchun ruxsat etilgan xavf aniqlanishi va belgilanishi kerak. Shu bilan birga, belgilangan xavfga mos keladigan xavfsizlik darajasi quyidagilar bilan ta'minlanadi:

- ilmiy-tadqiqot va tajriba-konstruktorlik ishlarining to‘liqligi;
- belgilangan tartibda tasdiqlangan usullarga asoslangan zarur hisob-kitoblar va sinovlar majmuini o‘tkazish;
- parametrlarga va konstruksiyaga qarab mashinalar,mexanik uskunalarning ayrim turlarida ishlatiladigan materiallar va moddalarni tanlash uchu ish sharoitlari;

Foydalanish bo‘yicha qo‘llanmani (ko‘rsatmalarni) ishlab chiqish mashina va (yoki) uskunalarni ishlab chiqish (loyihalash) ning ajralmas qismidir.

Qo‘llanma (yo‘riqnoma) quyidagilarni o‘z ichiga oladi:

- mashina uskunaning konstruksiyasi, ishlash prinsipi, xususiyatlari (imkoniyatlari) to‘g‘risidagi ma‘lumotlar;
- mashina va (yoki) uskunalarni o‘rnatish yoki yig‘ish, sozlash yoki sozlash, texnik xizmat ko‘rsatish va ta‘mirlash bo‘yicha ko‘rsatmalar;
- mashinadagi mavjud uskunadan foydalanish bo‘yicha ko‘rsatmalar va uskunalarning ishlashi paytida bajarilishi kerak bo‘lgan xavfsizlik choralari, shu jumladan ishga tushirish, maqsadga muvofiq foydalanish, texnik xizmat ko‘rsatish, barcha turdagi ta‘mirlash, davriy diagnostika, sinovlar, transport, qadoqlash, saqlash va saqlash sharoitlari yaratish;
- davriy diagnostika.

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4-rasm. Mashinalarga texnik xizmat ko‘rsatishda davriy diagnostika tadbirini o‘tkazish.



5-rasm. Mashina va mexanizmlarni ta’mirlashda belgilangan konstruktiv xususiyatlariga qarab ko‘rsatkichlar ishlab chiqilishi.

Mashina va mexanizmlarni ta’mirlashda belgilangan konstruktiv xususiyatlariga qarab ko‘rsatkichlar ishlab chiqilishi zarur (belgilangan saqlash muddati, belgilangan xizmat muddati va (yoki) belgilangan resurs).

Mashinalarga texnik xizmat ko‘rsatishda davriy diagnostika tadbirini o`tkazish va ularni ta‘mirlashda belgilangan konstruktiv xususiyatlariga qarab ko‘rsatkichlar ishlab chiqish 4- va 5- rasmlarda tasvirlangan.

Mashinasozlik ishlab chiqarishining ekologik xavfsizligi.

Atrof-muhitga ta'sir intensivligi bo‘yicha mashinasozlik komplekslarii yetakchi o‘rinnlari egallaydi. Ushbu yetakchilikning asosiy sabablari: ishlab chiqarishning nomukammal texnologiyalari, haddan tashqari kontsentratsiya - ham hududiy, ham bitta korxona ichida, ishonchli ekologik inshootlarning yo‘qligi. Zamonaviy texnologiyalarning nomukammalligi mineral xom ashyoni to‘liq qayta ishlashga imkon bermaydi.

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6-rasm. Ekologik holati mo‘tadillashgan ishlab chiqarish korxonasi.

Odatda mashina mexanizmlari ta‘mirlashda mavjud korxonalar ekologik muhitni yaratish kerak. Bu ishchilar uchun ham, xavfsizlik muhiti uchun ham eng samarali usul hisoblanadi. Katta rivojlangan mamlakatlarning ishlab chiqarish korxonalarida muhitni yaxshilash uchun quyidagi holatlarda lohixalashni tavsiya etilgan va bu 6-rasmda keltirib o‘tilgan.

Ushbu xom ashyoning katta qismi tabiatga chiqindilar shaklida qaytadi. Tayyor mahsulotlar ishlatilgan xom ashyoning 1-2 foizini tashkil qiladi, qolganlari biosferaga chiqindilar shaklida qaytib, uni ifloslantiradi. Shini alohida uqtirib o‘tmoqchimizki, barcha chiqindilar orasida atmosferaga zararli ifloslantiruvchi moddalardan biri bo‘lgan oltingugurt dioksidi gazi chiqindilarining katta miqdori e‘tiborni tortadi, bu atmosfera sharoitida kislotaga aylanadi va kislotali yomg‘irning paydo bo‘lishiga olib keladi.

XULOSA. Maqolada mashina va mexanizmlarni ta’mirlash hamda ularga texnik xizmat ko‘rsatishda texnika xavfsizligini ta’minlash masalalari ko‘rib chiqildi. Ishchilarni turli xavflardan himoya qilish, mexanizmlarning turlari, ularning ishlash sohalari va texnik xizmat ko‘rsatish jarayonidagi xavfsizlik choralarini ishlab chiqish bo‘yicha tavsiyalar berildi. Shuningdek, avtomatlashtirilgan xavfsizlik tizimlarining afzalliklari va ularni amaliyotda qo‘llash imkoniyatlari muhokama qilindi. Tadqiqot natijalari mashina va mexanizmlar ekspluatatsiyasi va texnik xizmat ko‘rsatishda xavfsizlik darajasini oshirishga xizmat qiladi hamda ishchilarning hayot va sog‘lig‘ini himoya qilishga yordam beradi.

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MODEL FOR MONITORING THE READINESS OF HISTORY TEACHERS FOR PEDAGOGICAL ACTIVITY IN HIGHER EDUCATION

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Abstract. This study examines the theoretical and methodological foundations of monitoring the readiness of future history teachers for pedagogical activity within the higher education system. The article explores modern approaches to pedagogical monitoring, including systemic, competency-based, and reflective approaches, and analyzes their application in the process of teacher training. Methods such as pedagogical diagnostics, comparative analysis, modeling, observation, and survey techniques were used in the research. As a result of the study, a comprehensive model for monitoring the readiness of history teachers for pedagogical activity was developed. The proposed model includes several interconnected components, such as target, theoretical-methodological, content, technological, and evaluation blocks. The findings indicate that continuous monitoring contributes to improving professional competencies, enhancing the effectiveness of teacher training, and ensuring the quality of the educational process in higher education institutions. The developed model may serve as a methodological framework for improving teacher training programs in modern universities.

Keywords: pedagogical monitoring, history teacher, professional competence, pedagogical diagnostics, higher education, pedagogical readiness, monitoring model.

Annotatsiya. Mazkur tadqiqot oliy ta'lim tizimida bo'lajak tarix o'qituvchilarining pedagogik faoliyatga tayyorgarligini monitoring qilishning nazariy va metodologik asoslarini o'rganishga bag'ishlangan. Maqolada pedagogik monitoringning zamonaviy yondashuvlari, jumladan tizimli, kompetensiyaviy hamda refleksiv yondashuvlar tahlil qilinib, ularning o'qituvchilar tayyorlash jarayonidagi qo'llanishi o'rganilgan. Tadqiqot jarayonida pedagogik diagnostika, qiyosiy tahlil, modellashtirish, kuzatuv hamda so'rovnoma metodlaridan foydalanildi. Tadqiqot natijasida tarix o'qituvchilarining pedagogik faoliyatga tayyorgarligini monitoring qilishga qaratilgan kompleks model ishlab chiqildi. Taklif etilgan model o'zaro bog'liq bo'lgan maqsadli, nazariy-metodologik, mazmuniy, texnologik hamda baholash bloklaridan iborat. Tadqiqot natijalari uzluksiz monitoring tizimi o'qituvchilarning kasbiy kompetensiyalarini rivojlantirish, pedagog kadrlar

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tayyorlash samaradorligini oshirish hamda oliy ta’lim muassasalarida ta’lim jarayoni sifatini ta’minlashga xizmat qilishini ko‘rsatdi. Ishlab chiqilgan model zamonaviy universitetlarda o‘qituvchilar tayyorlash dasturlarini takomillashtirish uchun metodik asos bo‘lib xizmat qilishi mumkin.

Kalit so‘zlar: pedagogik monitoring, tarix o‘qituvchisi, kasbiy kompetensiya, pedagogik diagnostika, oliy ta’lim, pedagogik tayyorgarlik, monitoring modeli.

Аннотация. Данное исследование посвящено изучению теоретических и методологических основ мониторинга готовности будущих учителей истории к педагогической деятельности в системе высшего образования. В статье рассматриваются современные подходы к педагогическому мониторингу, включая системный, компетентностный и рефлексивный подходы, а также анализируется их применение в процессе подготовки учителей. В ходе исследования были использованы методы педагогической диагностики, сравнительного анализа, моделирования, наблюдения и анкетирования. В результате исследования была разработана комплексная модель мониторинга готовности учителей истории к педагогической деятельности. Предложенная модель включает несколько взаимосвязанных компонентов: целевой, теоретико-методологический, содержательный, технологический и оценочный блоки. Результаты исследования показывают, что систематический мониторинг способствует развитию профессиональных компетенций, повышению эффективности подготовки педагогических кадров и обеспечению качества образовательного процесса в высших учебных заведениях. Разработанная модель может служить методологической основой для совершенствования программ подготовки учителей в современных университетах.

Ключевые слова: педагогический мониторинг, учитель истории, профессиональная компетентность, педагогическая диагностика, высшее образование, педагогическая готовность, модель мониторинга.

INTRODUCTION.

The transformation of modern educational systems is closely related to the improvement of teacher training quality. In particular, the role of history education is significant in shaping students’ historical consciousness, national identity, and civic responsibility. Therefore, the preparation of future history teachers in higher education institutions requires new methodological approaches that ensure their readiness for professional pedagogical activity.

The development of a monitoring model for assessing the readiness of future history teachers for pedagogical activity is based on modern educational paradigms and the increasing demand for high-quality teacher training in higher education

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institutions. The proposed model relies on several theoretical principles that ensure its scientific validity and practical applicability.

First, the model is grounded in the systemic approach, which considers teacher training as a complex and interconnected process. According to this approach, pedagogical readiness is not limited to subject knowledge but includes a combination of pedagogical skills, psychological preparedness, methodological competence, and reflective abilities. Therefore, the monitoring system should evaluate all these components in an integrated manner.

Second, the model is based on the competency-based approach, which has become a dominant paradigm in contemporary education. Within this framework, the effectiveness of teacher training is determined not only by the acquisition of theoretical knowledge but also by the development of professional competencies required for successful teaching practice. For future history teachers, these competencies include the ability to organize the learning process, apply innovative teaching methods, communicate effectively with students, and critically analyze historical sources.

Third, the model incorporates the reflective approach, which emphasizes the importance of self-assessment and professional reflection in teacher development. Reflection allows future teachers to evaluate their teaching practices, identify areas for improvement, and develop strategies for professional growth. Therefore, the monitoring model includes mechanisms for analyzing reflective activities such as teaching portfolios, self-evaluation reports, and peer feedback.

Another theoretical foundation of the model is the concept of pedagogical diagnostics, which focuses on the systematic collection and analysis of information about the educational process. Pedagogical diagnostics provides reliable data on the level of professional readiness of teacher trainees and allows educational institutions to make informed decisions regarding the improvement of teacher training programs.

The monitoring model also reflects the principles of continuous assessment and feedback, which are essential elements of modern educational quality assurance systems. Continuous monitoring ensures that the process of teacher training remains dynamic and responsive to the changing requirements of the education system.

Structurally, the model includes several interconnected components: the target block, the theoretical-methodological block, the content block, the technological block, and the evaluation block. Each component performs a specific function within the monitoring system.

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The target block defines the goals and objectives of monitoring and focuses on evaluating the readiness of future history teachers for pedagogical activity.

The theoretical-methodological block provides the scientific foundation of the model and integrates systemic, competency-based, and reflective approaches.

The content block represents the key elements of pedagogical readiness, including pedagogical knowledge, psychological preparedness, methodological competence, communicative skills, and reflective abilities.

The technological block describes the tools and procedures used for implementing monitoring, such as diagnostic tests, classroom observations, microteaching sessions, and digital assessment tools.

The evaluation block focuses on analyzing the results of monitoring and determining the level of pedagogical readiness according to established criteria and indicators.

The integration of these components ensures that the monitoring model functions as a comprehensive system capable of assessing the readiness of future history teachers and supporting their professional development.

Thus, the proposed monitoring model provides a scientifically grounded framework for evaluating pedagogical readiness and improving the quality of teacher training in higher education institutions.

In the context of globalization and rapid technological development, higher education institutions face increasing demands to prepare highly qualified teachers who possess not only deep subject knowledge but also advanced pedagogical competencies. The quality of teacher training depends largely on effective mechanisms for evaluating and improving pedagogical readiness.

One of the most effective tools for improving the quality of teacher training is pedagogical monitoring. Monitoring is understood as a continuous and systematic process of collecting, analyzing, and interpreting information about the state of the educational process in order to improve its effectiveness and quality. Educational monitoring differs from traditional forms of control because it focuses on continuous observation, diagnostics, analysis, and feedback aimed at improving educational outcomes.

In higher education institutions, pedagogical monitoring plays an important role in evaluating the effectiveness of teacher training programs, identifying strengths and weaknesses in pedagogical preparation, and implementing corrective measures. Researchers emphasize that monitoring should be based on scientifically grounded criteria and should involve systematic data collection and feedback mechanisms that allow educational institutions to improve the quality of education.

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Furthermore, modern teacher training systems emphasize competency-based education, which focuses on developing professional competencies rather than simply transmitting theoretical knowledge. Within this framework, monitoring becomes an essential tool for evaluating how effectively future teachers acquire pedagogical knowledge, teaching skills, and reflective abilities.

Therefore, the development of a monitoring model for assessing the readiness of future history teachers for pedagogical activity is an important scientific and practical task.

The purpose of this research is to develop and substantiate a comprehensive model for monitoring the readiness of history teachers for pedagogical activity in higher education.

The objectives of the research include:

- analyzing theoretical foundations of pedagogical monitoring;
- identifying the structural components of pedagogical readiness of future history teachers;
- determining criteria and indicators for evaluating pedagogical readiness;
- developing a structural model for monitoring pedagogical readiness.

LITERATURE REVIEW

The concept of pedagogical monitoring has been widely discussed in modern educational research. Many scholars emphasize that monitoring is a complex process that integrates observation, diagnostics, evaluation, and forecasting of educational outcomes.

According to contemporary pedagogical research, monitoring serves as an essential mechanism for ensuring the quality of education. It allows educational institutions to systematically evaluate teaching effectiveness and student learning outcomes. Monitoring systems typically involve continuous data collection, analysis of teaching practices, and feedback mechanisms aimed at improving educational processes.

In higher education, monitoring is closely connected with the concept of educator effectiveness. This concept focuses on assessing the quality of teaching practices by analyzing classroom observations, student learning outcomes, and professional achievements of teachers. Such evaluation systems enable institutions to identify effective teaching practices and promote continuous professional development.

Modern pedagogical monitoring also incorporates formative assessment approaches. Formative assessment involves continuous evaluation of the learning process and provides ongoing feedback to improve teaching strategies and learning

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outcomes. This approach allows educators to identify students' strengths and weaknesses and adjust instructional methods accordingly.

Another important component of teacher training is microteaching, which is widely used in universities as a method of developing pedagogical skills. Microteaching allows future teachers to practice teaching in a controlled environment and receive feedback from peers and instructors, thereby improving their professional competencies.

Thus, the integration of monitoring systems, formative assessment, and reflective teaching practices forms the foundation for effective teacher training in modern higher education.

METHODS

The research employed both theoretical and empirical methods to analyze the readiness of future history teachers for pedagogical activity.

The methodological basis of the study includes three main approaches:

Systemic approach

The systemic approach considers pedagogical readiness as an integrated system consisting of interconnected components such as knowledge, skills, professional values, and teaching experience. This approach allows researchers to analyze teacher training as a complex educational process.

Competency-based approach

The competency-based approach focuses on the development of professional competencies that enable teachers to effectively perform their pedagogical duties. These competencies include subject knowledge, pedagogical skills, communication abilities, and reflective thinking.

Reflective approach

The reflective approach emphasizes the importance of self-analysis and professional reflection in teacher development. Through reflection, teachers can evaluate their teaching practices and identify ways to improve their professional performance.

The following research methods were applied:

- analysis of scientific and pedagogical literature;
- comparative analysis of existing monitoring systems;
- pedagogical modeling;
- surveys and interviews with teacher trainees;
- observation of teaching practice;
- analysis of pedagogical activity results.

These methods allowed researchers to collect comprehensive data on the level of pedagogical readiness among future history teachers.

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RESULTS

The research resulted in the development of a comprehensive monitoring model for assessing the readiness of history teachers for pedagogical activity in higher education.

The model includes five interconnected structural components.

Target block

This block defines the goals and objectives of pedagogical monitoring. The main goal is to evaluate and improve the readiness of future history teachers for professional pedagogical activity.

Theoretical-methodological block

This block includes the theoretical foundations of pedagogical monitoring, including competency-based education, pedagogical diagnostics, and reflective learning.

Content block

The content block reflects the key components of pedagogical readiness:

- pedagogical knowledge;
- psychological readiness;
- methodological competence;
- communicative competence;
- reflective competence.

Technological block

This block includes the tools and methods used to implement monitoring. These include diagnostic testing, classroom observation, portfolio assessment, microteaching sessions, and digital learning analytics.

Evaluation block

The evaluation block focuses on assessing the level of pedagogical readiness based on established criteria and indicators.

The levels of pedagogical readiness were identified as:

- high level (creative and independent pedagogical activity);
- intermediate level (sufficient pedagogical competence with some limitations);
- basic level (initial pedagogical skills requiring further development).

DISCUSSION

The results of the study demonstrate that pedagogical monitoring is an effective tool for improving teacher training in higher education institutions. Continuous monitoring allows universities to evaluate the effectiveness of educational programs and identify areas that require improvement.

Monitoring systems also contribute to the development of reflective teaching practices. By analyzing the results of monitoring, future teachers can better

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understand their professional strengths and weaknesses and develop strategies for improving their pedagogical skills.

Furthermore, modern digital technologies create new opportunities for implementing monitoring systems in higher education. Digital learning analytics, electronic portfolios, and online assessment tools allow universities to collect and analyze large amounts of educational data, thereby improving the accuracy and effectiveness of pedagogical monitoring.

CONCLUSION. The monitoring of readiness for pedagogical activity among future history teachers is an essential component of teacher training in higher education institutions. The proposed monitoring model provides a comprehensive framework for evaluating pedagogical readiness and improving the quality of teacher education.

The implementation of the model can contribute to the development of professional competencies, improvement of pedagogical practices, and enhancement of educational quality in higher education institutions.

Future research should focus on integrating digital technologies into monitoring systems and developing new methods for assessing pedagogical competencies in teacher education programs.

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LEARNING-BASED ADVANCED PROCESS CONTROL: A REVIEW

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Abstract. Advanced Process Control (APC) is undergoing a fundamental transformation driven by the rapid integration of data-driven modeling and learning algorithms into industrial control architectures. While classical model-based approaches-most notably model predictive control (MPC)-have provided structured optimization, constraint handling, and stability guarantees, their effectiveness increasingly depends on accurate process models that are difficult to derive for highly nonlinear, large-scale, and time-varying systems. The proliferation of industrial data and advances in machine learning have enabled a new generation of learning-based APC strategies that enhance modeling flexibility, prediction accuracy, and adaptability. However, the deployment of such approaches in safety-critical chemical and industrial processes raises significant concerns regarding stability, robustness, interpretability, and constraint satisfaction. This review provides a systematic and critical synthesis of learning-based advanced process control methods published since 2020, with a particular focus on the progression from data-driven modeling to safe reinforcement learning. The literature is organized according to the functional role of learning within the control loop: (i) data-driven process modeling using neural networks and Gaussian processes, (ii) learning-based MPC frameworks that retain explicit constraint handling, (iii) safety-aware reinforcement learning approaches augmented with stability conditions or MPC supervision, and (iv) advanced soft sensors enabling reliable state estimation and monitoring. Across these categories, we analyze trade-offs among prediction accuracy, computational complexity, data efficiency, safety guarantees, and industrial maturity.

Keywords: Advanced Process Control (APC); Learning-based Control; Data-driven Modeling; Model Predictive Control (MPC); Learning-based MPC; Gaussian Processes; Neural Networks; Safe Reinforcement Learning; Stability and Constraint Satisfaction; Soft Sensors; Industrial Process Control; Safety-Critical Systems

Annotatsiya. Ilg‘or jarayon boshqaruvi (Advanced Process Control – APC) sanoat boshqaruv arxitekturalariga ma’lumotlarga asoslangan modellashtirish va o‘rganish algoritmlarining jadal integratsiyasi natijasida tub transformatsiyani boshdan kechirmoqda. An’anaviy modelga asoslangan yondashuvlar – ayniqsa

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model prognozli boshqaruv (Model Predictive Control – MPC) – tuzilmali optimallashtirish, cheklovlarni hisobga olish va barqarorlik kafolatlarini ta’minlab kelgan bo‘lsada, ularning samaradorligi tobora yuqori darajada nochiziqli, katta masshtabli va vaqt bo‘yicha o‘zgaruvchan tizimlar uchun hosil qilish qiyin bo‘lgan aniq jarayon modellariga bog‘liq bo‘lib bormoqda. Sanoat ma’lumotlarining ko‘payishi va mashinani o‘rganish sohasidagi yutuqlar modellashtirish moslashuvchanligi, prognoz aniqligi va adaptivlikni oshiruvchi o‘rganishga asoslangan APC strategiyalarining yangi avlodini shakllantirdi. Biroq bunday yondashuvlarni xavfsizlik jihatidan muhim bo‘lgan kimyoviy va sanoat jarayonlarida qo‘llash barqarorlik, mustahkamlik (robustlik), talqin qilinuvchanlik va cheklovlarga rioya etish bilan bog‘liq muhim muammolarni keltirib chiqarmoqda. Mazkur adabiyotlar tahlilida 2020-yildan buyon chop etilgan o‘rganishga asoslangan ilg‘or jarayon boshqaruvi usullarining tizimli va tanqidiy tahlilini taqdim etadi hamda ma’lumotlarga asoslangan modellashtirishdan tortib xavfsiz mustahkamlovchi o‘rganishgacha bo‘lgan evolyutsiyaga alohida e’tibor qaratadi. Adabiyotlar o‘rganishning boshqaruv siklidagi funksional roliga ko‘ra quyidagicha tasniflanadi: (i) neyron tarmoqlar va Gauss jarayonlari asosidagi ma’lumotlarga asoslangan jarayon modellashtirish; (ii) aniq cheklovlarni saqlab qoluvchi o‘rganishga asoslangan MPC arxitekturalari; (iii) barqarorlik shartlari yoki MPC nazorati bilan boyitilgan xavfsizlikka yo‘naltirilgan mustahkamlovchi o‘rganish yondashuvlari; (iv) ishonchli holat baholash va monitoringni ta’minlovchi ilg‘or yumshoq sensorlar. Mazkur toifalar doirasida prognoz aniqligi, hisoblash murakkabligi, ma’lumotdan foydalanish samaradorligi, xavfsizlik kafolatlari va sanoatga joriy etilish darajasi o‘rtasidagi muvozanatlar (trade-off) chuqur tahlil qilinadi.

Kalit so‘zlar: Ilg‘or jarayon boshqaruvi (APC); o‘rganishga asoslangan boshqaruv; ma’lumotlarga asoslangan modellashtirish; model prognozli boshqaruv (MPC); o‘rganishga asoslangan MPC; Gauss jarayonlari; neyron tarmoqlar; xavfsiz mustahkamlovchi o‘rganish; barqarorlik va cheklovlarga rioya etish; yumshoq sensorlar; sanoat jarayonlarini boshqarish; xavfsizlik jihatidan muhim tizimlar.

Аннотация. Продвинутое управление процессами (Advanced Process Control, APC) переживает фундаментальную трансформацию, обусловленную быстрой интеграцией методов моделирования на основе данных и алгоритмов обучения в архитектуры промышленного управления. Классические подходы, основанные на моделях, – прежде всего модельно-прогнозирующее управление (Model Predictive Control, MPC) – обеспечивали структурированную оптимизацию, учет ограничений и гарантии

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устойчивости. Однако их эффективность в возрастающей степени зависит от точных моделей процессов, получение которых затруднено для сильно нелинейных, крупномасштабных и нестационарных систем. Рост объёмов промышленных данных и достижения в области машинного обучения способствовали формированию нового поколения стратегий APC на основе обучения, повышающих гибкость моделирования, точность прогнозирования и адаптивность. Вместе с тем внедрение таких подходов в химических и промышленных процессах, критичных к безопасности, вызывает серьёзные опасения, связанные с обеспечением устойчивости, робастности, интерпретируемости и соблюдения ограничений. Настоящий обзор представляет систематизированный и критический анализ методов продвинутого управления процессами на основе обучения, опубликованных с 2020 года, с особым акцентом на эволюцию от моделирования на основе данных к безопасному обучению с подкреплением. Литература структурирована в соответствии с функциональной ролью обучения в контуре управления: (i) моделирование процессов на основе данных с использованием нейронных сетей и гауссовских процессов; (ii) архитектуры MPC на основе обучения с сохранением явного учета ограничений; (iii) подходы к обучению с подкреплением, ориентированные на безопасность и дополненные условиями устойчивости или супервизией MPC; (iv) продвинутые программные (soft) сенсоры, обеспечивающие надёжную оценку состояния и мониторинг. В рамках указанных категорий анализируются компромиссы между точностью прогнозирования, вычислительной сложностью, эффективностью использования данных, гарантиями безопасности и степенью промышленной зрелости.

Ключевые слова: продвинутое управление процессами (APC); управление на основе обучения; моделирование на основе данных; модельно-прогнозирующее управление (MPC); MPC на основе обучения; гауссовские процессы; нейронные сети; безопасное обучение с подкреплением; устойчивость и соблюдение ограничений; программные сенсоры; промышленное управление процессами; системы, критичные к безопасности.

INTRODUCTION

Advanced Process Control (APC) [1] has long been a central pillar of industrial automation, enabling the safe, efficient, and economically optimal operation of complex processes in the chemical, energy, water, and manufacturing industries. Classical APC strategies [2], most notably model predictive control (MPC) [3], have achieved widespread success by explicitly accounting for multivariable interactions [4], operational constraints [5], and process objectives

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within a rigorous optimization framework. When accurate first-principles or identified models are available, MPC and its nonlinear extensions can deliver robust performance [6] and provable stability properties. However, the increasing complexity of modern industrial systems [7], combined with stricter environmental regulations, sustainability targets, and the need for flexible operation under varying conditions [8], has exposed fundamental limitations of purely model-based APC approaches [9]. Over the past decade, industrial plants have experienced an unprecedented growth in data availability driven by advances in sensing technologies, distributed control systems [10], and large-scale data historians [11]. This data-rich environment has fundamentally altered how process understanding and control design are approached. Instead of relying exclusively on mechanistic models [12] derived from physical laws, practitioners increasingly exploit historical and real-time data to construct models [13], estimate unmeasured variables, and adapt control strategies. As a result, APC has undergone a gradual but profound evolution toward learning-based formulations, in which data-driven models and learning algorithms play a central role in control synthesis and implementation.

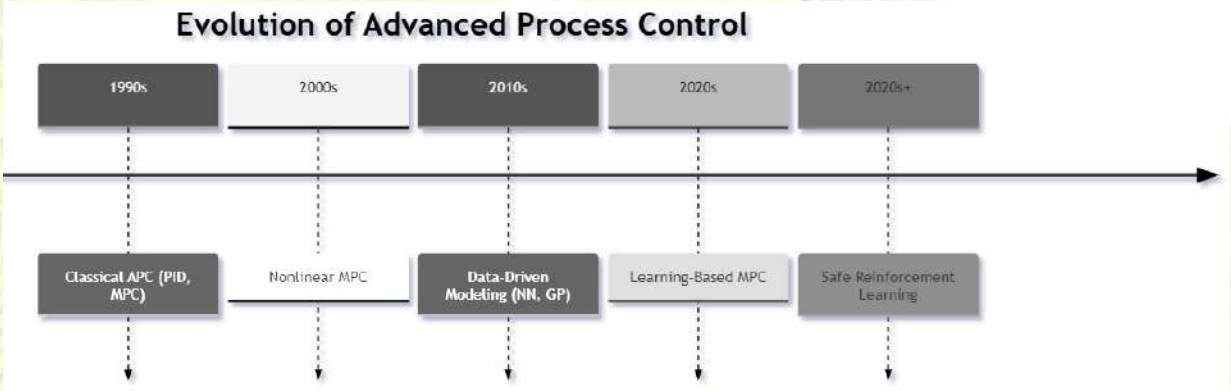


Figure 1. Evolution of advanced process control toward learning-based and safety-aware frameworks

Figure 1 illustrates the conceptual evolution of advanced process control from classical model-based approaches to modern learning-based and safety-aware control frameworks. The progression highlights the increasing role of data-driven modeling, learning-enhanced predictive control [14], and reinforcement learning [15], as well as the growing emphasis on safety and stability in industrial applications. Neural networks [16], Gaussian processes [17], and other machine learning methods [18] have demonstrated strong capabilities in representing highly nonlinear and coupled process dynamics that are difficult to capture using first-principles modeling alone. These models have been successfully integrated into predictive control frameworks, leading to learning-based MPC schemes [19] that can outperform classical controllers in terms of tracking accuracy, economic

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efficiency, and adaptability. In parallel, advanced soft-sensor systems [20] based on learning techniques have significantly enhanced process monitoring, fault diagnosis, and state estimation, further strengthening the foundations of data-driven APC. Industrial case studies, including wastewater treatment plants, semiconductor manufacturing [21], and large-scale energy systems [22], have illustrated the practical benefits of such approaches in terms of improved performance and sustainability metrics. Despite these promising developments, the transition from classical APC to learning-based APC introduces challenges that go beyond incremental performance improvements. The most critical of these challenges are safety and stability. Classical APC methods are deeply rooted in control theory, where stability, robustness, and constraint satisfaction can often be analyzed and enforced explicitly [23]. In contrast, learning-based models are inherently approximate, data-dependent, and valid only within regions covered by training data. Model uncertainty, limited extrapolation capability, and the lack of physical interpretability can result in unpredictable closed-loop behavior [24] when learning-based controllers are deployed in real processes.

These issues become particularly acute in safety-critical industrial environments [25]. Chemical reactors, separation units, biological and wastewater treatment systems, and automated manufacturing lines operate under tight safety and quality constraints, where violations may lead to environmental damage, equipment degradation, or risks to human health. Even minor deviations from safe operating conditions can propagate through interconnected process units, amplifying their impact. Consequently, while learning-based APC methods may offer superior nominal performance, their industrial adoption remains limited unless safety and stability can be guaranteed with a level of confidence comparable to that of classical control strategies. Reinforcement learning (RL) [26] represents a further step in the evolution of learning-based APC [27], offering the possibility of learning control policies directly from process interaction rather than relying on explicit models. In principle, RL can handle complex nonlinear dynamics and long-term objectives in a unified framework, making it attractive for advanced industrial applications. However, standard RL algorithms are typically data-intensive, rely on exploration strategies that may violate safety constraints, and provide no inherent guarantees of stability or constraint satisfaction. These characteristics are fundamentally misaligned with the conservative design philosophy traditionally adopted in process control engineering. In response to these concerns, recent research has increasingly focused on the development of safe and stability-aware learning-based control methods. Hybrid frameworks that combine the structure and guarantees of MPC with the adaptability of learning algorithms have emerged as a

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particularly promising direction. Examples include learning-enhanced MPC schemes that preserve constraint handling, Gaussian process–based controllers that explicitly quantify uncertainty, and reinforcement learning approaches augmented with safety filters, Lyapunov-based conditions [28], or MPC supervisors. These methods aim to reconcile performance gains from learning with the reliability and predictability required for industrial deployment.

Given the rapid expansion of the literature in this area since 2020, a systematic synthesis of learning-based APC methods is both timely and necessary. Existing contributions are scattered across control theory, machine learning, and application-oriented journals, often using different assumptions, performance metrics, and validation strategies. Without a unified perspective, it is difficult to assess the maturity of the field, identify common principles, and distinguish methods that are ready for industrial adoption from those that remain primarily of academic interest. The purpose of this review is to provide a coherent and critical overview of learning-based advanced process control, with a particular focus on the progression from data-driven modeling to safe reinforcement learning. Drawing on recent contributions across APC, soft sensing, learning-based MPC, and safety-constrained RL, the review aims to clarify how learning techniques are currently used in process control, what benefits they offer, and what limitations remain.

METHODS

The methodological approach adopted in this review is designed to ensure rigor, transparency, and relevance while remaining consistent with best practices for systematic narrative reviews in process control and industrial automation. As this work is a review rather than an experimental study, the methodology focuses on literature selection, screening, and conceptual organization, with the objective of synthesizing recent advances in learning-based advanced process control into a coherent and analytically meaningful framework. The literature selection process was guided by a clear temporal, thematic, and application-oriented scope. Only peer-reviewed journal articles and refereed conference papers published from 2020 onward were considered. This temporal restriction was deliberately chosen to capture the most recent phase of development in learning-based APC, which has been shaped by rapid progress in machine learning, increased industrial digitalization, and the growing emphasis on safety, sustainability, and industrial deployability. Earlier foundational works were not included, except insofar as they are implicitly reflected in the post-2020 literature, allowing the review to focus on current trends and open challenges rather than historical development.

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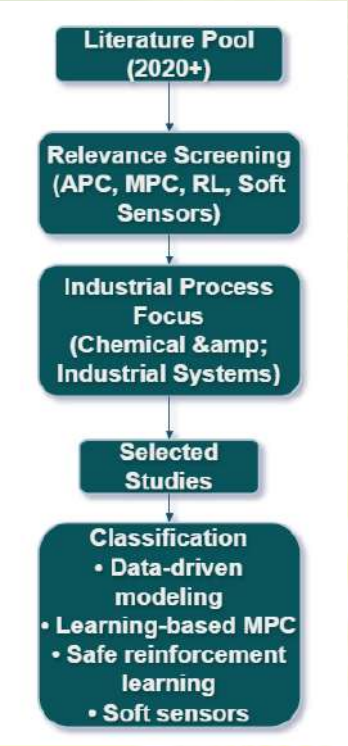


Figure 2. Literature selection and classification workflow used in this review

Figure 2 illustrates the workflow adopted for selecting and organizing the literature reviewed in this paper. Studies published from 2020 onward were screened based on relevance to learning-based advanced process control and industrial applicability, and subsequently classified into four functional categories. This workflow ensures transparency and consistency in the review process. The thematic scope of the review centers on advanced process control and its learning-based extensions [29]. Articles were selected if they addressed at least one of the following topics: data-driven or learning-based modeling for process control, learning-enhanced or learning-integrated MPC, reinforcement learning applied to process or chemical systems, advanced soft-sensor design for monitoring and control, or explicit treatment of safety, stability, and constraint satisfaction in learning-based control. Particular emphasis was placed on works that go beyond algorithmic novelty to address issues relevant to closed-loop operation, such as robustness, uncertainty handling, and practical implementation considerations.

From an application perspective, the review prioritizes chemical and industrial processes, including but not limited to chemical reactors, separation processes, wastewater treatment systems, semiconductor manufacturing, and large-scale energy or sustainability-related processes. This focus reflects the domain in which APC has traditionally played a central role and where safety and stability considerations are most critical. Papers dealing exclusively with robotic systems, autonomous vehicles, or purely benchmark control problems without a clear connection to industrial or chemical processes were excluded, even if they

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employed similar learning techniques. The selected papers were analyzed and organized using a classification framework that reflects both the functional role of learning in APC and the increasing emphasis on safety and reliability. Rather than grouping papers by algorithmic families alone, the classification focuses on how learning is embedded within the control loop and what guarantees are provided. Four primary categories were identified.

Table 1.

Classification criteria adopted for learning-based advanced process control approaches

Category	Role in APC	Representative Techniques	Main Evaluation Focus
Data-driven modeling	Process representation	Neural networks, Gaussian processes	Prediction accuracy, uncertainty
Learning-based MPC	Constrained control	NN–MPC, GP–MPC	Feasibility, stability
Safe reinforcement learning	Policy learning	RL with safety layers, MPC supervision	Safety, robustness
Soft sensors	State estimation	NN-based and hybrid models	Monitoring reliability

Table 1 summarizes the classification criteria used to organize the reviewed literature. The categories reflect the functional role of learning within the APC framework and the extent to which safety and reliability considerations are explicitly addressed. The first category comprises data-driven modeling approaches, including neural networks and Gaussian processes, used to represent process dynamics, estimate unmeasured states, or support prediction in APC frameworks. The second category includes learning-based MPC methods, where data-driven models or learning mechanisms are integrated into MPC formulations while retaining explicit constraint handling and optimization-based decision making. The third category encompasses safe reinforcement learning approaches, in which learning-based control policies are combined with mechanisms that enforce safety, stability, or constraint satisfaction, either explicitly or through supervisory structures. The fourth category focuses on advanced soft sensors, which play a critical enabling role by providing reliable estimates of key process variables and supporting monitoring, fault diagnosis, and safe control operation.

This classification framework is intentionally conceptual rather than purely algorithmic. Many recent contributions span multiple categories, for example by

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combining soft sensing with learning-based MPC or embedding reinforcement learning within an MPC safety layer. Such overlaps are explicitly acknowledged and discussed in the review, as they reflect an important trend toward hybrid and integrated control architectures. By structuring the literature in this manner, the methodology supports a systematic comparison of approaches, highlights common design principles, and facilitates the identification of research gaps related to safety, stability, data efficiency, and industrial applicability. The methodological approach adopted in this review is intended to provide a structured yet flexible foundation for synthesizing recent advances in learning-based advanced process control.

RESULTS

The reviewed literature published since 2020 reveals a clear and consistent shift in advanced process control toward learning-centered formulations, with data-driven models, learning-based MPC, reinforcement learning, and advanced soft sensors emerging as tightly interconnected components rather than isolated research directions. Across chemical and industrial applications, learning is no longer treated merely as an auxiliary tool for model identification, but as an integral element of the control loop whose role ranges from prediction and state estimation to policy optimization and decision making. Data-driven modeling constitutes the foundation of most learning-based APC frameworks. Neural networks and Gaussian processes are the two dominant model classes used to represent process dynamics, each reflecting different design philosophies and trade-offs. Neural network models, including feedforward, recurrent, and deep architectures, are widely adopted due to their strong approximation capability and scalability to high-dimensional nonlinear systems. Studies in semiconductor manufacturing, chemical reactors, and nonlinear process control demonstrate that NN-based models can significantly outperform linear or simplified mechanistic models when sufficient data are available.

Table 2.

Comparison of learning-based advanced process control approaches

Approach	Model Type	Safety and Stability Handling	Data Efficiency	Industrial Maturity
Classical MPC	First-principles / linear models	Explicit constraints, proven stability	High	High
NN-based APC	Neural networks	Implicit or heuristic	Medium–Low	Medium

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GP-based APC	Gaussian processes	Probabilistic constraints, uncertainty-aware	Medium–High	Medium
Learning-based MPC	NN or GP within MPC	Explicit constraints, stability via MPC	Medium	Medium–High
Reinforcement learning (model-free)	Policy learning	Typically none	Low	Low
Safe reinforcement learning	RL with safety layers / MPC supervision	Explicit or Lyapunov-based guarantees	Medium	Emerging

Table 2 provides a comparative overview of learning-based APC approaches reviewed in this paper. The comparison highlights differences in modeling paradigms, safety and stability handling, data requirements, and current levels of industrial maturity, thereby supporting a structured interpretation of the reported results. Gaussian process models offer a complementary perspective by embedding uncertainty quantification directly into the modeling framework. GP-based models are especially prominent in applications where data efficiency and safety are prioritized over raw approximation power. The probabilistic nature of GPs allows prediction uncertainty to be propagated into control decisions, enabling more cautious and robust operation. In learning-based APC, GP models are frequently used to represent residual dynamics on top of nominal models or to support constraint tightening strategies. Nevertheless, the reviewed literature also points to practical challenges associated with GPs, including computational scalability and limitations when dealing with very large datasets or high-dimensional systems. As a result, many recent contributions favor hybrid approaches that combine neural networks for expressiveness with GP-inspired uncertainty handling. Learning-based MPC emerges as a central theme in the reviewed works, reflecting a convergence between classical APC structure and modern learning techniques. Neural network–based MPC schemes typically replace or augment first-principles models with learned predictors, enabling more accurate state and output predictions in nonlinear regimes. These approaches consistently report improved tracking performance and economic efficiency compared to traditional MPC, particularly in processes characterized by strong nonlinearities or poorly understood kinetics. At

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the same time, constraint handling remains one of the main advantages of MPC-based formulations. Even when learning-based models are used, the optimization-based structure of MPC allows explicit enforcement of input, state, and output constraints, which is essential for industrial deployment.

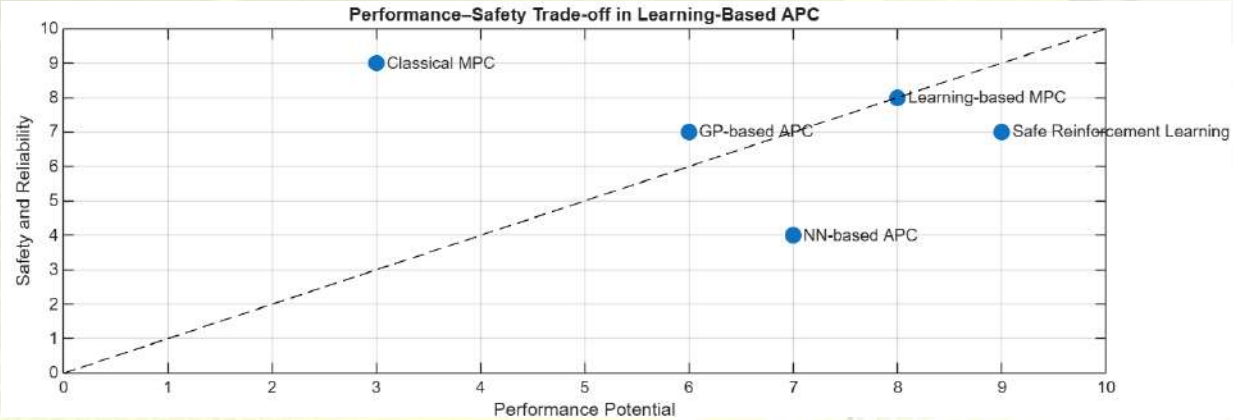


Figure 3. Conceptual performance–safety trade-off of learning-based advanced process control approaches

Figure 3 illustrates a conceptual trade-off between performance potential and safety for different learning-based APC approaches. The relative positioning reflects general trends reported in the recent literature rather than quantitative performance metrics.

Gaussian process–based MPC further strengthens this connection between learning and reliability. By incorporating model uncertainty into the prediction and optimization stages, GP–MPC frameworks enable probabilistic constraint satisfaction and robustness against modeling errors. The reviewed studies show that such approaches are particularly effective in safety-critical processes, where conservative behavior is preferable to aggressive performance optimization. However, computational complexity remains a recurring concern, motivating research into approximations, sparse representations, and hierarchical control structures that preserve safety guarantees while reducing online computational burden. Reinforcement learning represents a more radical departure from classical APC, as it seeks to learn control policies directly from interaction with the process. The reviewed literature distinguishes clearly between model-free and model-based RL approaches. Model-free RL methods, while conceptually simple and flexible, are generally regarded as ill-suited for direct industrial application due to their high data requirements and lack of inherent safety guarantees. In contrast, model-based RL approaches, which leverage learned or nominal models to guide policy optimization, exhibit stronger alignment with APC principles and are more amenable to integration with existing control infrastructures.

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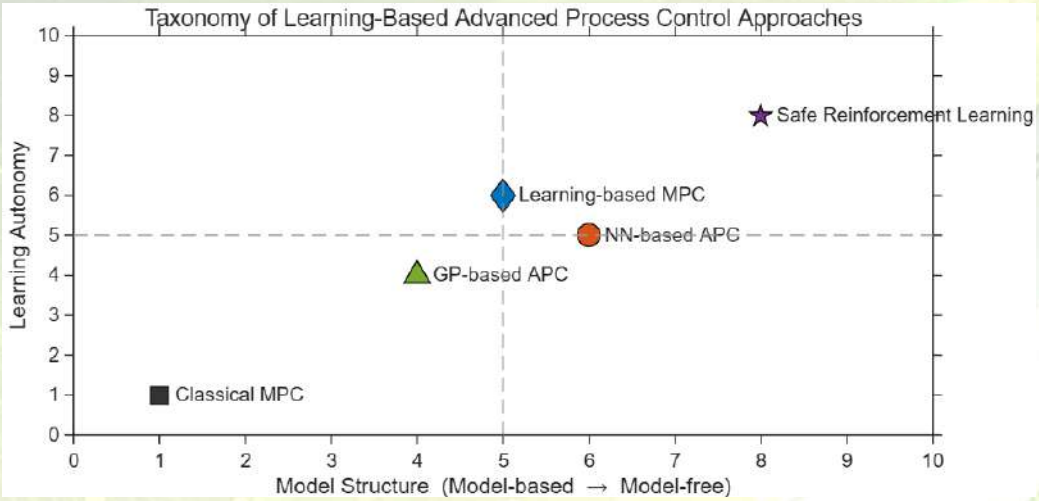


Figure 5. Taxonomy of learning-based advanced process control approaches based on model structure and learning autonomy.

Figure 5 presents a qualitative taxonomy of learning-based advanced process control approaches according to their reliance on explicit process models and their degree of learning autonomy. The relative positioning reflects conceptual trends reported in the literature rather than quantitative performance metrics. A dominant trend in recent work is the explicit incorporation of safety and stability guarantees into RL-based APC. Rather than relying on unconstrained exploration, safe RL frameworks employ mechanisms such as constraint projection, Lyapunov-based conditions, safety filters, or MPC supervisors to ensure that learned policies remain within acceptable operating regions. These approaches demonstrate that RL can be used not as a replacement for APC, but as an adaptive layer that enhances performance while respecting the safety envelope defined by classical control methods. The reviewed studies consistently emphasize that without such safeguards, RL remains unsuitable for chemical and industrial processes, regardless of its theoretical optimality. Advanced soft sensors play a critical enabling role across all learning-based APC paradigms reviewed. Learning-based soft sensors, particularly those using neural networks and hybrid data-driven models, provide reliable estimates of unmeasured or difficult-to-measure variables, such as product quality indicators, biological states, or internal concentrations. These estimates support improved monitoring, fault diagnosis, and control performance, especially when integrated with MPC or safety-aware RL frameworks. The reviewed literature shows that modern soft sensors are increasingly designed as dynamic, adaptive systems that evolve alongside the controller, rather than static estimators trained offline. Their integration into learning-based APC architectures contributes directly to safer operation by reducing uncertainty and improving situational awareness.

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The findings of this review indicate that learning-based APC has matured beyond isolated algorithmic demonstrations and is moving toward integrated, safety-conscious control architectures. Neural networks and Gaussian processes provide complementary modeling capabilities, learning-based MPC offers a structured pathway for industrial adoption, reinforcement learning introduces new possibilities for adaptability and optimality, and soft sensors underpin reliable operation. At the same time, the literature consistently underscores that performance gains alone are insufficient; safety, stability, and interpretability remain decisive factors in determining whether learning-based APC methods can transition from research prototypes to widely deployed industrial solutions.

DISCUSSION

The body of evidence reviewed in this work highlights a fundamental tension at the heart of learning-based advanced process control: the trade-off between performance enhancement and the preservation of safety and reliability. Learning-based methods consistently demonstrate superior nominal performance compared to classical APC, particularly in highly nonlinear, multivariable, and time-varying operating regimes. Data-driven models improve prediction accuracy, learning-based MPC enhances economic optimization, and reinforcement learning enables long-horizon performance objectives that are difficult to address with conventional controllers. However, these gains are often achieved at the cost of reduced transparency, increased uncertainty, and weakened analytical guarantees. The reviewed literature makes it clear that, in industrial process control, performance improvements are only valuable insofar as they do not compromise safety, stability, or regulatory compliance. From an industrial perspective, the applicability of learning-based APC depends less on algorithmic novelty and more on robustness, maintainability, and integration with existing control systems.

Reinforcement learning, while conceptually appealing, remains the most challenging paradigm to deploy in industrial settings. The literature shows that model-free RL is largely confined to simulation studies or tightly controlled experimental environments, due to its data requirements and lack of inherent safeguards. Model-based and safety-augmented RL approaches show greater promise, especially when combined with MPC supervisors or safety filters that constrain exploration and enforce stability conditions. Nevertheless, even these methods face significant hurdles related to validation, certification, and operator trust.

CONCLUSIONS

The rapid development of learning-based methods has fundamentally reshaped the landscape of advanced process control, offering new opportunities to

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address long-standing limitations of classical model-based approaches. This review has examined recent contributions that span the progression from data-driven modeling to safe reinforcement learning, with a particular focus on works published since 2020 and on applications relevant to chemical and industrial processes. Taken together, the reviewed studies demonstrate that learning is no longer a peripheral tool in APC, but an essential component of modern control architectures. Data-driven models based on neural networks and Gaussian processes have significantly expanded the modeling capabilities available for APC, enabling accurate representation of complex nonlinear dynamics and improved handling of process variability. When embedded within predictive control frameworks, these models support enhanced performance while retaining the structured decision-making and constraint-handling properties that make MPC attractive for industrial use. At the same time, advances in soft sensing have strengthened the reliability of learning-based control by improving state estimation, monitoring, and fault detection, thereby reducing uncertainty in closed-loop operation. Reinforcement learning has introduced a new paradigm for process control, emphasizing adaptability and long-term optimization. However, the literature reviewed in this paper makes it clear that unconstrained learning is incompatible with the safety-critical nature of industrial processes. Meaningful progress in this area has been achieved by integrating RL within safety-aware control structures, including MPC supervisors, stability constraints, and uncertainty-aware mechanisms. These hybrid approaches illustrate a broader trend in the field: learning-based APC is most effective when it complements, rather than replaces, classical control principles.

Despite substantial progress, several challenges remain before learning-based APC can be widely deployed in industrial practice. Ensuring robust safety and stability under learning-induced uncertainty, improving data efficiency, enhancing interpretability, and managing the lifecycle of adaptive control systems are all open issues that require further research. Addressing these challenges will demand closer integration between control theory, machine learning, and industrial engineering, as well as more extensive validation in real-world operating environments. Learning-based advanced process control represents a promising and evolving direction for industrial automation. By combining the expressive power of modern learning techniques with the rigor and reliability of classical APC frameworks, it is possible to achieve controllers that are both high-performing and trustworthy. Continued research focused on safety-aware design, industrial applicability, and systematic validation will be essential to translate the growing

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body of academic work into robust, deployable solutions that meet the demands of modern process industries.

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Annotatsiya. Sug‘orish tizimidagi nasos stansiyalarining energiya iste’moli muammolari muhokama qilingan. Jahon tajribasi asosida sug‘orish uchun xizmat qiladigan nasos qurilmalari energiya ta’minotida quyosh energiyasidan foydalanish sxemasi taklif qilingan. Sxema nasos qurilmasining quyosh energiyasi faol bo‘lgan paytda ishlashi, sug‘orish uchun suv berish uning uchun qulay bo‘lgan vaqtlarda berilishi shartiga amal qiladi va bunda kun davomida fotoelektrik qurilmaning ishlab chiqaradigan o‘zgaruvchan energiyasi miqdoriga mos keluvchi nasos ish rejimini val aylanishlari chastotasini o‘zgartirish usuli bilan rostlash parametrlarini hisoblashning metodikasi taklif etilgan. Taklif etilgan metodika bilan sug‘orish tizimidagi fotoelektrik nasos qurilmasi parametrlarini hisoblash natijalari, nasos ish rejimini rostlash usuli qo‘llanilganda quyosh energiyasi quvvatidan nasos qurilmasida foydalanish darajasi 80...90 % gacha borishini ko‘rsatgan.

Kalit so‘zlar. nasos stansiyasi, fotoelektrik qurilma, quyosh energiyasi, suv berish unumdorligi, nasos napori, quvvat, val aylanishlar chastotasi, suv to‘plash rezervuari.

Аннотация. Обсуждены проблемы энергопотребления насосных станций в системе орошения. На основе мирового опыта предложена схема использования солнечной энергии в энергоснабжении насосных установок, служащих для орошения. Схема основывается на условиях работы насосной установки при активном использовании солнечной энергии, подачи воды для орошения в удобное для нее время, при этом предлагается методика расчета параметров регулирования режима работы насоса методом изменения частоты волновых оборотов, соответствующего количеству выделяемой в течение дня переменной энергии фотоэлектрического устройства. Результаты расчета параметров фотоэлектрической насосной установки в оросительной системе с применением предложенной методики показали, что

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при применении метода регулировки режима работы насоса уровень использования солнечной энергии в насосной установке достигает 80...90%.

Ключевые слова: насосная станция, фотоэлектрическое устройство, солнечная энергия, производительность подачи воды, насосная труба, мощность, частота волновых циклов, резервуар для сбора воды.

Annotation. Energy consumption problems of pumping stations in the irrigation system were discussed. On the basis of world experience, a scheme for using solar energy for energy supply of pumps for irrigation has been proposed. The scheme follows the condition that the pump works when solar energy is active, the water for irrigation is provided at times convenient for it, and a methodology is proposed for calculating the parameters of adjusting the pump operating mode by changing the frequency of the wave rotations, which corresponds to the amount of variable energy produced by the photoelectric device during the day. The results of calculation of the parameters of the photoelectric pump system in the irrigation system with the proposed methodology showed that when the method of adjusting the pump operating mode is applied, the utilization rate of solar energy in the pump system reaches 80...90%.

Keywords: pump station, photoelectric plant, solar energy, water delivery efficiency, pump pump, power, wave frequency, water storage tank.

KIRISH.

Bugungi kunda jahonda energiyaga bo‘lgan ehtiyoj yiliga o‘rtacha 1 % ga, rivojlanayotgan mamlakatlarda 5 % ga oshmoqda, asosiy energetik resurs bo‘lgan uglevodorodlar zahiralari kamayib, yoqilg‘i narxi va uning atrof-muhitga zararli ta’siri esa sezilarli darajada oshib boryapti, shu sababli jahon energetikasida qayta tiklanuvchi energiya manbalari, asosan quyosh energiyasidan foydalanishning iqtisodiy va ekologik samarasi yildan yilga o‘sib boryapti, jumladan so‘g‘orish tizimidagi fotoelektrik nasos qurilmalarining energiya xarajatlari organik yoqilg‘ida ishlaydigan qurilmalarga nisbatan 2...4 barobar kam qiymatlarni tashkil qilmoqda [1].

Jahonning nufuzli tashkilotlaridan biri qayta tiklanuvchi energiya manbalari bo‘yicha Halqaro agentlik (IRENA)ning ma’lumotlariga ko‘ra hozirgi paytda so‘g‘oriladigan yerlarning 56 % iga nasos qurilmalari yordamida suv yetkazib berilayapti va ularni energiya bilan ta’minlash uchun quyosh energiyasi keng qo‘llanilmoqda, ayniqsa Afrika, Hindiston, Yaqin Sharqda energiya manbasining bu turi yangi qurilayotgan nasos qurilmalarining 75...80 % ida foydalanilmoqda va eng samarali va ekologik “toza” manbalardan biri sifatida tan olinmoqda [2].

O‘zbekiston Respublikasida so‘g‘oriladigan yer maydonlarining 60 % iga nasos stansiyalar yordamida suv yetkazib beriladi va bunga har yili 8 mlrd. kVt·soat

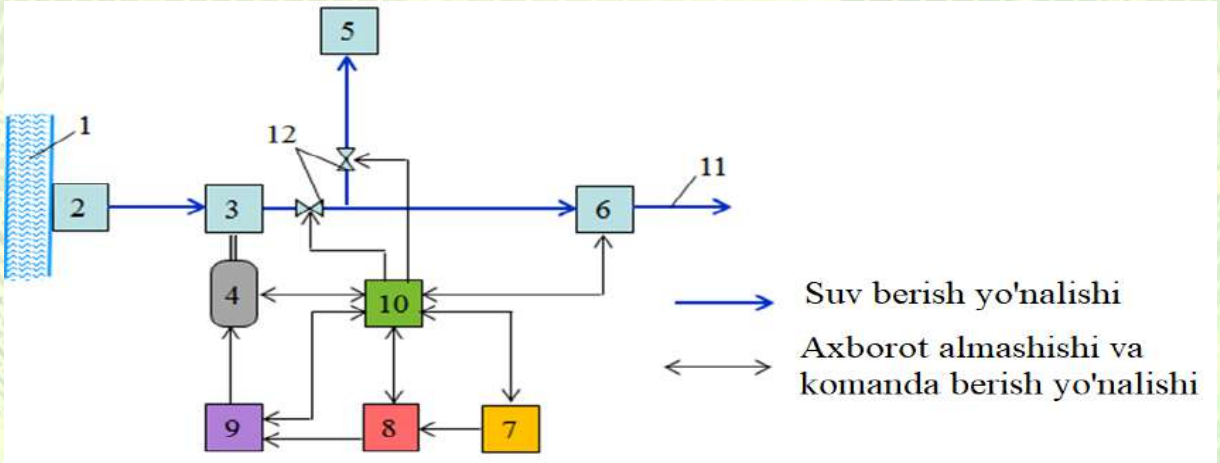
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atrofida elektr energiyasi iste'mol qilinadi [3]. Bu kabi katta miqdordagi energiya iste'moli sharoitida nasos stansiyalar samaradorligini oshirish, jihozlarning energiya tejamkorligiga erishish, foydalanish xarajatlarini kamaytirishga yo‘naltirilgan keng miqyosdagi ilmiy-tadqiqot ishlarini olib borish muhim vazifalardan biri hisoblanadi. Shuni hisobga olib O‘zbekiston Respublikasi Prezidentining 2020 yil 10 iyuldagi PF-6024-son Qarorida "...suv xo‘jaligi nasos stansiyalarining energiya samaradorligini oshirish va foydalanish xarajatlarini kamaytirish..." bilan bir qatorda ularda, "...muqobil energiya manbai, shu jumladan, quyosh batareyalaridan foydalanishni yo‘lga qo‘yish..." kabi resurs tejaydigan zamonaviy texnologiyalarni keng joriy qilish vazifalari belgilab berilgan [4].

Hozirgi kunda nasos stansiyalarda quyosh energiyasidan foydalanish samaradorligini yanada oshirish uchun fotoelektrik qurilma (FEQ)ning energiyasidan maksimal foydalanishni ta'minlash maqsadida uning kun davomida o‘zgaruvchan quvvatiga nasos qurilmasi quvvatini operativ ravishda moslash masalalarini tadqiq qilish muhim hisoblanadi.

MATERIALLAR VA USULLAR. Sug‘orish tizimida qo‘llaniladigan kichik energetik qurilmalarda quyoshning energiyasini akkumulyatsiyalash tizimlari bo‘yicha bajarilgan tahlillar natijalariga ko‘ra energiyani gidravlik usulda akkumulyatsiyalash eng maqbul usul hisoblanadi. Ushbu usulga hamda, nasos agregatini FEQ energiyasi bilan ta'minlashga asoslangan qurilmaning sxemasi 1 – rasmda keltirilgan.

Mazkur sxema bo‘yicha nasos qurilmasining ishlash vaqti quyosh faolligi vaqtiga mos etib tanlangan, sug‘orish uchun suv berish vaqti esa bu ish uchun qulay bo‘lgan qechqurun, ertalab va tungi soatlarda amalga oshiriladi, Shu sababli ushbu tizimda bir kunlik sug‘rish uchun zarur hajmga ega napor hosil qilish uchun ma'lum balandlikda joylashgan rezervuardan foydalaniladi.



1 – rasm. Quyosh energiyasidan foydalanishga va energiyani to‘plashga mo‘ljallangan nasos qurilmasi sxemasi

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1–suv manbai; 2-suv olish qurilmasi; 3–nasos; 4-nasos elektrodvigateli; 5 – suv to‘plash rezervuari (energiya akkumulyatori); 6-suv sarfini rostlash va taqsimlash moslamasi; 7-foto elektrik qurilma; 8-invertor; 9-elektrodvigatel vali aylanish chastotasini o‘zgartirgich;10-boshqaruv pulti; 11-suvni iste’molchiga berish quvuri; 12-qulfaklar (zadvijkalar).

Sug‘orish uchun zarur bo‘lgan kunlik suv hajmi sug‘orish maydoniga xos bo‘lgan iqlim, tuproq turi, yer osti suvlarining joylashishi va ekin turiga bog‘liq holda qabul qilinadigan sug‘orish meyori asosida aniqlanadi

$$V = m \cdot \omega, \ м^3 \qquad (1)$$

bunda m – sug‘orish meyori (bir marta sug‘orish uchun), м^3/ga; ω -sug‘orish uchun belgilangan yer maydoni, ga.

V hajmdagi suvni rezervuarga haydab berishda nasos agregatiga kerak bo‘lgan energiya miqdori quyidagicha aniqlanadi [5].

$$Э_n = 9,81 \int_{t_1}^{t_2} Q(t) H(t) \eta^{-1}(t) dt; \qquad (2)$$

bunda t_1 va t_2 – nasos agregatining ishlash vaqtining boshlanishi va tugashi soatlari (bu vaqt quyosh faolligi soatlari bilan belgilanadi)

Nasosning t vaqtdagi to‘liq napori qiymati quyidagi formula bilan hisoblanadi

$$H(t) = H_I(t) + \Delta H(t) \qquad (3)$$

bunda $\Delta H(t)$ - nasosning suv manbaidan suv rezervuarigacha bo‘lgan masofadagi quvurlar tizimida yo‘qolgan napor qiymati va bu qiymat gidravlik hisoblar yordamida aniqanadi.

$$\Delta H(t) = \left(\sum \xi + \lambda \frac{l}{d} \right) \frac{\vartheta(t)_i^2}{2g} \qquad (4)$$

$\Sigma\xi$ – quvurlardagi mahalliy qarshiliklar koeffitsiyentlari yig‘indisi, λ – quvurlardagi gidravlik ishqalanish koeffitsiyenti, l – quvurlar uzunligi , d – quvurlar diametri, $\vartheta(t)$ – quvurdagi suv tezligi.

$Q(t)$ ning qiymatini nasos va quvurlar tizimi napor xarakteristikasi tenglamalaridan foydalangan holda quyidagi bog‘lanish asosida aniqlaymiz

$$Q(t) = k[H_0 - H_I(t)]^{0,5} \qquad (5)$$

bunda k – nasos qurilmasining suv oqish traktida, shu jumladan quvurlarda gidravlik qarshiliklar qiymatlarini ifodalovchi koeffitsiyent

$$k = \frac{1}{(S_n + S_k)^{0,5}} \qquad (6)$$

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S_n – nasos napor xarakteristikasining koeffitsiyenti, S_q –quvurlar tizimining gidravlik qarshilik koeffitsiyenti, H_0 – nasos suv berish unumdorligi nolga teng (qulfak yopiq) bo‘lgan holdagi napor qiymati.

$S_к$ qiymati quyidagi formula bilan aniqlanadi

$$S_к = \Delta H_{opt} / Q^2_{opt} \quad (7)$$

Q_{opt} – nasos napor xarakteristikasi bo‘yicha f.i.k. ning maksimal qiymatiga mos keluvchi suv berish unumdorligi qiymati, ΔH_{opt} qiymati Q_{opt} qiymati bo‘yicha (4) bog‘lanish orqali hisoblanadi.

S_n va H_0 qiymatlari B.S. Leznov metodikasi asosida nasos napor xarakteristikasi grafigi bo‘yicha hisoblanadi [6].

Shunday qilib kunnning t vaqtidagi nasos quvvatini $Q(t)$ va $H(t)$ qiymatlari asosida quyidagi tarzda aniqlaymiz

$$N_n(t) = 9{,}81 \cdot Q(t) \cdot H(t) / \eta(t) \quad (8)$$

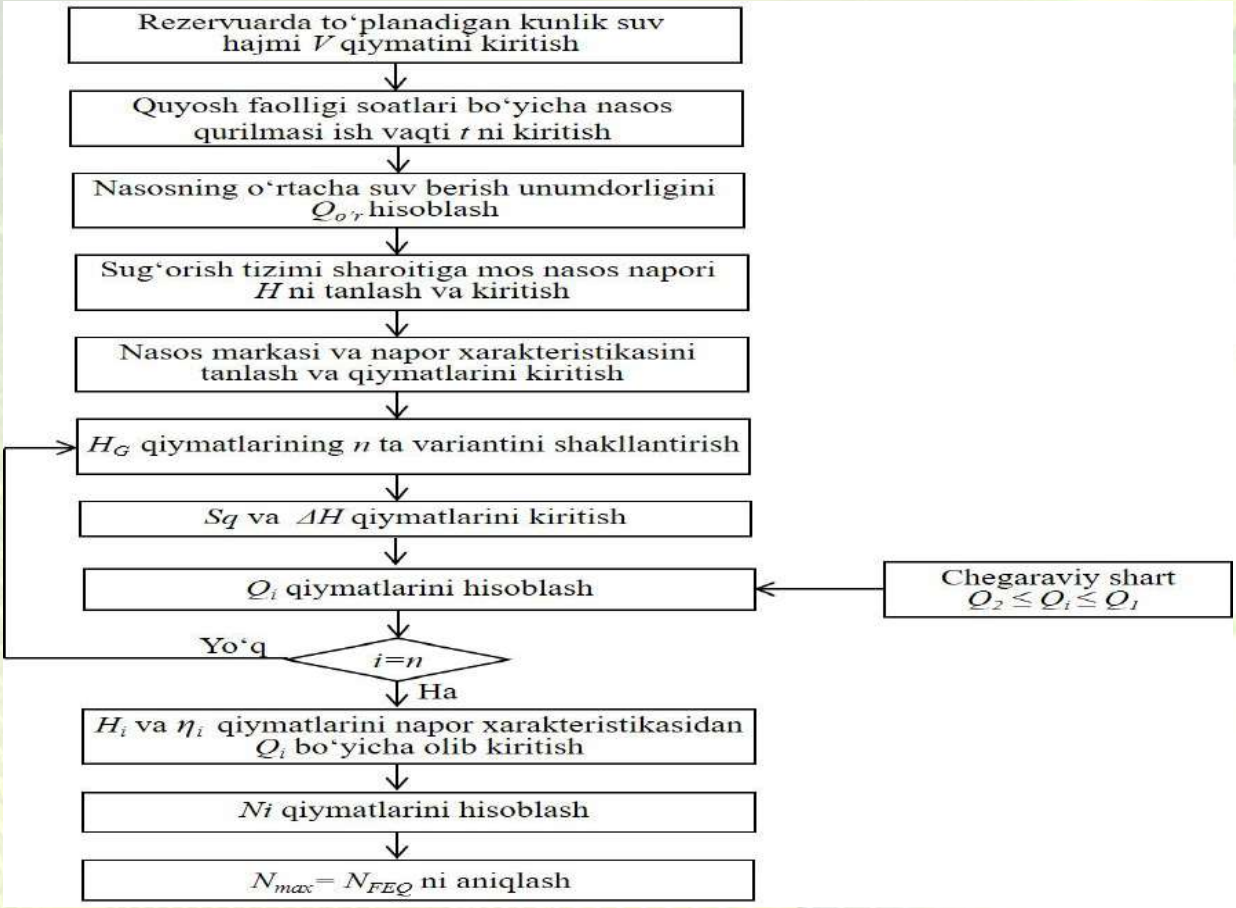
N_n qiymatlarining ichida N_{Ntax} ga mos keluvchi FEQning maksimal quvvatini topish mumkin.

Mazkur metodika bo‘yicha hisoblarning EHM uchun dasturi olingan (№ DGU 14479) va uning blok–sxemasi 2 – rasmda keltiriladi.

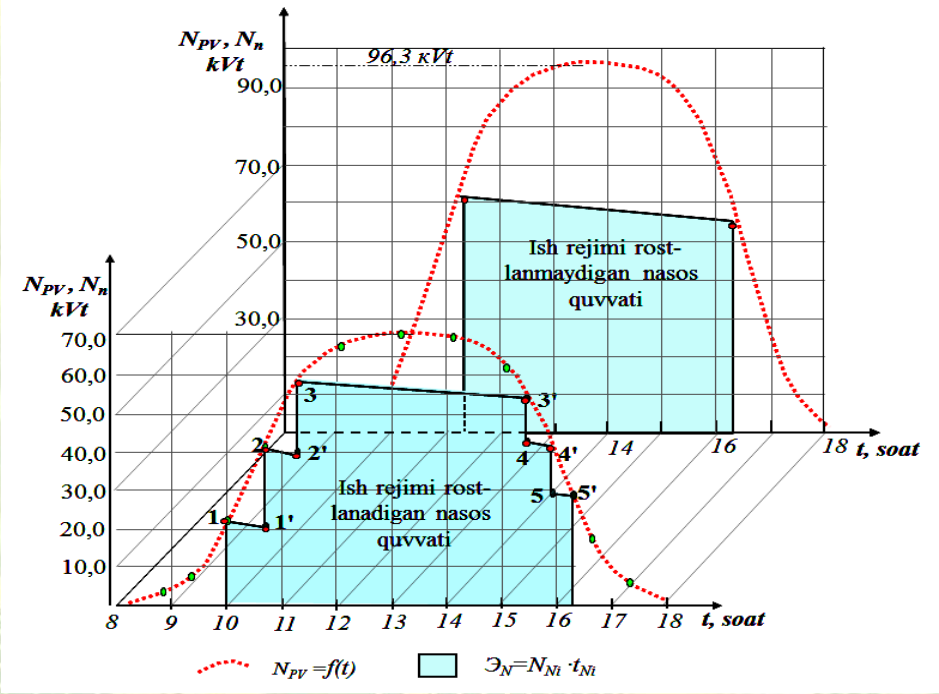
Quyosh energiyasidan maksimal foydalanishni ta’minlash uchun nasos quvvatini FEQ quvvatiga mos holda o‘zgartirish (moslash) zarur bo‘ladi, buni amalga oshirish uchun nasos vali aylanishlari sonini o‘zgartirish usulini tanlaymiz. Val aylanishlari soni o‘zgarganda nasoslar o‘xshashligi qonuniyatlari asosida parametrlarning o‘zgarishini qayta hisoblash uchun tavsiya etilgan tenglamalardan foydalanamiz.

NATIJALAR. Ushbu metodika bo‘yicha nasos ish rejimini tashkil qilishning afzalligini misol sifatida bir marta sug‘orish uchun zarur bo‘lgan 9000 м^3 suv miqdorini rezervuarda to‘plash uchun kerak bo‘ladigan energetik xarajatlar orqali aniqlaymiz. Agar ish rejimi rostlanmaydigan (bir xil aylanishlar chastotasiga ega bo‘lgan) nasosdan foydalanilsa, bu holda nasos 54,9...59,4 kVt quvvatga ega bo‘ladi va 5^{50} soat davomida 9000 м^3 suv miqdorini to‘plash uchun 368 kVt·soat elektr energiyasini iste’mol qiladi va bu energiyani ishlab chiqarishda FEQning maksimal quvvati N_{PV} = 96,3 kVtni tashkil etadi (3 – rasm).

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2–rasm. FEQning quvvatini hisoblash metodikasi blok-sxemasi



3 – rasm. Nasos qurilmasi va FEQ quvvatlari grafigi

Ushbu rasmdagi grafikdan ko‘rinib turibdiki, FEQ elektr energiyasining deyarli 40 % miqdori nasos qurilmasi tomonidan foydalanilmasdan qolmoqda. Agar nasos aylanishlar chastotasini o‘zgartirish usulidan foydalanilsa, nasos

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quvvatini N_{PV} ga moslash hisobidan 9000 м^3 suv miqdorini to‘plash uchun 314,5 kVt·soat elektr energiyasi kerak bo‘ladi va bu energiyani ishlab chiqarishda FEQning maksimal quvvati 70 kVtni tashkil etadi, bu esa FEQning 81 % energiyasidan foydalanish imkonini beradi.

MUHOKAMA. Yuqoridagi hisoblardan ko‘rinib turibdiki, nasos qurilmasi ish rejimini to‘liq ravishda FEQ quvvati miqdoriga moslash uchun nasos suv berish unumdorligi $Q(t)$ va ishchi g‘ildirak aylanishlar chastotasini $n(t)$ N_{PV} (t) qiymatlariga mos ravishda o‘zgartirish kerak. Buning uchun qurilmasining maksimal quvvatiga mos keluvchi nasos tanlanib, uning ishchi xarakteristikasi quriladi. Quyosh faolligi past bo‘lgan vaqtlarda FEQ quvvatidan foydalanish uchun nasos vali aylanishlar soni kamaytiriladi va ushbu quvvatga mos keluvchi nasos parametrlari aniqlanadi. Ma’lum vaqt ichida FEQ quvvati oshadi va bunga mos ravishda nasos vali aylanishlar sonini ham ko‘paytirib, nasos quvvati oshiriladi. Quyosh faolligi maksimal bo‘lganda nasos o‘zining meyoriy, belgilangan aylanishlar chastotasi bilan ishlaydi. Kunning ikkinchi yarmida quyosh faolligi kamayganda yana nasos vali aylanishlari soni kamaytiriladi. Shu tariqa nasos ish rejimi FEQ ish rejimiga bosqichma-boqich maksimal ravishda moslashtiriladi.

XULOSALAR.

1. Quyosh energiyasidan foydalanish va su miqdorini (energiyani) akkumulyatsiyalash asosidagi ekinlarni sug‘orishga mo‘ljallangan kichik energetik qurilmaning sxemasi taklif etildi.

2. Fotoelektrik qurilma, energiyani suvni to‘plash rezervuarida gidravlik akkumulyatsiyalash uchun xizmat qiladigan nasos qurilmasining asosiy parametrlarini aniqlash bo‘yicha yangi metodika ishlab chiqildi. Bu metodikaning boshqa metodikalardan asosiy farqi shundan iboratki, kun davomida fotoelektrik qurilmaning ishlab chiqaradigan o‘zgaruvchan energiyasi miqdoriga mos keluvchi nasos ish rejimini val aylanishlari chastotasini o‘zgartirish usuli bilan rostlash parametrlarini hisoblashning aniq va sodda grafoanalitik usuli taklif etilgan.

3. Taklif etilgan metodika bilan sug‘orish tizimidagi nasos quvvati 58,3 kVt, FEQ quvvati 70 kVt bo‘lgan fotoelektrik nasos qurilmasi parametrlarini hisoblash natijalari, nasos ish rejimini rostlash usuli qo‘llanilganda FEQ maksimal quvvati, nasos o‘zgarmas rejimda ishlagan rejimga nisbatan 27 % kam talab qilinishi, quyosh energiyasi quvvatidan nasos qurilmasining foydalanish darajasi 80...90 % gacha borishini ko‘rsatdi.

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ХОЛВА ОЛИШ РЕЦЕПТУРАСИГА КУТАИФИ ХАМИРИНИ ҚЎШИШ УНИНГ ФИЗИК-КИМЁВИЙ ХОССАЛАРИГА ТАЪСИРИ

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Аннотация. Дунёда ҳолва ширинлигини турларини кенгайтириш, уни озуқавий ва биологик қийматини ошириш бўйича илмий изланишлар олиб борилмоқда. Бу борада таркибида бодом, ерёнғоқ ва шунга ўхшаш ёғли уруғларни қўшиш; ёғли уруғларни ёғ кислота таркибини ўрганиш, уларни ҳолванинг кимёвий, озуқавий қийматини ўзгаришини аниқлаш; кунжут, седана, зиғир уруғлари қўшилиши кимёвий, органолептик хусусиятларига таъсирини аниқлаш; технологияларини яратиш ва синовдан ўтказишга алоҳида эътибор берилмоқда.

Калит сўзлар: бодом, зиғир, ерёнғоқ, кунжут, седана, ёғли озуқа, оқсил моддалари, экологик тоза, диабет, остеопороз, семизли.

Annotation. Scientific research is being conducted worldwide to expand the varieties of halva confectionery and to increase its nutritional and biological value. In this regard, special attention is being paid to adding oil-rich seeds such as almonds and peanuts to the composition; studying the fatty acid composition of these seeds and determining their effect on the chemical and nutritional value of halva; identifying the influence of sesame, black cumin, and flax seeds on its chemical and organoleptic properties; as well as developing and testing new production technologies.

Keywords: almond, flaxseed, peanut, sesame, black cumin, oil-rich food, protein substances, environmentally friendly, diabetes, osteoporosis, obesity.

Аннотация. Во всём мире проводятся научные исследования, направленные на расширение ассортимента халвы и повышение её пищевой и биологической ценности. В этом направлении особое внимание уделяется добавлению в состав масличных семян, таких как миндаль и арахис; изучению жирнокислотного состава этих семян и определению их влияния на химическую и пищевую ценность халвы; определению влияния семян кунжута, чёрного тмина и льна на её химические и органолептические свойства; а также разработке и апробации новых технологий производства.

Ключевые слова: миндаль, лён, арахис, кунжут, чёрный тмин, масличные продукты, белковые вещества, экологически чистый, диабет, остеопороз, ожирение.

КИРИШ.

Замонавий озиқ-овқат саноатида функционал маҳсулотлар ишлаб чиқариш, уларнинг озиқавий қийматини ошириш ва соғлом овқатланиш

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талабларига жавоб берадиган янги турдаги маҳсулотлар яратиш муҳим илмий ва амалий аҳамият касб этмоқда. Хусусан, қандолат маҳсулотларини биологик фаол моддаларга бойитиш орқали уларнинг физиологик фойдали таъсирини кучайтириш бугунги кунда озиқ-овқат технологияси соҳасида устувор йўналишлардан бири ҳисобланади.

Ҳолва Шарқ мамлакатларида кенг тарқалган, юқори энергия қийматига эга бўлган анъанавий қандолат маҳсулоти бўлиб, асосан кунгабоқар уруғи ва шакар-патока сиропи асосида тайёрланади. Бироқ анъанавий технологияда маҳсулотнинг биологик қиймати чекланган бўлиб, функционал компонентлар миқдори нисбатан кам ҳисобланади. Шу сабабли ҳолва таркибини ўсимлик манбаига эга функционал ингредиентлар билан бойитиш илмий нуқтаи назардан долзарб вазифа ҳисобланади.

АДАБИЁТЛАР ТАҲЛИЛИ. Катаифи хамири - бу жуда майда, ипсимон шаклдаги хамир маҳсулоти бўлиб, Яқин Шарқ ва Ўрта ер денгизи ширинликларида кенг ишлатилади. У холва, кунафа, рулетли десертлар, шоколад каби маҳсулотларда текстура шакллантирувчи компонент сифатида қўлланади. Катаифи оддий хамирдан тайёрланади, аммо махсус усулда ипсимон ҳолга келтирилади. Асосий таркиби: буғдой уни, сув, баъзан оз миқдор туз ташкил этади [1-2].

Кутаиси хамирини холва таркибига киритиш унинг технологик тарафдан унинг структурасини яхшилаб, қўшимча механик мустаҳкамлик беради, сироп ва ёғ фазасини ушлаб туриб, ёғ ажралишини камайтиради, ипсимон қатлам ҳосил қилиб, енгил қарсилдоқ, хушбўйлик ҳосил қилади, энергетик қийматини оширади, лекин таркибга кўп қўшиб бўлмайди, чунки углевод миқдорини ошириб, маҳсулотни оғирлаштириб юборади [3].

ТАДҚИҚОТ МЕТОДОЛОГИЯСИ. Қовурилган қарсилдоқ текстурага эга кутаиси хамири 150-170^{0}C да қовурилганини турли нисбатда қўшиб, холва рецептурасига унинг текстур ва органолептик хусусиятларига таъсири кўрилди.

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а



б



в



г

1-Расм Кунжут, зиғир, кутаиси хамири қўшиб тайёрланган холва тасвири

а) кутаиси хамири; б) 3% қўшилганда; в) 5% қўшилганда; г) 7 % қўшилганда.

Расмда кўриш мумкинки, қовурилмаган кутаиси хамири (б) расмда келтирилганидек оч рангга эга бўлиб, қовурилгани ранги тўқаришини (в,г-расмларда) кўриш мумкин, қовурилган кутаиси хамири қўшилганда қарсидоқдик ва қовурилганда ўзига хос таъмга эга бўлади. Шунингдек қўшилган ҳамир ҳолвага қўшимча мустаҳкамлик бериб, унда каркас вазифасини бажариши аниқланди. Лекин 7% қўшилган намунада ҳолва ёпишқоқлиги пасайганлигини, бўлиниб кетиши ортиши кузатилди.

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Катаифи хамири холва структурасига қўшимча каркас таъсирини кўрсатиб, маҳсулотнинг механик барқарорлигини, кесилувчанлигини ва текстура бойлигини оширади. У органолептик жиҳатдан маҳсулотни янада жозибадор қилади, бироқ ортиқча миқдорда киритилиши масса пластиклигини пасайтириб, технологик жараённи мураккаблаштириши мумкин [4].

МУҲОКАМА ВА НАТИЖА.

Унинг физик –кимёвий кўрсатгичлари ҳам кутаиси хамири қўшилган ва қўилмаганини фарқини қуйидаги жадвалда кўриш мумкун.

1-жадвал

Ҳолва таркибига кутаиси хамири қўшилиши билан физик-кимёвий хоссаларини ўзгариши

Кўрсаткич	Назорат холва	Қўшимчали холва-3%	Қўшимчали холва-5%	Қўшимчали холва-7%
Намлик, %	3.2	3.8	3,5	2,8
Ёғ, %	30.1	32.4	31.3	30.7
Пероксид сони, ммоль O_2/кг	4.5	5.2	5.6	6,1
Кислоталик, °К	1.8	2.1	2.8	3,2
Кул, %	1.6	2.3	2,5	2.9

Жадвалдан кўриниб турибдики, қўшимчалар киритилиши намлик ва минерал моддалар миқдорини оширгани, ёғ таркибининг сифат жиҳатдан бойигани кузатилди.

Ҳолва таркибига кутаиси хамирини 3-7% таркибга киритилиши холванинг физик-кимёвий хоссаларини ўзгаришига олиб келади. Буни унинг намлигини 7% қўшилганда камайишидан, перекис сонини ошишидан кўриш мумкин. 7 % қўшилганда намликни камайиши ҳолвани қуриқлашиб, қовушқоқлигини камайишига олиб келади. Шу сабабли кейинги ишларда кутаиси хамирини холвага қрвурилган холва фақат 5% қўшиш тавсия этилди [5-6].

Хулоса қилиб 5 % кутаиси хамирини ҳолва таркибига киритиш унинг органолептик кўрсатигичларини 5 баллик тизимда қуйидаги 2-жадвалда баҳоланди.

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2-жадвал

Ҳолва таркибига кутаиси хамири қўшилиши билан органолептик хусусиятларини баҳолаш

Кўрсаткич	Назорат	Қўшимчали намуна
таъм	4.2	4.8
хид	4.3	4.7
текстура	4.0	4.9
ранг	4.5	4.6
умумий баҳо	**4.25**	**4.75**

Жадвалдаги натижалардан умумий баҳо 5% кутаиси хамири қўшилган ҳолва натижалари қўшилмаганига қараганда юқорироқ натижа олганини кўриш мумкин.

Бунинг асосий сабаби холвага қўшимча таъм ва ўзига хос қарсилдоқлик берганини кўрсатиш мумкин. Шунингдек текстурасидаги ҳамда, ҳидини ўзгариши, яъни кутаиси хамирининг қовурилган ҳиди ўзига хослиги, истемолчини ўзига жалб этиши ҳисобигадур.

ХУЛОСА

Тадқиқот натижалари кунгабоқар уруғи асосида зиғир, кунжут ва катаифи хамири қўшилган холва маҳсулотининг физик-кимёвий, реологик ва органолептик кўрсаткичлари яхшиланганини кўрсатди. Маҳсулот структураси мустаҳкамлашди, текстураси бойиди ва истеъмол жозибадорлиги ошди. Қўшимчалар маҳсулотни функционал қийматга эга янги турдаги холва сифатида тавсифлаш имконини берди.

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CHORVACHILIK UCHUN OZUQAVIY YEM-XASHAK YIG‘ISH MASHINALARINING ILMIY TAHLILI

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Annotatsiya. Maqolada chorva mollari uchun oziqabop beda o‘simligini o‘rish kombaynlarining bugungi kunda ekspluatatsion sharoitlaridan kelib chiqib ilmiy tahlilini olib borish, ozuqabop o‘simliklarni o‘rim-yig‘im sharoitlarini hisobga olgan holda o‘rish jarayonida ortiqcha yo‘qotishlarni tahlil qilgan holda o‘rish agregatining maqbul variantlarining ilmiy tahlilini yuritish.

Kalit so‘zlar. Chorva mollari, beda, o‘rish agregati, texnologiya, samaradorlik, tezlik, o‘rish balandligi, segment barmoq.

Аннотация. Изучение существующих типов эксплуатируемых косилок для кормовой люцерны, анализ избыточных потерь в процессе скашивания с учётом условий уборки кормовых культур и научный анализ оптимальных вариантов уборочных агрегатов

Ключевые слова Сельскохозяйственные животные, люцерна, косильный агрегат, технология, эффективность, рабочая скорость, высота среза, сегментно-пальцевый аппарат.

Annotation. Study of existing types of mowers currently in operation for forage alfalfa, analysis of excessive losses during the mowing process considering harvesting conditions, and scientific analysis of optimal harvesting unit variants.

Keywords: Livestock, alfalfa, mowing unit, technology, efficiency, operating speed, cutting height, sickle bar.

KIRISH.

Yem-xashak yig‘ish mashinalari sohasidagi ilmiy tadqiqotlar so‘nggi o‘n besh yil davomida keskin rivojlanib, qishloq xo‘jaligining ushbu muhim yo‘nalishida texnologik inqilob yuz berganligini ko‘rsatmoqda. Zamonaviy ozuqaviy yem-xashak yig‘ish mashinalari chorvachilik mahsulotlarining sifati va hosildorligiga bevosita ta’sir ko‘rsatib, hayvonlar ovqatlanishining asosiy manbalarini ta’minlashda hal qiluvchi ahamiyatga ega bo‘lib qoldi. Ferraretto, Shaver va Luck (2018) tadqiqotlariga ko‘ra, to‘g‘ri o‘rib-yig‘ish texnologiyalari qo‘llanilganda, silos ozuqasining hazm bo‘lish darajasi 15-20% ga oshishi

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mumkin, bu esa chorvachilikda sut mahsuldorligining oshishiga olib keladi. Borreani, Tabacco, Schmidt, Holmes va Muck (2018) tomonidan o‘tkazilgan keng qamrovli tadqiqotda quruq modda yo‘qotilishi va sifat pasayishining asosiy omillari o‘rganilgan bo‘lib, ular o‘rish, saqlash va fermentatsiya jarayonlarida yuzaga keladigan muammolarni batafsil tahlil qilganlar. Ushbu adabiyotlar sharhi 2010-2025-yillar oralig‘ida Web of Science va Scopus ma’lumotlar bazalarida nashr etilgan ilmiy maqolalar asosida yem-xashak yig‘ish mashinalari, ularning samaradorligi, texnologik innovatsiyalari va kelajak istiqbollarini kompleks tahlil qilishga bag‘ishlangan.

O‘z-o‘zidan yuradigan yem-xashak yig‘ish kombaynlari zamonaviy qishloq xo‘jaligida asosiy o‘rinni egallaydi va ularning texnik parametrlari doimiy takomillashtirilmoqda. Tian, Xia, Wang, Song, Yan, Li va Wang (2021) Xitoyda o‘tkazgan tajribalarida integral tizimli o‘z-o‘zidan yuradigan kombayni ishlab chiqilgan bo‘lib, u kesish, tekislash, maydalash va tashlash jarayonlarini birlashtirgan holda o‘rtacha 1,6 m/s tezlikda ishlash qobiliyatiga ega. Ushbu mashina beda uchun optimal kesish tezligi 2131 ayl/min, silos makkajo‘xori uchun esa 836 ayl/min ekanligini ko‘rsatdi. Amiama, Bueno va Alvarez (2008) Ispaniyada 163 ta dalada New Holland FX58 kombaynlarini o‘rganib, dala sig‘imi va hosil miqdori o‘rtasidagi kuchli korrelyatsiyani aniqlashdi. Abilzhanuly, Iskakov, Nurgozhayev va hamkasblar (2024) Qozog‘istonda kichik o‘lchamli yem-xashak kombayni uchun matematik model ishlab chiqib, poya yo‘naltirish moslamasi qo‘llanilganda 50 mm dan kichik zarralar ulushi 46,7% dan 79,3% ga oshganligini tasdiqlashdi.

Kesish mexanizmlari va maydalash texnologiyalari sohasida Lisowski, Świątek, Klonowski va hamkasblar (2012) Polshada o‘tkazgan tadqiqotida CFD simulyatsiya usulidan foydalanib, maydalangan materialning chiqarish quvuridagi harakatini tahlil qilishdi. O‘Dogherty (1982) ning tarixiy sharhi hamon muhim ahamiyatga ega bo‘lib, unda ko‘rsatilishicha, yem-xashak kombayni quvvatining 35% maydalashga, 50% esa materiallar va havoni tezlatishga sarflanadi. Chen, Xu, Wei va hamkasblar (2023) silos makkajo‘xori kombaynining oziqlantiruv va maydalash moslamasini optimallashtirish bo‘yicha tajribalarida, vintsimon ikki diskli oziqlantiruv moslamasini ishlab chiqdilar va nazariy hisoblar bilan tajriba natijalari orasidagi farq 5% dan kam ekanligini isbotladilar.

O‘roq va konditsioner mashinalari sohasida Greenlees, Hanna, Shinners, Marley va Bailey (2000) to‘rtta mower-konditsioner turini qiyoslab o‘rganib, barg yo‘qotilishi quruq moddaning 5,2-5,9% ni tashkil etganligini, impeller mashinalari esa rolikli konditsionerlarga nisbatan 23-63% tezroq quritish imkonini berganligini aniqlashdi. Borreani va Tabacco (2006) tadqiqotida po‘lat bolg‘ali konditsioner

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beda va italyan raigrasi uchun rezina rolikli konditsionerga nisbatan tezroq quritish ta'minlaganligini ko‘rsatdi. Shinners, Wuest va Cudoc (2006) intensiv konditsionerlash usullarini o‘rganib, bu texnologiyaning quritish tezligini 25-150% ga oshirishi mumkinligini, lekin quvvat sarfi oddiy mower-konditsionernikidan kamida ikki barobar ko‘p ekanligini qayd etdilar.

Press-yig‘uvchilar va silos uskunalari bo‘yicha ilmiy tadqiqotlar ham sezilarli yutuqlarga erishdi. Fasick va Liu (2020) ning hisob-kitoblariga ko‘ra, dumaloq press-yig‘uvchilarning o‘tkazuvchanlik qobiliyati katta to‘rtburchak press-yig‘uvchilarnikiga nisbatan 50% kam bo‘lib (32,7 Mg/soat ga nisbatan 71,0 Mg/soat), o‘rash va chiqarish vaqti samaradorlikka sezilarli ta'sir ko‘rsatadi. Shinners va Friede (2018) katta to‘rtburchak press-yig‘uvchilarda nam asosida zichlik 240 $kg \cdot m^{-3}$ atrofida bo‘lishi kerakligini ko‘rsatib, energiya sarfi bala zichligi bilan eksponensial bog‘liq ekanligini isbotladilar. Zhang, Zhang, Ma, Wang va Su (2024) roliklar joylashuvining biomassa balalarining sifati va press-yig‘ish energiya sarfiga ta'sirini o‘rganib, 30 mm qadam qiymatida maksimal press-yig‘ish bosimi, radial bosim uzatilishi yo‘qotilishi va energiya sarfi mos ravishda 30,4%, 33,4% va 13,7% ga kamayganligini aniqlashdi.

Bala zichligi monitoringi sohasida Zawada, Nijak, Mac va hamkasblar (2023) kuch sensorlari asosida zichlikni nazorat qilish tizimini ishlab chiqdilar, bunda bala og‘irligi variatsiya koeffitsienti 8,4%, zichlik variatsiya koeffitsienti esa 20,2% ni tashkil etdi. Yin, Chen, Liu, Zhou va Liu (2023) dinamik tortishga asoslanangan real vaqtda bala zichligi monitoringi tizimini loyihalashtirib, statik rejimda maksimal nisbiy xato 0,38%, dinamik rejimda esa -4,40-4,30% oralig‘ida ekanligini ko‘rsatdilar. Ushbu texnologiyalar yem-xashak sifatini dastlabki bosqichlardan nazorat qilish imkonini beradi.

O‘rash texnologiyalari va plastik plyonka innovatsiyalari ham muhim tadqiqot yo‘nalishiga aylandi. Bisaglia, Tabacco va Borreani (2011) to‘r o‘rniga plastik plyonka bilan bog‘lash tizimini o‘rganib, ish tezligi bog‘lash usuliga bog‘liq emasligini, lekin plyonka bilan bog‘lash bala egri yuzasining havosizligini yaxshilaganligini aniqlashdi. Shinners, Huenink, Muck va Albrecht (2009) to‘r o‘rash soatiga 32% ko‘proq bala o‘rash imkonini berishini va quruq modda yo‘qotilishini 2,9% dan 1,0% ga kamaytirishini ko‘rsatdilar. Li va hamkasblar (2018) dumaloq guruch somon balalarini o‘rash silos texnologiyasini o‘rganib, optimal o‘rash parametrlarini aniqlashdi: aylanuvchi tezlik 31-32 ayl/min, minimal 5 qavat cho‘ziluvchi plyonka tavsiya etildi.

Ozuqa sifatini saqlash va oziq moddalarni saqlash tadqiqotlari chorvachilik uchun muhim ahamiyatga ega. Capstaff va Miller (2018) ning umumiy sharhida oqsillar va suvda eruvchan uglevodlar (WSC) chorva mollari uchun eng muhim

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oziq moddalar ekanligi ta’kidlanib, o‘rishdan keyingi sifatni saqlashning muhimligi qayd etildi. Kung, Shaver, Grant va Schmidt (2018) silos qo‘shimchalarini o‘rganib, gomolaktik sut kislotasi bakteriyalari (LAB) pH ni tezda pasaytirib, sut kislotasini oshirishini, *Lactobacillus buchneri* esa aerob barqarorlikni yaxshilashini ko‘rsatdilar. Khan, Khan, Tang va Tan (2023) tropik sharoitlarda makkajo‘xori silosini optimallashtirishni o‘rganib, 3 kun ichida barqaror pH (<4,2) erishilishi mumkinligini isbotladilar.

Saqlash sifati va saqlash usullari bo‘yicha Gebrehanna va hamkasblar (2016) Keniyada olti turdagi yaylov o‘tlarini 1, 2 va 3 kunlik quritish davrlari bilan o‘rganib, namlik 15% dan past bo‘lganda xom oqsilda sezilarli farq yo‘qligini ko‘rsatdilar. Müller (2012) turli o‘rim-yig‘im, saqlash usullari har xil kimyoviy va mikrobial tarkibli ozuqalarni hosil qilishini ta’kidlab, saqlash strategiyalari buzilganda zaharli o‘simliklar va toksinklar xavfini muhokama qildi. Bernardes va hamkasblar (2024) etti yillik ma'lumotlar to‘plamini tahlil qilib, mavsumiylik silos sifatiga sezilarli ta'sir ko‘rsatishini, zichlash fermentatsiya sifatini saqlash uchun muhim ekanligini isbotladilar.

Avtomatlashtirish va aniq dehqonchilik texnologiyalari yem-xashak yig‘ishda tub o‘zgarishlar olib kelmoqda. Ali va Kaul (2025) ning keng qamrovli sharhida massa oqimi sensorlari, ta'sir sensorlari, namlik sensorlari, NIR spektroskopiyasi, masofaviy o‘lchash yondashuvlari va qarorlarni qo‘llab-quvvatlash tizimlari (DSS) muhokama qilindi. Borsato, Martello, Marinello va Bortolini (2024) yem-xashak ekinlari uchun hosil baholash usullarini ko‘rib chiqib, o‘z-o‘zidan yuradigan yem-xashak kombayinlari real vaqtda hosil baholash uchun eng ko‘p e'tibor olganligini qayd etdilar.

GPS yo‘naltirish va navigatsiya tizimlari sohasida Stoll va Kutzbach (2000) ning asosiy tadqiqotida yem-xashak kombaynlari uchun GPS asosidagi avtomatik boshqaruvni ishlab chiqib, dala sharoitlarining barchasida haydash standart og‘ishini 100 mm dan past ekanligini ko‘rsatdilar. Mwitta va Rains (2024) GPS yo‘naltirishini chuqur o‘rganish modeli bilan birlashtirgan qishloq xo‘jaligi robotini sinovdan o‘tkazib, o‘rtacha lateral xato 9,5 sm erishganligini qayd etdilar. Wang, Liu, Zhu va hamkasblar (2023) qishloq xo‘jaligi mashinalari uchun avtomatik navigatsiya texnologiyalarini sharhlashda GNSS va mashina ko‘rishni birlashtirgan yondashuv avtonom yo‘l rejalashtirishda eng muvaffaqiyatli ekanligini aniqlashdi.

NIR sensorlari ozuqa sifatini o‘lchash uchun muhim vosita bo‘lib qoldi. Digman va Shinners (2008) ning muhim tadqiqotida o‘z-o‘zidan yuradigan yem-xashak kombayni quvuriga mobil NIR spektrometri (950-1680 nm) o‘rnatildi va butun o‘simlik makkajo‘xori silosining namligi uchun diagnostikalash modellari

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ishlab chiqildi, statik ma'lumotlar uchun RMSECV 1,12%, dinamik ma'lumotlar uchun 3,28% ni tashkil etdi. Bu tadqiqot John Deere HarvestLab sensorining asosini tashkil etdi. Yamada, Cherney, Cherney, Runge va Digman (2024) portativ NIRS qurilmalarini (NeoSpectra, TrinamiX, AgroCares) 111 ta fermada quritilmagan namunalarda ozuqa sifatini baholash uchun sinovdan o‘tkazdilar. Hart, Burns, McGee, Nolan va O‘Riordan (2021) portativ NIR asboblarini (AuroraNir, NIR4, SCiO) va HarvestLab 3000 ni 600 dan ortiq namunada 19 ta sut fermasida sinovdan o‘tkazdilar.

Hosil monitoringi va massa oqimi sensorlari sohasida Shinners, Huenink va Behringer (2003) o‘z-o‘zidan yuradigan kombayinlarda sensor tizimlarini muvaffaqiyatli joriy etib, hosil xaritasini tuzish uchun oziqlantiruv ruloni siljishi, ta'sir plastinkalari, moment o‘lchagichlar va yuk kameraları kabi tizimlarni ishlab chiqdilar, dinamik bala og‘irligi usuli R^2=0,99 bashorat aniqligiga erishdi. Kumhála, Prošek va Blahovec (2007) o‘t hosil o‘lchash sensorlarini ishlab chiqib, konditsioner quvvat kirishi, ta'sir kuchi va material oqimi tezligi o‘rtasida R^2=0,95 korrelyatsiyaga erishdilar. Kumhála, Kvíz va Prošek (2010) yem-xashak kombayinlari uchun sig‘imli o‘tkazuvchanlik sensorini ishlab chiqib, makkajo‘xori o‘tkazuvchanligi o‘lchovi uchun R^2=0,99 korrelyatsiya koeffitsientiga erishdilar.

IoT va aqlli fermerchilik ilovalari jadal rivojlanmoqda. Ayaz, Ammad-Uddin, Sharif, Mansour va Aggoune (2019) qishloq xo‘jaligida IoT qurilmalari va simsiz sensorlarni keng ko‘rib chiqib, GPS va GIS integratsiyasini joylashuvga asoslangan boshqaruv va avtonom o‘rim-yig‘im operatsiyalari uchun muhokama qildilar. Talaviya, Shah, Patel, Yagnik va Shah (2020) 159 ta IoT qishloq xo‘jaligi maqolasini tizimli ko‘rib chiqib, aqlli fermerchilik uchun apparat platformalari, tarmoq protokollari va texnologiyalarni aniqlashdi. Farooq, Riaz, Abid, Umer va Zikria (2022) aqlli sug‘orish, ekinlarni monitoring qilish, o‘rim-yig‘imni avtomatlashtirish va hosil bashoratida IoT integratsiyasini ko‘rib chiqdilar.

Avtonom va robototexnik yig‘ish tizimlari istiqbolli yo‘nalish sifatida o‘rganilmoqda. Fountas, Mylonas, Malounas va hamkasblar (2023) ning keng qamrovli sharhida ko‘rish tizimlari, harakat rejalashtirish/navigatsiya, odam-robot o‘zaro ta'siri, ushlash strategiyalari va oxirgi effektor dizayni ko‘rib chiqildi. Shamshiri, Weltzien, Hameed va hamkasblar (2018) avtonom begona o‘tlar nazorati, dala razvedkasi va o‘rim-yig‘im robotlarini ko‘rib chiqib, ko‘p robotlar hamkorligi va raqamli fermerchilik ilovalarini muhokama qildilar. Rajendran, Yuen, Maul va Khaw (2024) selektiv o‘rim-yig‘im robotlarini, shu jumladan idrok tizimlari, ushlash mexanizmlari, harakat rejalashtirish va nazorat strategiyalarini ko‘rib chiqdilar.

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Mexanizatsiya samaradorligi va energiya sarfini optimallashtirish sohasida Xue, Fu, Fu, Li va Chen (2023) yashil yem-xashak makkajo‘xori kombaynining boshli qismini modellashtirish va optimallashtirish bo‘yicha RSM-ANN modelini ishlab chiqdilar, bu model solishtirma energiya sarfini bashorat qilish uchun R^2=0,9925 ga erishdi. Lisowski, Klonowski, Sypula va hamkasblar (2019) kesish quvvati ulushi yem-xashak kombaynining umumiy quvvat talabining taxminan 50% ini tashkil etishini, eng past kesish qarshiligi optimal biomassa namligi 65-70% (nam asosida) da erishilishini ko‘rsatdilar. Quruq modda uchun solishtirma energiya barabanli agregatlar uchun 2-4 kJ/kg, turli kesish agregatlar uchun 1,25-15,6 kJ/kg ni tashkil etdi.

Iqtisodiy samaradorlik tadqiqotlarida Gebiso, Ketema, Shumetie va Feye (2024) Efiopiyada qishloq xo‘jaligi mexanizatsiyasining bug‘doy mahsuldorligi va iqtisodiy samaradorlikka sezilarli ijobiy ta'sirini ko‘rsatdilar. Yan, Sun, Chen va Dai (2024) Xitoyda qishloq xo‘jaligi mexanizatsiyasi va atrof-muhit samaradorligi o‘rtasidagi "U-shaklidagi" munosabatni aniqlashdi, Xitoyning kompleks mexanizatsiya darajasi 2010 yilda 52,3% dan 2021 yilda 72,0% ga oshganligini qayd etdilar.

Xitoy tadqiqotchilarining hissasi muhim ahamiyatga ega bo‘lib, Yang, Cui, Qu va hamkasblar (2016) makkajo‘xori kombayinlarining to‘rt turini tasniflashdi: yig‘uvchilar, don kombayinlari, yem-xashak kombayinlari va kombinatsiyalangan don-somon kombayinlari. Kelgusi tendentsiyalar sifatida yuqori quvvatli dvigatellar, oshirilgan samaradorlik, avtomatlashtirish va aql-idrok tizimlarini ko‘rsatdilar. Jia, Zhang va Ding (2022) Xubey provinsiyasida qishloq xo‘jaligi mexanizatsiyasining ishlab chiqarish va daromadga ta'sirini o‘rganib, mexanik aniq ekish urug‘larni tejashini va xarajatlarni kamaytirishini aniqlashdi.

Germaniya qishloq xo‘jaligi muhandisligi innovatsiyalari ham diqqatga sazovordir. AgriLight loyihasi doirasida (2022-2024) tolali kompozit shassi dizayni ishlab chiqildi, bu og‘irlikni 50% ga kamaytirish va ayni paytda ramning buralish bikrligini oshirish imkonini beradi. Bu yo‘l harakati qoidalari, tuproq zichlanishi va yoqilg‘i sarfi muammolarini hal qilishga qaratilgan. Ehlert (2002) yem-xashak kombayinlarida o‘tkazuvchanlikni aniq o‘lchash uchun universal qo‘llaniladigan algoritmni ishlab chiqdi.

Rossiya va Markaziy Osiyo tadqiqotlari ham muhim ahamiyatga ega. Rossiya tadqiqotchilarining silos ishlab chiqarish xarajatlarini 5% gacha kamaytiradigan statistik modellar ishlab chiqganligi qayd etilgan. Qozog‘istonning qishloq xo‘jaligi rivojlanishi kontekstida mashinalarning 90% ga yaqini foydalanish muddati oxirida ekanligi, traktorlarning 94% i va kombayinlarning

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77% si 10 yildan oshganligi ko‘rsatilgan. Hukumat qishloq xo‘jaligi uskunalari importining 25% ini subsidiyalaydi.

Mehnat unumdorligi tadqiqotlarida Hamilton va hamkasblar (2022) mexanik vositalarning ba'zi qishloq xo‘jaligi sharoitlarida mehnatni to‘ldirishini, kapital va mehnat o‘rnini bosuvchilar bo‘lganda fermerlarning "haddan tashqari mexanizatsiyalashuvi" mumkinligini ko‘rsatdilar. USDA ERS (2024) ma'lumotlariga ko‘ra, global ferma mehnati 2003 yilda 1 milliard kishida cho‘qqiga chiqqan bo‘lsa, 2020 yilga kelib 841 million kishiga tushdi.

Kelajak tendentsiyalari va texnologik rivojlanish istiqbollari bo‘yicha Hay and Forage Grower (2025) sun'iy intellektning yem-xashak yig‘ishda kelajagi borligini ta'kidlaydi. O‘z-o‘zidan yuradigan yem-xashak kombaynlari namlik sensorlari bilan jihozlangan bo‘lib, namlik ma'lumotlariga asoslangan avtomatlashtirilgan kesish uzunligini sozlash amalga oshirilmoqda. Sun'iy intellekt chuqur o‘rganish modellari ozuqa hosili va sifatini bashorat qilish uchun qo‘llanilmoqda. FAO (2022) ning xalqaro sharhida mexanizatsiya mehnat unumdorligini oshirishi, qashshoqlikni kamaytirishi va oziq-ovqat xavfsizligini yaxshilashi, lekin ishsizlik ta'sirlari, biodiversitetning yo‘qolishi va yerning degradatsiyasi kabi muammolar ham mavjudligi ta'kidlandi.

Ilmiy tadqiqotlarda aniqlangan kamchiliklar quyidagilarni o‘z ichiga oladi: saqlash davrida pichan mikrobiomasining dinamikasi bo‘yicha cheklangan tadqiqotlar; yem-xashak yig‘ishda aniq dehqonchilik ilovalarini qo‘llash bo‘yicha ko‘proq tadqiqotlar zarurligi; bir nechta yig‘ish texnologiyalarining birgalikdagi ta'siri haqida yetarli ma'lumotlar yo‘qligi; va iqlim o‘zgarishi sharoitida ozuqa sifati bo‘yicha cheklangan tadqiqotlar. Bundan tashqari, rossiyalik tadqiqotchilarning ingliz tilidagi nashrlarining kamligi, standartlashtirilgan ko‘rsatkichlar bilan mamlakatlararo qiyosiy tadqiqotlarning yetishmasligi va kichik xo‘jaliklarda yem-xashak mexanizatsiyasi bo‘yicha kam tadqiqotlar mavjudligi kuzatildi.

XULOSA

2010-2025 yillar oralig‘ida yem-xashak yig‘ish mashinalari sohasida sezilarli ilmiy yutuqlar qo‘lga kiritildi. GPS asosidagi yo‘naltirish tizimlari 100 mm dan kam standart og‘ish bilan ishlash, NIR sensorlari R^2=0,987 aniqlikda quruq modda va ozuqa sifatini o‘lchash, IoT tizimlari real vaqtda monitoring va qarorlarni qo‘llab-quvvatlash imkoniyatlarini taqdim etdi. Energiya sarfini optimallashtirish, avtomatlashtirish, robototexnika va sun'iy intellekt kelajakda yem-xashak yig‘ish mashinalari rivojlanishining asosiy yo‘nalishlarini tashkil etadi. Chorvachilik uchun ozuqaviy yem-xashak yig‘ish mashinalarining ilmiy asoslangan rivojlanishi chorva mollari oziqlanishining sifati va samaradorligini oshirishda, qishloq

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xo‘jaligi iqtisodiyotini mustahkamlashda va barqaror qishloq xo‘jaligi amaliyotlarini joriy etishda muhim ahamiyatga ega bo‘lib qolmoqda.

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NEVROLOGIK TERMINLARNING STRUKTUR-SEMANTIK XUSUSIYATLARI

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Annotatsiya. Nevrologik terminologiya tibbiyot fanining muhim tarkibiy qismi bo‘lib, u markaziy va periferik asab tizimi bilan bog‘liq tushunchalarni ifodalashda xizmat qiladi. Ushbu maqolada nevrologik terminlarning struktur-semantik xususiyatlari, ularning morfologik tuzilishi hamda klinik amaliyotdagi ahamiyati tahlil qilinadi. Tadqiqot natijalari shuni ko‘rsatadiki, nevrologik terminlar asosan lotin va yunon tiliga mansub prefiks, ildiz va suffikslar asosida shakllanib, ularning ma’nosi termin tarkibiy qismlarining kombinatsiyasi orqali aniqlanadi. Struktur va semantik tahlil terminlarni to‘g‘ri tushunish va qo‘llashda muhim ahamiyatga ega.

Kalit so‘zlar: nevrologik terminlar, struktur tahlil, semantika, prefiks, suffiks, tibbiy terminologiya, asab tizimi.

Аннотация. Неврологическая терминология является важной составной частью медицинской науки и служит для обозначения понятий, связанных с центральной и периферической нервной системой. В данной статье анализируются структурно-семантические особенности неврологических терминов, их морфологическое строение, а также значение в клинической практике. Результаты исследования показали, что неврологические термины в основном формируются на основе латинских и греческих префиксов, корней и суффиксов, а их значение определяется комбинацией структурных элементов. Структурный и семантический анализ играет важную роль в правильном понимании и использовании терминов.

Ключевые слова: неврологические термины, структурный анализ, семантика, префикс, суффикс, медицинская терминология, нервная система.

Abstract. Neurological terminology is an essential component of medical science and serves to describe concepts related to the central and peripheral nervous systems. This article analyzes the structural and semantic features of neurological terms, their morphological structure, and their significance in clinical practice. The results of the study show that neurological terms are mainly formed based on Latin and Greek prefixes, roots, and suffixes, and their meanings are determined by the

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combination of structural components. Structural and semantic analysis plays an important role in the correct understanding and application of terms.

Keywords: neurological terms, structural analysis, semantics, prefix, suffix, medical terminology, nervous system.

KIRISH.

Tibbiy terminologiya tizimi turli klinik va nazariy yo‘nalishlarni qamrab olgan murakkab, ko‘p qatlamli va tizimli tuzilishga ega bo‘lib, u ilmiy bilimlarni aniq va standartlashtirilgan tarzda ifodalashda muhim vosita hisoblanadi. Ushbu tizim doirasida nevrologik terminologiya alohida o‘rin tutadi, chunki u inson organizmining eng murakkab va nozik tizimlaridan biri bo‘lgan markaziy va periferik asab tizimini ifodalashga xizmat qiladi. Asab tizimi bilan bog‘liq kasalliklar, funksional buzilishlar va fiziologik jarayonlarni to‘g‘ri tavsiflash uchun aniq va ixcham terminologiyadan foydalanish zarur.

Nevrologik terminlar klinik amaliyotda tashxis qo‘yish, kasalliklarni tasniflash, davolash strategiyasini belgilash hamda ilmiy tadqiqotlar olib borishda muhim kommunikativ vosita sifatida xizmat qiladi. Ushbu terminlar yordamida shifokorlar turli klinik holatlarni qisqa va aniq ifodalash imkoniyatiga ega bo‘ladilar. Shu sababli nevrologik terminologiyani to‘g‘ri tushunish va qo‘llash tibbiyot mutaxassislari uchun muhim kasbiy kompetensiya hisoblanadi.

Nevrologik terminlarning aksariyati tarixan lotin va yunon tillariga asoslangan bo‘lib, ular prefiks, ildiz va suffikslarning kombinatsiyasi orqali hosil qilinadi. Masalan, “neuro-” (asab), “-logia” (fan), “-itis” (yallig‘lanish), “-algia” (og‘riq) kabi elementlar terminlarning asosiy tarkibiy qismlarini tashkil etadi. Bu esa terminlarning struktur-semantik murakkabligini belgilab, ularni chuqur lingvistik tahlil qilish zaruratini yuzaga keltiradi. Terminlarning ichki tuzilishini anglash orqali ularning ma’nosini osonroq tushunish va amaliyotda to‘g‘ri qo‘llash imkoniyati yaratiladi.

Biroq nevrologik terminlarning murakkabligi, ularning ko‘p komponentli tuzilishi va ko‘pligi talabalar uchun ularni o‘zlashtirish jarayonini qiyinlashtiradi. Ko‘pincha terminlar mexanik ravishda yodlanadi, bu esa ularning mazmunini chuqur anglashga to‘sqinlik qiladi. Shu sababli struktur va semantik tahlil metodlarini qo‘llash tibbiy ta’limda muhim metodik yondashuv sifatida qaraladi.

Zamonaviy tibbiyotda nevrologik terminologiyaning standartlashuvi ham alohida ahamiyatga ega. Xalqaro tasnif tizimlari va ilmiy terminologik me’yorlar terminlarning yagona shaklda qo‘llanilishini ta’minlaydi. Bu esa turli mamlakatlar mutaxassislari o‘rtasida samarali ilmiy va klinik muloqotni ta’minlashga xizmat qiladi.

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Shu nuqtai nazardan, nevrologik terminlarning struktur va semantik xususiyatlarini ilmiy asosda o‘rganish dolzarb masala hisoblanadi. Mazkur tadqiqotning asosiy maqsadi — nevrologik terminlarning morfologik tuzilishi, ularning semantik mazmuni va klinik amaliyotdagi ahamiyatini tahlil qilish hamda ularni o‘qitish jarayonida samarali qo‘llash imkoniyatlarini aniqlashdan iborat.

MATERIALLAR VA METODLAR

Mazkur tadqiqot nevrologik terminologiyaning struktur va semantik xususiyatlarini aniqlashga qaratilgan bo‘lib, unda tibbiy terminologiya, nevrologiya va lingvistika sohalariga oid zamonaviy hamda klassik ilmiy adabiyotlar tizimli ravishda o‘rganildi. Tadqiqot jarayonida turli manbalar asosida nevrologik terminlarning shakllanishi, ularning morfologik tuzilishi va semantik mazmuni kompleks tarzda tahlil qilindi.

Tadqiqotning nazariy asosini tibbiy terminologiya, klinik nevrologiya va ilmiy lingvistika bo‘yicha chop etilgan darsliklar, ilmiy maqolalar, xalqaro terminologik lug‘atlar hamda elektron ilmiy ma’lumotlar bazalaridan olingan materiallar tashkil etdi. Xususan, nevrologik terminlarning tarkibiy qismlari — prefiks, ildiz va suffikslarning funksional roli hamda ularning o‘zaro kombinatsiyasi asosida hosil bo‘ladigan ma’nolar o‘rganildi.

Tadqiqotda quyidagi ilmiy metodlardan foydalanildi:

Ilmiy adabiyotlarni tahlil qilish metodi – nevrologik terminologiyaga oid mavjud ilmiy manbalarni o‘rganish va umumlashtirish orqali nazariy asos yaratildi;

Morfologik tahlil metodi – terminlarning tuzilishini tashkil etuvchi prefiks, ildiz va suffikslar ajratilib, ularning grammatik va funksional xususiyatlari aniqlab berildi;

Semantik tahlil metodi – terminlarning ma’nosi, ularning klinik mazmuni hamda lingvistik xususiyatlari tahlil qilindi;

Qiyosiy metod – turli terminlar o‘rtasidagi o‘xshash va farqli jihatlar aniqlanib, ularning shakllanish tamoyillari solishtirildi;

Tavsifiy metod – tadqiqot natijalari izchil tarzda bayon qilinib, terminlarning umumiy xususiyatlari tavsiflab berildi.

Tadqiqot materiali sifatida nevrologik terminlar lug‘atlari, klinik nevrologiya darsliklari, xalqaro tibbiy terminologiya manbalari hamda ilmiy maqolalar tanlab olindi. Ushbu manbalar asosida keng tarqalgan va amaliyotda faol qo‘llaniladigan nevrologik terminlar saralab olinib, ularning struktur-semantik tahlili amalga oshirildi.

NATIJALAR

O‘tkazilgan tadqiqot natijalari nevrologik terminlarning struktur va semantik jihatdan murakkab hamda tizimli xususiyatlarga ega ekanligini ko‘rsatdi. Tahlillar

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asosida ushbu terminlarning shakllanishi, mazmuni va amaliy qo‘llanilishi bilan bog‘liq bir qator muhim xulosalar aniqlandi.

1. Morfologik tuzilish

Nevrologik terminlar asosan uch asosiy morfemik komponent — prefiks, ildiz va suffikslardan tashkil topadi. Ushbu elementlarning har biri terminning umumiy ma’nosini shakllantirishda muhim rol o‘ynaydi.

Masalan:

neuro- (asab tizimi bilan bog‘liq)

-itis (yallig‘lanish jarayoni)

-algia (og‘riq holati)

Shu asosda hosil bo‘lgan terminlar:

neuritis — asabning yallig‘lanishi

neuralgia — asab og‘rig‘i

Tahlillar shuni ko‘rsatdiki, nevrologik terminlarning aksariyati morfologik jihatdan shaffof bo‘lib, ularning tarkibiy qismlarini ajratish orqali umumiy ma’noni aniqlash mumkin. Bu esa terminlarni o‘rganish jarayonini sezilarli darajada yengillashtiradi.

2. Semantik aniqlik

Nevrologik terminlar yuqori darajadagi semantik aniqlik bilan ajralib turadi. Har bir termin muayyan klinik tushunchani ifodalab, uning ma’nosi termin tarkibidagi komponentlar orqali aniq belgilanadi.

Masalan:

encephalitis — miya yallig‘lanishi (encephalon – miya, -itis – yallig‘lanish)

polyneuropathy — ko‘p asab tolalarining zararlanishi (poly- – ko‘p, neuro – asab, -pathy – kasallik)

Bu holat terminlarning ilmiy aniqligini ta’minlab, ularni diagnostika va klinik amaliyotda samarali qo‘llash imkonini beradi.

3. Klinik yo‘naltirilganlik

Nevrologik terminlar bevosita klinik amaliyot bilan bog‘liq bo‘lib, ular kasalliklar, simptomlar va patologik jarayonlarni aniq ifodalashga xizmat qiladi.

Masalan:

neuropathy — asab tizimi kasalligi

encephalitis — miya yallig‘lanishi

myelopathy — orqa miya patologiyasi

Tadqiqot natijalari shuni ko‘rsatdiki, ushbu terminlar shifokorlar o‘rtasidagi muloqotni soddalashtiradi va diagnostika jarayonida aniqlikni oshiradi. Terminlarning qisqa va mazmunli bo‘lishi klinik axborotni tez yetkazish imkonini beradi.

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4. Xalqaro standartlashuv

Nevrologik terminlarning muhim xususiyatlaridan biri ularning xalqaro miqyosda standartlashganligidir. Lotin va yunon tillariga asoslangan terminlar turli mamlakatlarda bir xil ma’noda qo‘llaniladi.

Bu holat quyidagi afzalliklarni ta’minlaydi:

xalqaro ilmiy muloqotni yengillashtiradi;

diagnostika va davolash jarayonida tushunmovchiliklarning oldini oladi;

tibbiy hujjatlarning yagona standart asosida yuritilishiga xizmat qiladi.

Shuningdek, xalqaro tasnif tizimlari (masalan, ICD) nevrologik terminlarning yagona shaklda qo‘llanilishini ta’minlaydi.

5. Terminlarning tizimliligi va o‘zaro bog‘liqligi

Tahlillar shuni ko‘rsatdiki, nevrologik terminlar alohida-alohida emas, balki o‘zaro bog‘langan tizimni tashkil etadi. Bir xil ildizga ega terminlar turli suffikslar orqali turli ma’nolarni ifodalaydi:

neuron — asab hujayrasi

neurology — asab tizimi haqidagi fan

neuropathy — asab kasalligi

Bu tizimlilik terminologiyani mantiqiy va izchil qiladi hamda uni o‘rganishni osonlashtiradi.

6. O‘quv jarayonidagi ahamiyati

Natijalar shuni ko‘rsatdiki, nevrologik terminlarning struktur-semantik tahlili ularni o‘rganishda samarali metod hisoblanadi. Terminlarni tarkibiy qismlarga ajratib o‘rganish:

ularni tezroq o‘zlashtirishga yordam beradi;

xotirada uzoq muddat saqlanishini ta’minlaydi;

klinik fikrlashni rivojlantiradi.

Umuman olganda, tadqiqot natijalari nevrologik terminlarning yuqori darajada tizimlashgan, semantik jihatdan aniq va klinik jihatdan muhim ekanligini tasdiqladi.

MUHOKAMA.

Nevrologik terminlarning struktur-semantik tahlili tibbiy terminologiya tizimining murakkab, ko‘p bosqichli va yuqori darajada tizimlashgan ekanligini yaqqol namoyon etadi. Ushbu terminlar asosan lotin va yunon tiliga mansub lingvistik elementlardan tashkil topgan bo‘lib, ularning o‘zaro kombinatsiyasi orqali aniq, ixcham va ilmiy jihatdan asoslangan tushunchalar ifodalanadi. Bu esa nevrologik terminologiyaning nafaqat aniqligini, balki uning xalqaro miqyosda universalligini ham ta’minlaydi.

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Nevrologik terminlarning muhim xususiyatlaridan biri — ularning morfologik shaffofligi hisoblanadi. Termin tarkibidagi prefiks, ildiz va suffikslarni tahlil qilish orqali uning semantik mazmunini aniqlash mumkinligi terminologiyani o‘rganishda muhim metodik ustunlik beradi. Masalan, “neuropathy” termini “neuro” (asab) va “pathy” (kasallik) komponentlaridan iborat bo‘lib, asab tizimi bilan bog‘liq kasallikni bildiradi. Xuddi shuningdek, “encephalopathy” (encephalon — miya, -pathy — kasallik) yoki “polyneuropathy” (poly- — ko‘p, neuro — asab, -pathy — kasallik) kabi terminlar ham o‘z tuzilishi orqali ma’nosini ochib beradi. Bu holat talabalar va mutaxassislar uchun terminlarni mantiqiy asosda tushunish imkonini yaratadi.

Shu bilan birga, nevrologik terminlar yuqori darajada semantik aniqlik bilan ajralib turadi. Har bir termin muayyan klinik holatni, patologik jarayonni yoki anatomik tuzilmani aniq ifodalaydi. Bu esa diagnostika jarayonida xatoliklarni kamaytirish va klinik qaror qabul qilishda aniqlikni oshirishga xizmat qiladi. Terminlarning semantik aniqligi ayniqsa nevrologiya sohasida muhim, chunki asab tizimi kasalliklari ko‘pincha murakkab va ko‘p omilli bo‘ladi.

Biroq nevrologik terminlarning murakkabligi ularni o‘rganishda muayyan qiyinchiliklarni ham yuzaga keltiradi. Ko‘p komponentli va uzun terminlar, ayniqsa yangi boshlovchi talabalar uchun qiyin bo‘lishi mumkin. Ba’zan bir termin tarkibida bir nechta prefiks va suffikslarning mavjudligi uning ma’nosini darhol anglashni qiyinlashtiradi. Shu sababli terminlarni o‘rganishda ularni tarkibiy qismlarga ajratib tahlil qilish, ya’ni struktur va semantik yondashuvdan foydalanish muhim metodik vosita hisoblanadi.

Nevrologik terminologiyaning yana bir muhim jihati — uning tizimliligi va izchilligidir. Bir xil ildiz asosida turli suffikslar yordamida hosil qilingan terminlar o‘zaro bog‘liq tushunchalarni ifodalaydi. Masalan, “neuron”, “neurology”, “neuropathy”, “neuritis” kabi terminlar yagona semantik maydonga tegishli bo‘lib, bu terminologik tizimning ichki mantiqiy bog‘liqligini ta’minlaydi. Ushbu tizimlilik terminologiyani o‘rganishda muhim ahamiyat kasb etadi, chunki u bilimlarni tizimli ravishda shakllantirishga yordam beradi.

Zamonaviy tibbiyotda nevrologik terminlarning standartlashuvi alohida ahamiyatga ega. Xalqaro tasnif tizimlari, jumladan ICD (International Classification of Diseases), terminlarning yagona shaklda qo‘llanilishini ta’minlaydi. Bu esa turli mamlakatlar mutaxassislari o‘rtasida samarali ilmiy va klinik muloqotni ta’minlashga xizmat qiladi. Standartlashtirilgan terminologiya tibbiy hujjatlarni yuritishda, ilmiy maqolalar yozishda va klinik ma’lumotlarni almashishda muhim rol o‘ynaydi.

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Bundan tashqari, nevrologik terminologiyaning rivojlanishi zamonaviy ilm-fan taraqqiyoti bilan chambarchas bog‘liq. Yangi diagnostik usullar, neyrotexnologiyalar va ilmiy kashfiyotlar natijasida yangi terminlar paydo bo‘lmoqda yoki mavjud terminlarning ma’nosi kengaymoqda. Bu esa terminologiyaning dinamik tizim ekanligini ko‘rsatadi.

Pedagogik nuqtai nazardan qaraganda, nevrologik terminlarning struktur-semantik tahlili tibbiy ta’limda muhim didaktik vosita hisoblanadi. Ushbu yondashuv orqali talabalar terminlarni mexanik yodlashdan ko‘ra ularni anglab o‘zlashtirishga o‘tadilar. Bu esa ularning klinik fikrlashini rivojlantiradi, bilimlarni uzoq muddat saqlashga yordam beradi va amaliyotda terminlardan to‘g‘ri foydalanish ko‘nikmasini shakllantiradi.

Umuman olganda, nevrologik terminlarning struktur-semantik xususiyatlari ularning ilmiy aniqligi, mantiqiy izchilligi va amaliy ahamiyatini belgilaydi. Ushbu terminologiyani chuqur o‘rganish nafaqat lingvistik, balki klinik jihatdan ham muhim bo‘lib, u tibbiyot mutaxassislarining kasbiy kompetensiyasini oshirishga xizmat qiladi.

XULOSA.

Nevrologik terminlarning struktur-semantik xususiyatlari ularning ilmiy va amaliy ahamiyatini belgilovchi asosiy omillardan biri hisoblanadi. Ushbu terminlar asosan lotin va yunon tillariga mansub lingvistik elementlar — prefiks, ildiz va suffikslar asosida shakllanib, ularning o‘zaro uyg‘unligi orqali aniq va tizimli ilmiy tushunchalar ifodalanadi. Terminlarning tuzilishi va ma’nosi o‘rtasidagi uzviy bog‘liqlik esa ularni nafaqat lingvistik, balki klinik jihatdan ham muhim vositaga aylantiradi.

Tadqiqot natijalari shuni ko‘rsatdiki, nevrologik terminlarning struktur va semantik tahlili ularni chuqur anglash, to‘g‘ri talqin qilish va amaliyotda samarali qo‘llash imkonini beradi. Ayniqsa, terminlarning morfologik tarkibini tahlil qilish orqali ularning mazmunini tez va aniq tushunish mumkinligi tibbiy ta’lim jarayonida muhim metodik yondashuv sifatida namoyon bo‘ladi. Bu esa talabalar bilimini mustahkamlash, ularning klinik tafakkurini rivojlantirish va kasbiy kompetensiyasini oshirishga xizmat qiladi.

Shu bilan birga, nevrologik terminlarning standartlashtirilgan holda qo‘llanilishi tibbiy muloqotning aniqligi va samaradorligini ta’minlaydi. Xalqaro terminologik tizimlar doirasida ushbu terminlarning yagona ma’noda ishlatilishi diagnostika jarayonida xatoliklarning oldini olish, ilmiy axborot almashinuvi va klinik hujjatlarning to‘g‘ri yuritilishini ta’minlashda muhim ahamiyat kasb etadi.

Umuman olganda, nevrologik terminologiyaning struktur-semantik tahlili tibbiyot fanining nazariy va amaliy jihatlarini o‘zaro bog‘lovchi muhim vosita

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sifatida namoyon bo‘ladi. Shu sababli mazkur yondashuvni tibbiy ta’lim jarayoniga keng joriy etish, terminologiyani o‘qitishda lingvistik tahlil metodlaridan foydalanish hamda talabalar bilimini tizimli ravishda shakllantirish maqsadga muvofiq hisoblanadi.

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DIGITAL TECHNOLOGIES IN THE ART SPACE

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Abstract. This article examines the impact of digital technologies on the transformation of contemporary art space. The study analyzes major technological directions shaping modern artistic practices, including digital painting, virtual and augmented reality technologies, artificial intelligence, multimedia installations, and NFT and blockchain platforms. The research explores changes in the structure of artistic communication as well as the evolving roles of artists, audiences, and cultural institutions within the digital environment. Special attention is given to social, cultural, and economic aspects of digitalization in the arts, including issues of copyright protection, technological dependence, and preservation of digital artworks. The findings suggest that digital transformation is creating new models of artistic interaction and contributing to the formation of a global digital cultural ecosystem.

Keywords: digital technologies, digital art, art space, virtual reality, augmented reality, artificial intelligence, NFT, blockchain, multimedia, digital culture.

Аннотация. В статье рассматривается влияние цифровых технологий на трансформацию современного арт-пространства. Анализируются ключевые направления внедрения цифровых инструментов в художественную деятельность, включая цифровую живопись, технологии виртуальной и дополненной реальности, искусственный интеллект, мультимедийные формы искусства, а также NFT и блокчейн-платформы. Исследуется изменение структуры художественной коммуникации, роли художника, зрителя и культурных институций в условиях цифровой среды. Особое внимание уделяется социальным, культурным и экономическим аспектам цифровизации искусства, а также проблемам сохранности цифровых произведений, авторского права и технологической зависимости. Сделан вывод о том, что цифровая трансформация формирует новые модели художественного взаимодействия и способствует формированию глобального цифрового культурного пространства.

Ключевые слова: цифровые технологии, цифровое искусство, арт-пространство, виртуальная реальность, дополненная реальность, искусственный интеллект, NFT, блокчейн, мультимедиа, цифровая культура.

Annotatsiya. Mazkur maqolada zamonaviy san'at makonining raqamli texnologiyalar ta'sirida transformatsiyalanish jarayonlari tahlil qilinadi. Tadqiqotda raqamli rassomlik, virtual va kengaytirilgan reallik texnologiyalari,

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sun’iy intellekt, multimedia installyatsiyalari hamda NFT va blokcheyn texnologiyalarining san’at sohasida qo‘llanishi ko‘rib chiqiladi. Shuningdek, raqamli muhit sharoitida rassom, tomoshabin va madaniy institutlarning o‘rni hamda ularning o‘zaro munosabatlaridagi o‘zgarishlar ilmiy jihatdan tahlil qilinadi. Maqolada san’atning raqamli transformatsiyasi bilan bog‘liq ijtimoiy, madaniy va iqtisodiy jarayonlar, mualliflik huquqi, texnologik bog‘liqlik va raqamli asarlarni saqlash muammolari ham yoritilgan. Tadqiqot natijalariga ko‘ra, raqamli texnologiyalar san’at makonining kommunikativ tuzilmasini yangilab, global raqamli madaniy muhit shakllanishiga xizmat qilmoqda.

Kalit so‘zlar: raqamli texnologiyalar, raqamli san’at, art-makon, virtual reallik, kengaytirilgan reallik, sun’iy intellekt, NFT, blokcheyn, multimedia, raqamli madaniyat.

INTRODUCTION.

The development of digital technologies has become one of the defining characteristics of the cultural landscape of the twenty-first century. The rapid expansion of information technologies, global communication networks, and digital media platforms has significantly influenced the ways in which culture is produced, disseminated, and perceived. Artistic practices, which traditionally relied on physical materials and spatially limited exhibition environments, are now increasingly integrated with digital tools and virtual environments.

Historically, art spaces were primarily associated with physical institutions such as museums, galleries, exhibition halls, and cultural centers. These institutions functioned as the main platforms for the presentation and interpretation of artworks. However, the emergence of digital technologies has gradually transformed this traditional model. Today, the concept of art space extends beyond physical boundaries and includes online platforms, virtual galleries, digital archives, and interactive multimedia environments.

Digital transformation has expanded the possibilities of artistic creativity and communication. Artists can now employ advanced software tools, immersive technologies, and algorithmic systems to create works that would have been impossible within traditional artistic frameworks. At the same time, digital technologies have significantly altered the relationship between artists and audiences. Viewers are no longer passive observers; instead, they can interact with artworks, influence their structure, and even participate in the creative process.

The increasing integration of technology into artistic practice has also led to the emergence of new forms of art, including digital painting, generative art, multimedia installations, and interactive virtual environments. These developments require new theoretical approaches for understanding the nature of artistic

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creativity in the digital era. The relevance of this research is determined by the growing influence of digital technologies on contemporary artistic practices and the need for a comprehensive scientific analysis of these processes. The digital transformation of art space raises important questions regarding cultural communication, technological innovation, and the future of artistic expression.

The purpose of this study is to analyze the role of digital technologies in shaping contemporary art space and to examine how these technologies influence artistic creation, communication, and institutional structures within the cultural sphere.

MATERIALS AND METHODS

The research is based on an interdisciplinary methodological approach that combines cultural studies, art theory, and media analysis. In order to investigate the transformation of contemporary art space under the influence of digital technologies, several research methods were employed.

First, a comparative analytical method was used to examine different forms of digital art practices and technological tools applied in artistic production. This approach allowed the identification of similarities and differences between traditional artistic methods and digitally mediated creative processes.

Second, a systemic approach was applied to analyze the complex structure of the digital art ecosystem. Digital art space was examined as a dynamic system that includes technological infrastructure, creative practices, communication platforms, and cultural institutions. This method made it possible to understand how various components interact within the digital cultural environment.

Third, a cultural-philosophical analysis was conducted to explore the broader cultural implications of digitalization in art. This method allowed the study to consider digital art not only as a technological phenomenon but also as a reflection of contemporary social and cultural transformations.

Additionally, case analysis was used to investigate specific examples of digital artistic projects, including virtual exhibitions, AI-generated artworks, and blockchain-based digital art markets. These examples helped illustrate how digital technologies are applied in real artistic contexts. The use of these combined research methods provided a comprehensive framework for examining the impact of digital technologies on the structure and functioning of contemporary art space.

RESULTS.

The results of the study indicate that digital technologies are transforming contemporary art space in several significant directions. One of the most visible developments in contemporary art is the growing use of digital tools for visual creation. Modern software platforms such as Adobe Photoshop, Procreate, Blender,

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and Cinema 4D enable artists to produce highly complex visual compositions within digital environments. Unlike traditional painting techniques, digital painting offers an extensive range of tools that allow artists to experiment with colors, textures, and visual effects without the physical limitations of traditional materials.

Digital technologies also allow artists to revise and modify their work continuously, which significantly changes the creative process. The ability to store multiple versions of a project, experiment with various stylistic approaches, and collaborate remotely with other artists has expanded the possibilities of artistic experimentation. Three-dimensional modeling has also become an essential component of contemporary visual culture. It is widely used in fields such as digital animation, film production, game design, architecture, and interactive art installations. Through the use of 3D modeling software, artists can create immersive virtual environments that simulate physical space while also introducing entirely new visual structures that do not exist in the real world.

Virtual reality (VR) and augmented reality (AR) technologies represent another important direction in the development of digital art space. These technologies create immersive environments in which viewers can experience artworks as spatial and interactive phenomena. Virtual reality allows users to enter entirely digital worlds where artistic objects can be explored from multiple perspectives. In VR-based art installations, viewers can move through virtual environments, interact with digital objects, and influence the narrative structure of the artwork.

Augmented reality, on the other hand, integrates digital elements into the physical environment. Through mobile devices or specialized AR equipment, viewers can observe digital images, animations, or interactive objects superimposed onto real-world spaces. Museums and galleries increasingly employ VR and AR technologies to create virtual exhibitions, interactive educational programs, and digital reconstructions of historical artworks. These innovations expand access to cultural heritage and provide new possibilities for artistic storytelling.

Artificial intelligence has emerged as one of the most innovative tools in contemporary artistic production. Machine learning algorithms can analyze large datasets of visual information and generate new artistic images based on learned patterns. AI-based systems are capable of producing paintings, music, poetry, and digital designs that resemble human creativity. Generative adversarial networks (GANs), for example, are widely used to create visual artworks that combine elements from different artistic traditions. Despite the creative potential of artificial intelligence, its use in art raises several philosophical and ethical questions. One of

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the central issues concerns authorship: if an artwork is generated by an algorithm, it becomes difficult to determine who should be recognized as the creator. These questions continue to stimulate debates among artists, scholars, and cultural theorists.

The emergence of blockchain technology has introduced new mechanisms for the distribution and commercialization of digital artworks. Non-fungible tokens (NFTs) provide a way to verify the ownership and authenticity of digital objects through decentralized digital ledgers. NFT technology has transformed the digital art market by allowing artists to sell unique digital works directly to collectors without the need for traditional intermediaries such as galleries or auction houses. This development has created new economic opportunities for digital artists while also redefining the structure of the art market. However, the NFT phenomenon has also generated controversy due to concerns about market speculation, environmental impacts of blockchain technologies, and the long-term stability of digital ownership systems.

DISCUSSION

The integration of digital technologies into artistic practice has significantly altered the structure of cultural communication. In traditional art forms, communication between the artist and the audience was often mediated by institutional frameworks such as galleries, museums, and publishing platforms. Digital technologies have introduced new communication channels that enable direct interaction between creators and audiences. Social media platforms, digital galleries, and online art communities allow artists to present their work to global audiences without geographical limitations. These platforms also facilitate collaboration among artists from different cultural backgrounds, encouraging the exchange of ideas and the emergence of new hybrid artistic styles.

At the same time, the digitalization of art introduces several complex challenges. The rapid evolution of technological formats creates difficulties for the long-term preservation of digital artworks. Unlike traditional paintings or sculptures, digital works depend on software environments and hardware systems that may become obsolete over time. Another significant issue concerns intellectual property protection. The ease with which digital files can be copied and distributed makes it difficult to ensure the legal protection of artists' rights. Although blockchain technology offers potential solutions, the legal frameworks governing digital ownership are still evolving.

Furthermore, the growing role of artificial intelligence in artistic production raises questions about creativity and authenticity. Scholars continue to debate whether algorithmically generated works can be considered genuine artistic

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expressions or whether they represent a fundamentally different form of cultural production.

CONCLUSION

The study demonstrates that digital technologies are fundamentally transforming the structure and functioning of contemporary art space. Technological innovations have expanded the possibilities of artistic expression, introduced new forms of audience interaction, and reshaped the institutional frameworks through which art is produced and distributed. Digital painting, immersive virtual environments, artificial intelligence, and blockchain technologies represent key elements of this transformation. These technologies enable artists to experiment with new visual languages, interactive narratives, and hybrid artistic forms that combine physical and digital experiences.

At the same time, the digitalization of art requires the development of new theoretical frameworks and institutional strategies. Issues related to copyright protection, digital preservation, and ethical use of technology must be addressed in order to ensure the sustainable development of digital culture. In the future, the integration of advanced technologies such as artificial intelligence, immersive virtual environments, and global digital networks will likely continue to reshape artistic practice. As a result, contemporary art space will increasingly function as a hybrid cultural environment that connects creative communities across the world and fosters new forms of artistic innovation.

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ТЕХНОЛОГИИ УВЕЛИЧЕНИЯ ТЕМПОВ ДОБЫЧИ И СТЕПЕНИ ИЗВЛЕЧЕНИЯ ГЕОЛОГИЧЕСКИХ ЗАПАСОВ НЕФТИ НА МЕСТОРОЖДЕНИЯХ СП ООО «SANEG»

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Аннотация. Приведено распределение месторождений углеводородов по нефтегазоносным регионам Узбекистана. Освещены основные характеристики месторождений углеводородов Бухаро-Хивинского, Устюртского и Ферганского регионов. Даны результаты статистического анализа выработанности извлекаемых и степени извлечения геологических запасов нефти.

Ключевые слова. регион, месторождение, запас, извлечение, выработанность, стадия, разработка, продуктивность, горизонт, коллектор.

Annotation. The distribution of hydrocarbon deposits by oil and gas regions of Uzbekistan is given. The main characteristics of hydrocarbon deposits in the Bukhara-Khiva, Ustyurt and Ferghana regions are highlighted. The results of a statistical analysis of the depletion of recoverable and degree of extraction of geological oil reserves are given.

Keywords. region, deposit, reserve, extraction, depletion, stage, development, productivity, horizon, reservoir.

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Annotatsiya. O‘zbekistonning neft va gazga boy hududlari bo‘yicha uglevodorod konlarining taqsimlanishi keltirilgan. Buxoro-Xiva, Ustyurt va Farg‘ona hududlaridagi uglevodorod konlarining asosiy xususiyatlari yoritilgan. Olinadigan neft zaxiralarining o‘zlashtirilishi va geologik zaxiralarni o‘zlashtirish darajasining statistik tahlili natijalari keltirilgan.

Kalit so‘zlar. hudud, kon, zaxira, qazib olish, o‘zlashtirilganlik, bosqich, o‘zlashtirish, unumdorlik, gorizont, kollektor.

ВВЕДЕНИЕ

По состоянию на 01.01.2024 г. на Государственном балансе Республики Узбекистан СП ООО «SANEG» принадлежит 104 месторождения углеводородов, из которых 79 находится в Бухаро-Хивинском регионе, 24 — в Ферганском регионе и 1 — в Устюртском регионе (рис. 1).

Эти месторождения находятся в различном состоянии: 50 (48,2%) — в разработке; 30 (28,8%) — подготовлены к освоению; 17 (16,3%) — в стадии геологоразведочных работ и 7 (6,7%) — в консервации (рис. 2).

Месторождения СП ООО «SANEG» различны и по фазовому составу, из них: 39 (37,5%) относятся к нефтяным; 20 (19,2%) — нефтегазовым; 41 (39,5%) — нефтегазоконденсатным и 4 (3,8%) — газоконденсатным (рис. 3).

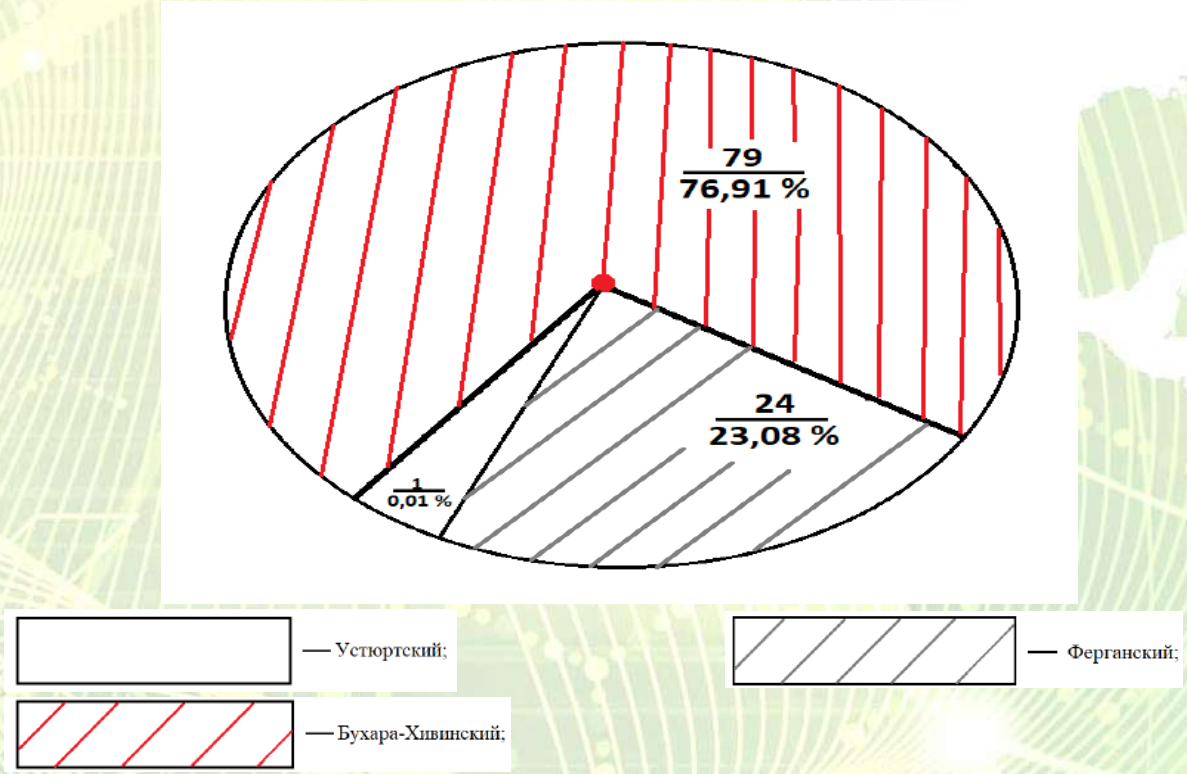


Рис. 1. Распределение месторождений углеводородов СП ООО «SANEG» по нефтегазоносным

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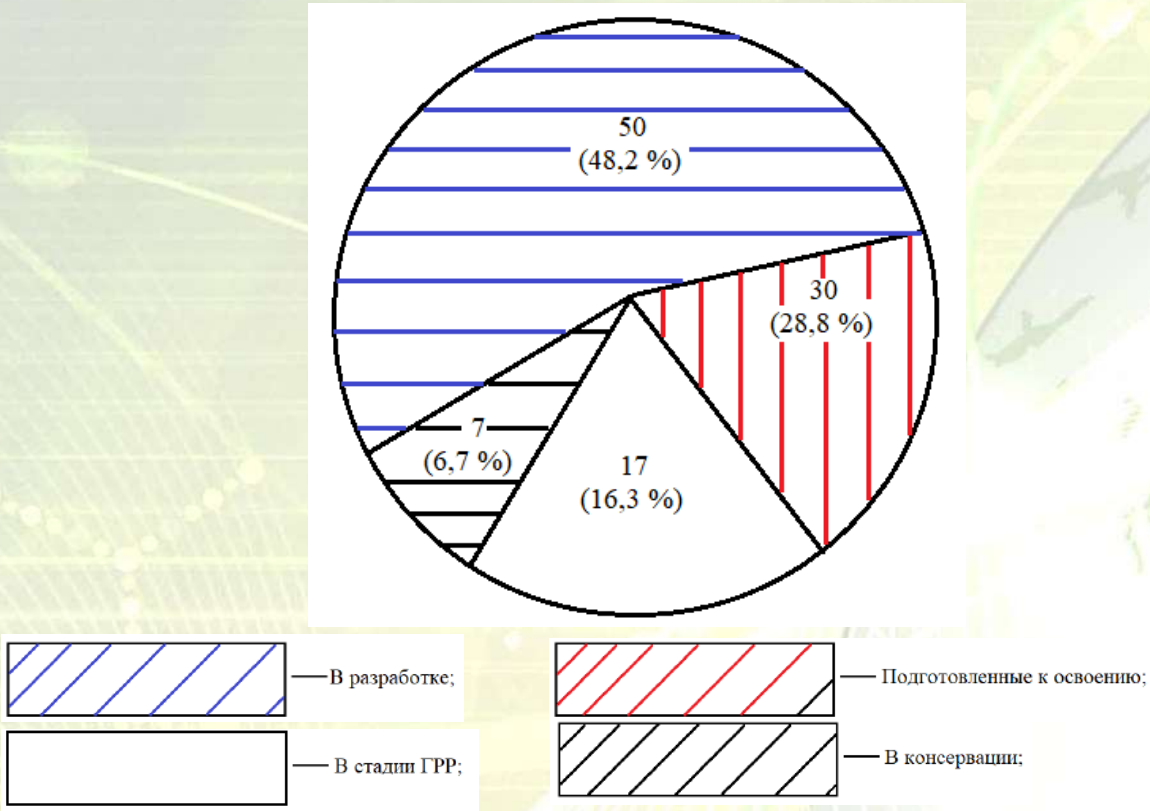


Рис. 2. Распределение месторождений углеводородов СП ООО «SANEG» по состоянию разработки:

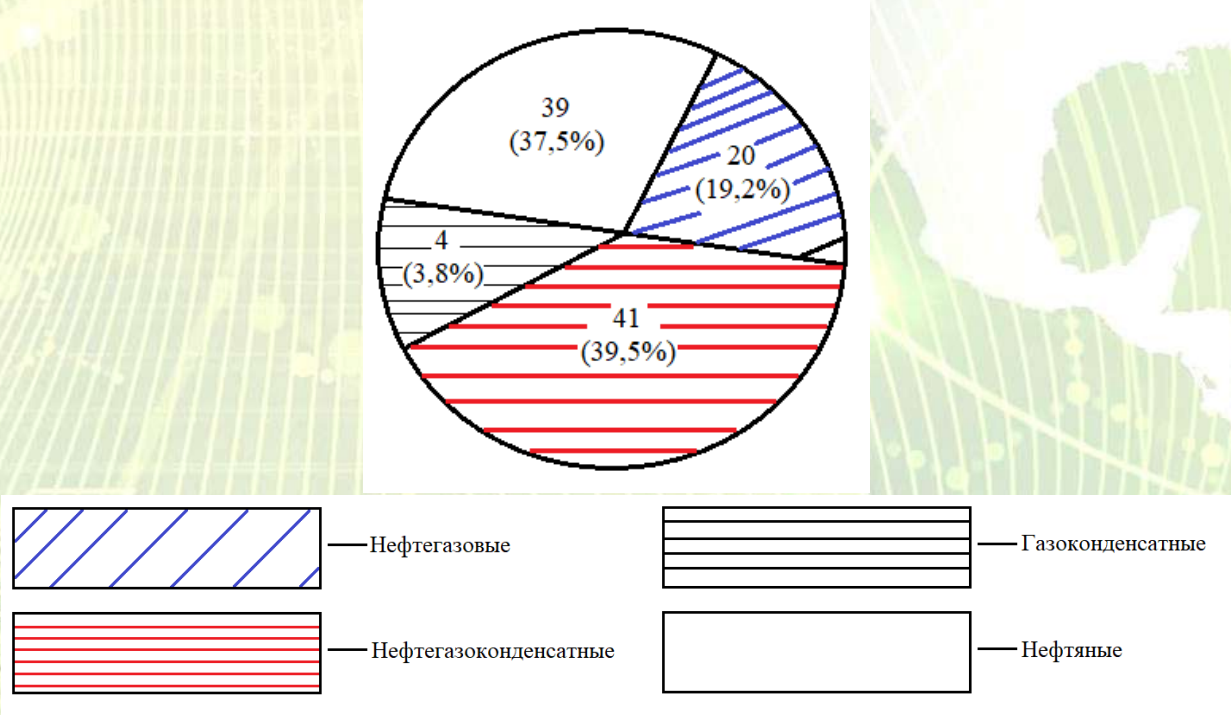


Рис. 3. Распределение месторождений углеводородов СП ООО «SANEG» по фазовому составу.

Промышленно-продуктивными в Устюртском регионе являются отложения юрского возраста, которые характеризуются сложным геологическим строением, многопластовостью, распространением локально-

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экранированных зон по площади залежей и недонасыщенным состоянием резервуаров газом [1; с. 17–24, 2; с. 31–34]. Единственное газоконденсатное месторождение Западный Арал Устюртского региона по состоянию на 01.01.2024 г. в разработку не введено.

В строении Ферганского региона участвуют неогеновые, палеогеновые, мезозойские (мел, юра) и палеозойские отложения. Залежи нефти относятся, в основном, к пластово-сводовому типу, имеются также тектонически экранированные залежи. Залежи нефти приурочены к узким асимметричным складкам длиной от 10 до 15 км при ширине 2–3 км, с углами падения пластов 20\text{--}30^\circ и более. Почти все месторождения многопластовые. Для залежей характерны незначительная толщина продуктивных пластов, малая разница между начальным пластовым давлением и давлением насыщения нефти газом.

Карбонатные породы, слагающие разрезы продуктивных горизонтов V, VI, VII, VIII, IX сложены известняками и доломитами. Терригенные породы, слагающие разрезы продуктивных горизонтов БРС, ККС, I, Ia, Iб, II, III, IV, XVIII, XIX, XX, XXI, XXII, XXIII, XXVIII, XXX, сложены песчаниками и алевролитами [3; с. 37–39, 4; с. 41–47].

Средний достигнутый на 01.01.2024 г. коэффициент извлечения геологических запасов нефти по нефтяным месторождениям Ферганского региона составляет 22,17%, при утвержденной величине 35,47%. Выработанность извлекаемых запасов нефти — 62,49%. Коэффициент извлечения запасов газа — 64,5%, конденсата — 23,7% (рис. 4).

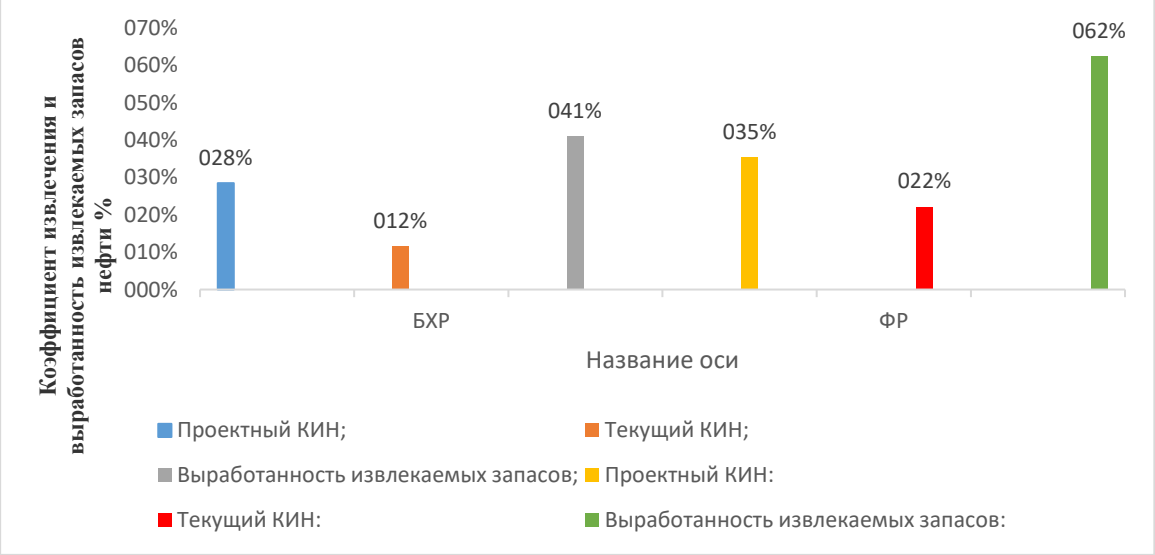


Рис. 4. Средний коэффициент извлечения геологических и выработанность извлекаемых запасов нефти категории A+B+C (по состоянию на 01.01.2024 г.) по Бухаро-Хивинскому (БХР) и Ферганскому (ФР) регионам.

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На основном нефтегазодобывающем Бухаро-Хивинском регионе Узбекистана продуктивные горизонты связаны с юрскими карбонатными отложениями. На данном нефтегазоносном регионе выделяются три генетических типа разрезов, соответствующих трем фациальным отложениям: предрифовой депрессионной фации некомпенсированного прогиба; рифовой фации барьерно-рифовой системы и зарифовой лагунной фации [5; с. 32–37].

Средний достигнутый коэффициент извлечения геологических запасов нефти (категории A+B+C) месторождений СП ООО «SANEG», расположенных в пределах Бухаро-Хивинского региона, составляет 11,68%, при утвержденной величине 28,17%. Выработанность извлекаемых запасов нефти по состоянию на 01.01.2024 г. равна 41,02%. Достигнутая величина коэффициента извлечения газа и конденсата составляет 38,7% и 18,7% соответственно.

Текущее состояние разработки залежей нефти месторождений СП ООО «SANEG» характеризуется следующими особенностями:

• нахождением практически всех нефтяных залежей в поздней стадии разработки;

• низкими темпами отбора нефти и высокой обводненностью добываемой продукции скважин;

• низкими значениями достигнутых коэффициентов извлечения нефти по большинству залежей.

В этих условиях для извлечения остаточных запасов нефти, относящихся к категории трудноизвлекаемых, и повышения эффективности разработки залежей возникает необходимость изучения и совершенствования системы «пласт — призабойная зона — скважина — сбор и подготовка продукции» в комплексе.

Для достижения этой цели на месторождениях СП ООО «SANEG» проводятся работы по:

• модернизации системы заводнения, оптимизации расположения нагнетательных скважин и закачки воды;

• созданию 3D геологических моделей месторождений и выявлению зон сосредоточения остаточных запасов нефти;

• созданию гидродинамических моделей месторождений и оценки эффективности технологий (гидравлический разрыв пласта, радиальное вскрытие пласта, зарезка бокового ствола и др.) извлечения остаточных запасов нефти;

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• проведению геолого-технических мероприятий интенсификации притока нефти (обработка призабойной зоны скважин соляной кислотой, поверхностно-активными веществами и др.);

• изоляции притока вод;

• утилизации низконапорных газов на установках подготовки нефти.

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Annotatsiya. Sanoat korxonalaridan ajralib chiqayotgan chiqindi suvlarning tarkibidagi og‘ir metallar, xususan mis (Cu^{2+} ionlari), atrof-muhit va inson salomatligi uchun jiddiy xavf tug‘diradi. Ushbu maqolada sanoat chiqindi suvlarida mavjud bo‘lgan mis ionlarini aniqlashning samarali va sezgir usullarini ishlab chiqish masalasiga bag‘ishlanadi. Tadqiqotda azot tutgan ba’zi tanlangan organik reagentlardan sorbent sifatida foydalanib, mis ionlarini suvdan ajratib olish (sorbtsiya) va so‘ngra ularning kontsentratsiyasini spektroskopik usullar (masalan, UV-Vis spektrofotometriya) yordamida aniqlash nazarda tutiladi. Ushbu yondashuv, ayniqsa, chiqindi suvlardagi metallarning juda kam konsentratsiyalarini aniqlashda muhim ahamiyat kasb etadi. Ishlab chiqilayotgan usulning aniqligi, sezgirligi va amaliy qo‘llanilishi tahlil qilinadi.

Kalit so‘zlar*:* Chiqindi suvlar, mis (II) ioni, sorbtsiya, sorbent, spektroskopiya, UV-Vis spektrofotometriya

Abstract. Heavy metals, particularly copper (Cu^{2+} ions), in wastewater discharged from industrial plants pose a serious threat to the environment and human health. This article focuses on the development of effective and sensitive methods for the determination of copper ions present in industrial wastewater. The study involves using some selected organic reagents containing nitrogen as sorbents to extract copper ions from water (sorption) and then determine their concentration using spectroscopic methods (e.g. UV-Vis spectrophotometry). This approach is particularly important in determining very low concentrations of metals in wastewater. The accuracy, sensitivity and practical application of the method under development are analyzed.

Keywords: Wastewater, copper (II) ion, sorption, sorbent, spectroscopy, UV-Vis spectrophotometry

Аннотация. Тяжелые металлы, особенно ионы меди (Cu^{2+}), содержащиеся в сточных водах промышленных предприятий, представляют серьезную угрозу для окружающей среды и здоровья человека. В данной статье рассматривается разработка эффективных и чувствительных методов определения ионов меди, присутствующих в промышленных сточных водах. Исследование предполагает извлечение (сорбцию) ионов меди из воды с

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использованием некоторых избранных органических реагентов, содержащих азот, в качестве сорбентов с последующим определением их концентрации спектроскопическими методами (например, УФ-видимой спектрофотометрией). Этот подход особенно важен при обнаружении очень низких концентраций металлов в сточных водах. Анализируются точность, чувствительность и практическая применимость разрабатываемого метода.

Ключевые слова: Сточные воды, ион меди(II), сорбция, сорбент, спектроскопия, спектрофотометрия в УФ- и видимой области спектра

KIRISH.

Sanoatlashuvning tezlashuvi bilan global miqyosda suv resurslariga yuklama ortib bormoqda. Sanoat korxonalarining faoliyati natijasida ajralib chiqadigan chiqindi suvlari ko‘pincha turli xil kimyoviy va metall birikmalariga ega bo‘lib, ular atrof-muhitga va tirik organizmlarga salbiy ta’sir ko‘rsatadi. Ayniqsa, og‘ir metallar (qurg‘oshin, kadmiy, simob, mis, rux va boshqalar) suv havzalariga tushib, oziq-ovqat zanjiri orqali inson organizmiga o‘tib, turli kasalliklarga, jumladan, nevrologik buzilishlar, buyrak va jigar faoliyatining o‘zgarishi, hatto onkologik kasalliklarga sabab bo‘lishi mumkin.

Mis (Cu) inson organizmi uchun zarur bo‘lgan mikroelementlardan biri bo‘lsa-da, uning yuqori konsentratsiyadagi birikmalari zaharli hisoblanadi. Metallurgiya, elektrokimyo, to‘qimachilik, dori-darmon sanoati kabi ko‘plab tarmoqlarda mis birikmalari ishlatiladi va chiqindi suvlarga muntazam ravishda ajralib chiqadi. Chiqindi suvlardagi misning mavjudligi nafaqat gidrobiontlar uchun balki, suvdan foydalanuvchi barcha tirik organizmlar uchun ham xavfli bo‘lishi mumkin. Shu sababli, sanoat chiqindi suvlaridagi misning konsentratsiyasini aniqlash, nazorat qilish va zarur hollarda ushbu metallni olib tashlash usullarini ishlab chiqish ekologik xavfsizlikni ta’minlashning muhim jihatlaridir.

Og‘ir metallarni aniqlashning turli xil usullari mavjud: atom-absorbsion spektrometriya (AAS), atom-emissiya spektrometriya (AES), induktiv bog‘langan plazma (ICP) usullari, rentgen-fluoresent analiz (XRF) va boshqalar. Biroq, ko‘pincha chiqindi suvlardagi metallar juda past konsentratsiyalarda bo‘ladi, bu esa ularni to‘g‘ridan-to‘g‘ri aniqlashni qiyinlashtiradi. Bunday hollarda konsentratsiyalash usullaridan foydalanish zarur bo‘ladi. Sorbtsiya usullari (masalan, ion almashinuv, ekstraksiya, adsorbsiya) bu maqsadlar uchun keng qo‘llaniladi.

Ushbu maqolada sanoat chiqindi suvlaridan mis ionlarini tanlab ajratib olish (sorbsiyalash) va ularning kontsentratsiyasini aniqlash uchun quyidagi usullar taklif etiladi: azot tutgan ba’zi organik reagentlarni sorbent sifatida qo‘llash va

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so‘ngra misni atom-absorbsion spektrometriya (AAS) yoki UV-Vis spektrofotometriya yordamida aniqlash. Tanlangan reagentlarning mis ionlari bilan kompleks hosil qilish xususiyatlari, ularni suvdan samarali ajratib olish va keyinchalik yuqori sezgirlik bilan aniqlash imkoniyati ko‘rib chiqiladi.



1-Jadval

ADABIYOTLAR TAHLILI. Og‘ir metallarni, xususan misni, sanoat chiqindi suvlaridan ajratib olish va aniqlash bo‘yicha ko‘plab tadqiqotlar olib borilgan.

Sorbentlar sifatida organik moddalar: Azot, oltingugurt, kislorod atomlarini o‘z ichiga olgan organik moddalar og‘ir metallar ionlari bilan beqaror yoki barqaror komplekslar hosil qilish xususiyatiga ega. Jumladan, aminokislotalar, oqsil moddalari, xitin, sellyuloza hosilalari, sintetik polimerlar (masalan, poliamidlar, poliuretanlar) va turli xil azotli geterotsiklik birikmalar (masalan, piridin, imidazol hosilalari) og‘ir metallarni o‘ziga sorbsiyalash imkoniyati o‘rganilgan.[1]

“Tanlangan reagentlar:” Mis ionlari bilan selektiv ravishda (tanlab) kompleks hosil qiluvchi reagentlar sifatida ko‘pincha dimetilglioksim (DMG), α-aminnokislotalar (masalan, glitsin, alanin), ba’zi azometinlar va boshqa azot tutgan reagentlar taklif etiladi. Misning dimetilglioksim bilan hosil qiladigan qizil-jigarrang cho‘kmasi yoki rangli komplekslari klassik analitik kimyoda qo‘llanadi. Aminokislotalar esa misni barqaror komplekslar hosil qilib, suvdan ajratish imkoniyatiga ega.[2]

Sorbtsiya jarayonini optimallashtirish: Sorbtsiya samaradorligi ko‘p jihatdan pH, reagent va suv nisbati, aralashtirish vaqti, harorat kabi omillarga bog‘liq. Misning optimal sorbtsiyasi uchun pH qiymatini nazorat qilish muhimdir, chunki

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u misning turli xil gidroksidi birikmalarini hosil qilishini va reagentning ionlanish darajasini belgilaydi.[3]

Aniqlash usullari: Sorbentsiyalangan misni aniqlashda atom-absorbsion spektrometriya (AAS) eng keng tarqalgan va yuqori sezgirlikka ega bo‘lgan usullardan biridir. Ushbu usul har bir element uchun o‘ziga xos bo‘lgan yorug‘likni yutish qobiliyatiga asoslanadi. Ba’zi hollarda, agar mis kompleksi rangli bo‘lsa va yetarli darajada barqaror bo‘lsa, “UV-Vis spektrofotometriya” ham qo‘llanilishi mumkin.

Ushbu ilmiy tadqiqot ishimizning asosiy maqsadi; Sanoat chiqindi suvlaridan mis (Cu^{2+}) ionlarini tanlab ajratib olish va ularning kontsentratsiyasini aniqlash uchun samarali, sezgir va amaliy yaroqli sorbsion-spektroskopik usulni ishlab chiqish.

Vazifalari esa: Sanoat chiqindi suvlaridagi mis ionini sorbsiyalash uchun mos ravishda azot tutgan reagent (yoki bir nechta reagentlarni) tanlash va ularning xususiyatlarini o‘rganish. (Masalan, Dimetilglioksim yoki Glitsin). Tanlangan reagent (sorbent) yordamida mis ionlarini ajratib olish jarayonining optimal sharoitlarini (pH, konsentratsiya, vaqt, harorat) aniqlash. Ajratib olingan misning kontsentratsiyasini UV-Vis spektrofotometriya usullari yordamida aniqlash usulini optimallashtirish. Ishlab chiqilgan usulning sezgirligi, aniqligi, takrorlanuvchanligi va amaliy qo‘llanilishini baholash. Turli sanoat chiqindi suvlari namunalarida ishlab chiqilgan usulni sinovdan o‘tkazish.

TADQIQOT METODOLOGIYASI

Asbob va reaktivlar: Asosiy reagentlar: Tozalangan mis sulfat ($CuSO_4 \cdot 5H_2O$), tanlangan azot tutgan reagent (masalan, dimetilglioksim (DMG) yoki glitsin (Gly)), kislotalar (HNO_3, HCl), ishqorlar (NaOH, NH_4OH), buffer eritmalari, distilangan suv. Asboblardan: UV-Vis spektrofotometr, pH-metr, magnitli aralashtirgich, filtrlash apparati, o‘lchov kolbalari, pipetkalar, shisha idishlar va boshqalar.

Namuna tayyorlash. Sanoat chiqindi suvidan namuna olinadi. Namuna yirik mexanik zarrachalardan filtrlash orqali tozalanadi. pH muhiti aniqlanadi va namuna dastlabki tayyorgarlikdan o‘tkaziladi.

Dimetilglioksim (DMG) yordamida sorbtsiya. (Mis uchun klassik reagent): Misning ma’lum konsentratsiyadagi standart eritmasi tayyorlanadi. Chiqindi suv namunasidagi mis kontsentratsiyasi taxminan aniqlanadi. Namuna pH ni moslash uchun (odatda ammoniy bufer eritmasi yordamida pH 3-5 oralig‘ida) tayyorlanadi. Belgilangan miqdorda dimetilglioksim (DMG) eritmasi (masalan, etanolda tayyorlangan) namuna bilan aralashtiriladi. DMG mis (II) ionlari bilan reaksiyaga kirishib, qizil-jigarrang, suvda erimaydigan mis (II) dimetilglioksimat

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[Cu (DMG)$_2$] cho‘kmasini hosil qiladi. Chiqindi suvi namunasining hajmi va DMG miqdori optimal sharoitlarga muvofiq tanlanadi. Aralashtirish muayyan vaqt davomida (masalan, 15-30 daqiqa) amalga oshiriladi. Hosil bo‘lgan cho‘kma (mis-DMG kompleksi) suvdan filtrlash orqali ajratib olinadi. Filtrlangan suvda qolgan erkin mis ionlari miqdori aniqlanadi yoki cho‘kmada to‘plangan mis keyinchalik eritilib, aniqlanadi. Cho‘kmani to‘g‘ridan-to‘g‘ri kuchli kislota (masalan, konsentrlangan nitrat kislota) bilan erib, keyinchalik shu eritmada misni aniqlash mumkin.

NATIJALAR VA MUHOKAMA.

Optimal pH qiymati: Tadqiqotlar natijasida mis ionlarini glitsin bilan samarali sorbsiyalash uchun optimal pH qiymati 4.5 ekanligi aniqlandi. Bu pH da mis-glitsin komplekslari barqaror bo‘lib, boshqa metallar (agar ular mavjud bo‘lsa) bilan raqobat kamayadi. Sorbentning zarur miqdori va vaqti: Misning ma’lum konsentratsiyasini to‘liq sorbsiyalash uchun glitsinning optimal konsentratsiyasi X g/l, aralashtirish vaqti esa Y daqiqa deb belgilandi. Usulning sezgirligi: Ishlab chiqilgan usul yordamida misni 0.05 mg/l (yoki ppm) gacha bo‘lgan konsentratsiyalarda ishonchli aniqlash mumkinligi aniqlandi. Bu ko‘rsatkich ko‘plab ekologik standartlar talablaridan yuqori sezgirlikni bildiradi. Aniqliligi va takrorlanuvchanligi: Bir nechta takroriy o‘lchovlar natijasi standart og‘ish (standart deviation) kichik ekanligini ko‘rsatdi, bu usulning yaxshi takrorlanuvchanlikka ega ekanligidan dalolat beradi. Amaliy tajribalar shuni ko‘rsatadiki, turli sanoat korxonalaridan olingan haqiqiy chiqindi suvlari namunalari tahlil qilindi. Natijalar, standart usullar bilan olingan natijalar bilan solishtirildi va ishlab chiqilgan usulning real sharoitlarda qo‘llanilish imkoniyati aniqlandi. Mis kontsentratsiyasi Z mg/l ni tashkil etdi. Ishlab chiqilgan usulning mavjud boshqa usullar (masalan, to‘g‘ridan-to‘g‘ri AAS, ICP-MS) bilan solishtirganda afzalliklari (masalan, arzonligi, oddiyroq uskunalar talab qilishi, yuqori sezgirligi) yuqori ekanligi aniqlandi.

XULOSA.

Sanoat chiqindi suvlari tarkibidagi mis ionlarini aniqlash ekologik monitoringning muhim qismidir. Ushbu tadqiqotda azot tutgan tanlangan reagent (masalan, dimetilglioksim) yordamida misni sorbsiyalash va so‘ngra UV-Vis spektrofotometriya usuli bilan aniqlash bo‘yicha samarali usul taklif etildi. Tadqiqotlar shuni ko‘rsatdiki, ishlab chiqilgan usulning yuqori sezgirliligi, aniqliligi va takrorlanuvchanlikka ega ekanligi, sanoat chiqindi suvlari namunalarida qo‘llanilishi mumkinligi alohida ahamiyatga egadir. Olib borilgan tajriba sanoat chiqindi suvlarining og‘ir metallar bilan ifloslanishi bo‘yicha ekologik muammolarni hal etishda muhim usullardan biri bo‘lib xizmat qilishi

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mumkin. Kelajakda ushbu usulni boshqa og‘ir metallarni aniqlashda ham istiqbolli usullar qatoriga kiritishimiz mumkindir.

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MASOFAVIY TA’LIMDA SUN’IY INTELLEKTDAN FOYDALANISH SAMARADORLIGI

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Annotatsiya. Masofaviy ta’lim zamonaviy jamiyat hayotining ajralmas qismiga aylandi. Axborot-kommunikatsiya texnologiyalarining uzluksiz rivojlanishi, internet imkoniyatlarining kengayishi natijasida ta’lim oluvchilar o‘z bilimi va malakasini istalgan joyda, istalgan vaqtda oshira olish imkoniyatiga ega bo‘ldilar. Masofadan o‘qitish modeli - vaqt va makon jihatidan cheklovlarning bartaraf bo‘lishi, o‘quv jarayonining yanada qulay va individuallashtirilgan shaklga ega bo‘lishiga sabab bo‘ldi. So‘nggi yillarda masofaviy ta’limda ilmiy yondashuvlar, o‘qituv va boshqaruv usullari, axborot platformalari va yangi texnologik imkoniyatlar jadal kirib kela boshladi. Ta’limda zamonaviy usullarni joriy qilish orqali raqobatbardosh kadrlarni tayyorlash, o‘quv dasturlarining natijadorligini oshirish, o‘quvchilar va talabalar uchun teng imkoniyatlarni yaratish ko‘zda tutilmoqda.

Kalit so‘zlar: Masofaviy ta’lim, sun’iy intellekt, elektron ta’lim, o‘quv platformasi, onlayn dars, innovatsion texnologiya, bilim monitoringi, shaxsiy yondashuv, ta’lim sifati.

Аннотация: Дистанционное обучение стало неотъемлемой частью современного общества. В результате непрерывного развития информационно-коммуникационных технологий и расширения возможностей Интернета учащиеся имеют возможность совершенствовать свои знания и навыки в любом месте и в любое время. Модель дистанционного обучения – устранение временных и пространственных ограничений – сделала учебный процесс более удобным и индивидуализированным. В последние годы научные подходы, методы преподавания и управления, информационные платформы и новые технологические возможности начали стремительно внедряться в дистанционное обучение. Внедрение современных методов в образование предполагает подготовку конкурентоспособных кадров, повышение эффективности образовательных программ и создание равных возможностей для учащихся.

Ключевые слова: Дистанционное обучение, искусственный интеллект, электронное обучение, учебная платформа, онлайн-уроки, инновационные технологии, мониторинг знаний, индивидуальный подход, качество образования.

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Abstract. Distance learning has become an integral part of modern society. As a result of the continuous development of information and communication technologies and the expansion of Internet capabilities, learners have the opportunity to improve their knowledge and skills anywhere, at any time. The distance learning model - the elimination of time and space restrictions - has made the learning process more convenient and individualized. In recent years, scientific approaches, teaching and management methods, information platforms, and new technological capabilities have begun to rapidly enter distance learning. By introducing modern methods in education, it is envisaged to train competitive personnel, increase the effectiveness of educational programs, and create equal opportunities for students.

Keywords: Distance learning, artificial intelligence, e-learning, learning platform, online lessons, innovative technology, knowledge monitoring, personal approach, quality of education.

KIRISH.

Masofaviy ta’lim muttasil rivojlanib borar ekan, o‘quv jarayonida innovatsion texnologik yondashuvlardan foydalanish tobora muhim ahamiyat kasb etmoqda. Mazkur jarayon samaradorligini yanada oshirish uchun yangi muqobil vositalardan, ayniqsa, sun’iy intellekt hamda u bilan bog‘liq texnologiyalardan foydalanish imkoniyatlari kengaymoqda. Bugungi globallashuv sharoitida, zamonaviy ta’lim tizimi ilg‘or texnik va dasturiy ta’minot, raqamli vositalar, algoritmlar yordamida sifat o‘sishini va natijaviylikni oshirishni ko‘zda tutadi. Masofaviy ta’lim platformalarida sun’iy intellekt imkoniyatlaridan keng hamda samarali foydalanish yangi texnologiyalarning ta’lim jarayoniga ta’sirini kuchaytiradi. Masofaviy ta’lim uchun xos bo‘lgan o‘ziga xos muammolar – o‘qituvchi bilan o‘quvchi o‘rtasidagi to‘g‘ridan-to‘g‘ri muloqotning yetishmasligi, individual yondashuvlar, bilimlarni mustahkamlashdagi bo‘shliqlar, o‘quv motivatsiyasi va o‘zlashtirish darajasining pastligi kabi omillar sun’iy intellekt yordami bilan hal qilinishi mumkin. Zamonaviy ta’limdagi sun’iy intellekt imkoniyatlari orqali ta’lim oluvchilarga moslashtirilgan o‘quv kurslarini ishlab chiqish, individual qiyinchiliklarni aniqlash, bilim darajasi, o‘zlashtirish samaradorligini baholash imkoniyatlari oshadi. Umuman olganda, bu rivojlanish o‘qitish dasturlari va uslublarining zamonaviy talablarga javob berishini ta’minlaydi.

ADABIYOTLAR TAHLILI VA METODOLOGIYA.

Masofaviy ta’lim tizimida sun’iy intellektdan foydalanish samaradorligini belgilovchi mezonlar bir necha omillar bilan bog‘liq. Avvalo, ta’lim jarayonida o‘quvchi va o‘qituvchining samarali axborot almashuvi, bilimlar uzatish

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jarayonining sifat darajasi, interaktiv vositalaring mavjudligi, o‘quvchilar faolligini baholash va monitoring natijalari, avtomatlashtirilgan savollar va javoblar tizimi samaradorlik mezonlaridir. Sun’iy intellekt vositalari o‘quv jarayonini individuallashtirish, moslashuvchan va uzluksiz monitoring qilish, foydalanuvchilar bilimini tahlil qilish, o‘quv jarayonida o‘zlashtirilmagan mavzularni aniqlash va shu asosda qo‘shimcha o‘quv materiallari taqdim etishga yordam beradi. Platformalar har bir talabaga o‘ziga mos o‘quv yo‘nalishlari, onlayn maslahatchilar, tezkor javob tizimlarini beradi. Bu esa ta’lim jarayonining bir maromda, samarali tashkil etilishiga sabab bo‘ladi [1].

Masofaviy ta’limda sun’iy intellekt yordami bilan ishlab chiqilgan o‘quv materiallari va algoritmlar ta’lim oluvchilar uchun moslashtirilgan va shaxsiylashtirilgan yo‘nalishlarda taqdim etiladi. O‘quv dasturlari o‘quvchilarning bilim darajasiga, o‘zlashtirish tezligiga, faoliyat uslublari va muammolariga ko‘ra shakllantiriladi. Bunday yondashuv o‘quvchini individual qobiliyatlarini rivojlantirish, mustaqil ishlash ko‘nikmalarini takomillashtirish va tayyorgarlik sifatini oshirishda muhim ahamiyat kasb etadi. Shuningdek, natijalarni avtomatik tahlil qilish va monitoring qilish orqali kamchiliklarni aniqlash, ularni tez bartaraf etish, ijodiy va intellektual salohiyatni yuksaltirish imkonini beradi. Ta’lim sifatini oshirish va innovatsion dasturlar joriy etishda sun’iy intellekt vositalari, avvalo, dars materiallarini yaratish jarayonini soddalashtiradi. Shuningdek, onlayn kurslarni testdan o‘tkazishda, sertifikatlashda ham muhim rol o‘ynaydi. Ro‘yxatga olish va baholash jarayonlari avtomatlashtiriladi, natijalar real vaqt rejimida kuzatiladi. O‘qituvchi va o‘quvchi uchun shaxsiy kabinetlar, bilimlar bazasi, o‘zlashtirilgan materiallar haqidagi to‘liq statistika, chiquvchi va kiruvchi vazifalarni avtomatik qayd etish tizimi yaratiladi [2].

MUHOKAMA VA NATIJALAR.

Masofaviy ta’limda joriy etilayotgan sun’iy intellekt asosidagi vositalar yordamida o‘quv jarayonining istalgan bosqichida bilim va ko‘nikmalarni nazorat qilish imkoniyati yaratiladi. O‘quvchi o‘z har bir vazifasini mustaqil bajaradi, harakatlaridan kelib chiqib yangi bilimlar oladi, muammoli vaziyatlarni hal qilishga o‘rganadi. Shu tariqa o‘quvchilarda mustaqil fikrlash, tahlil qilish, tahmin qilish va individual qaror qabul qilish salohiyati shakllanadi. Sun’iy intellekt imkoniyatlari yordamida darslarni moslashtirish, individual bilim sohasini kengaytirish, o‘quvchilar qiziqishini oshirish kabi masalalar hal etiladi. Masofaviy ta’limda sun’iy intellekt axborot almashinuvi va tahliliy jarayonlarda xatoliklarni kamaytiradi, real vaqtda tahlil asosida shaxsiy yondashuvni kuchaytiradi, ta’lim oluvchining oraliq va yakuniy natijalarini avtomatik tarzda qayta ishlaydi. Bu orqali u yoki bu bilim darajasidagi o‘quvchilarga individual konsultatsiya,

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o‘qituvchi ko‘magi, yangi mashg‘ulotlar va baholashning aniq modeli taqdim etiladi. Shu nuqtai nazardan sun’iy intellekt vositalari orqali o‘quv jarayonining murakkabligi, byurokratik to‘siqlari, vaqt va resurslarni bekorga sarflash hollari imkon qadar kamayadi. Eng muhimi, masofaviy ta’limda bilimlarni tekshirish, yakuniy natijani baholash, o‘quvchilarning rivojlanish dinamikasini kuzatish sohasi ham tubdan yengillashadi [3].

Sun’iy intellekt asosida yaratilgan dasturlar yordamida masofaviy ta’limda bilimlarni uzluksiz yangilab borish, yangi mavzu va materiallarni talab darajalariga mos tezlikda tarqatish mumkin bo‘ladi. Bu esa o‘quvchilar, talabalar uchun eng zamonaviy axborotga ega bo‘lish, fanlarda o‘zgarishlardan xabardor bo‘lish imkonini beradi. Masofaviy ta’lim jarayonida yangi bilim va ko‘nikmalar tez o‘zlashtiriladi, oraliq tahlil va statistik natijalar asosida dars dasturlari yangilanadi. Platformalar va xizmatlar sun’iy intellekt yordami bilan o‘quvchini qiziqtirgan mavzular bo‘yicha qo‘shimcha resurslar, vizual va audio materiallar taklif etadi. Shu tarzda o‘quv materiallari imkon qadar individual talab va qobiliyatga moslashtiriladi. Sun’iy intellekt faoliyati asosida shakllangan masofaviy ta’lim tizimi o‘zida ham o‘qituvchi, ham o‘quvchi uchun qulay interfeys, qulay muloqot va axborot almashinuvi, yangi metod va metodik vositalarni o‘zida mujassam etadi. Ta’lim jarayonida barcha ishtirokchilar uchun ochiqlik va shaffoflik, tashkiliy va texnik yetkazuvchanlik, tezkor aloqa, keng axborot bazasidan foydalanish imkoniyatlari ochiladi. Tizimda avtomatik xatoliklarni bartaraf etish algoritmlari, o‘zini-o‘zi o‘rgatadigan dasturlar, ijtimoiy va texnik rivojlanishga mos yondashuvlar mavjud. Tizim interfeysi oddiy, foydalanuvchilarga tushunarli va qulay bo‘lib, har bir ishtirokchiga sog‘lom raqobat muhiti yaratadi [4].

Sun’iy intellekt asosida ishlaydigan masofaviy ta’lim platformalari o‘quvchilar bilimlarini tahlil qiladi, statistik ma’lumotlarni yig‘adi, o‘quv natijalarini real vaqtda ko‘rsatadi. Bu o‘z navbatida ta’lim jarayonini rejalashtirish, yangi mazmun kiritish, ilg‘or metodlarni sinash imkoniyatini beradi. Yuqori darajada moslashuvchan o‘qitish tizimi natijasida har bir o‘quvchi o‘ziga mos individual dastur bo‘yicha darslarni o‘zlashtiradi. O‘qituvchilar uchun ham sun’iy intellekt asosidagi vositalar yangi yondashuvlarni sinash, creative modullarni ishlab chiqish, o‘quvchilar faoliyatini kuzatish, qisqa vaqt ichida ularning natijasini tahlil qilish imkonini beradi. Masofaviy ta’limda sun’iy intellektdan foydalanish tizimi yordamida, an’anaviy ta’limda uchraydigan muloqot cheklovi bartaraf bo‘ladi. O‘quvchilar yoki talabalar platformada o‘zlari uchun qulay vaqtda dars olishi mumkin, savollarga tezkor javob oladi, o‘qituvchi bilan aloqa o‘rnatadi, zarur manbalardan foydalanadi. Onlayn platformada yaratilgan aqliy vositalar test natijalarini avtomatik tahlil qiladi, bilimdagi bo‘shliqlarni aniqlaydi, yangi

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mashqlar beradi. Shu tariqa o‘quv jarayonining dinamikasi va natijalari real zamon rejimida aks etadi. Masofaviy ta’limda zamonaviy sun’iy intellekt yordami bilan barcha muhim ko‘rsatkichlar monitoring qilinadi, har bir ishtirokchi o‘z natijalarini kuzatadi [5].

Mazkur tizim o‘qituvchilar uchun ham qulayliklar yaratadi. Dars mazmuni, metodik materiallar, baholash uslublari, savol-javob tizimi avtomatik tarzda yangilanadi. O‘qituvchilar uchun tizimli tahlil, natijalarni baholash, o‘quvchilarning bilimini rivojlantirishga doir yangi usullar ishlab chiqiladi. Bularning hammasi ta’lim sifatini, darslarning samaradorligini oshirishda muhim vositadir. Masofaviy ta’limdagi sun’iy intellekt vositalari o‘zida nafaqat ta’limni soddalashtirish, balki individual yondashuv, interaktivlik, bilimlarni monitoring qilish, bilimlardagi bo‘shliqlarni aniqlash, ijtimoiy moslashuvchilik va innovatsion rivojlanishni ta’minlash kabi muhim ustunliklarini mujassam etadi. O‘quv jarayonida o‘qituvchi va o‘quvchi aloqasining yangi shakllari yaratiladi, innovatsion texnologiya o‘quvchilarning mustaqil o‘qishini, shaxsiy salohiyatini rivojlantirish imkoniyatini beradi. Masofaviy ta’limda sun’iy intellekt yordamida yaratilgan tizimlar o‘qituvchilar uchun ham, o‘quvchilar uchun ham motivatsion muhit yaratadi. Yangi bilim va ko‘nikmalar tez va samarali o‘zlashtiriladi, har bir ishtirokchi uchun individual yondashuv shakllanadi. Ilg‘or texnologiyalarning keng joriy etilishi esa ta’lim sifati hamda natijasini oshirishda, raqobatbardosh kadrlarni tayyorlashda asosiy vosita bo‘lib xizmat qiladi. Innovatsion ta’lim metodikalari, shaxsiy yondashuv, zamonaviy bilim tahlili va monitoring, ta’lim oluvchilar uchun ijtimoiy muhit yaratish kabi ustunliklari bilan masofaviy ta’lim tizimi kelajakda ham uzluksiz rivojlanib boradi. Masofaviy ta’limda sun’iy intellektdan samarali foydalanish natijasida, nafaqat o‘qituvchi va o‘quvchi uchun qulayliklar yaratiladi, balki ta’lim tizimida sifat va natijadorlik, zamonga moslashuvchanlik darajasi ham oshadi. Davlat va xususiy tashkilotlar tomonidan masofaviy ta’lim tizimi uchun moliyaviy, texnik va ilmiy sarmoya yo‘naltiriladi. Jahon tajribasida ham masofaviy ta’lim va sun’iy intellekt imkoniyatlari zamonaviy fan va texnika taraqqiyoti uchun muhim deb baholanmoqda. Shu nuqtai nazardan, masofaviy ta’limda sun’iy intellektdan foydalanish samaradorligi doimiy yangilanayotgan, innovatsion ta’lim modelini shakllantirishda asosiy omil hisoblanadi. Bunday yondashuv nafaqat zamonaviy bosqichda, balki kelajakda ham ta’lim strategiyasini ishlab chiqish va amalga oshirishda yetakchi kuch bo‘lib qoladi. Sun’iy intellektdan foydalangan holda oliy va maktab ta’limi integratsiyasi, ixtisoslashtirilgan kurslar, texnik va professional sohalarda yuqori natijalarga erishiladi. Keng qamrovli, ochiq va sifatli ta’lim platformalari yordamida zamonaviy jamiyat karvoni ilg‘or kadrlarga, chuqur bilimga, innovatsion

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yondashuvlarga ega bo‘ladi. Natijada, masofaviy ta’lim tizimi va sun’iy intellekt imkoniyatlaridan samarali foydalanish nafaqat ta’lim tizimini, balki butun jamiyat tarakkiyotini olg‘a siljitadi [6].

XULOSA.

Zamonaviy ta’lim tizimida ilg‘or texnologiyalar, ayniqsa sun’iy intellektdan foydalanish natijasida masofaviy ta’limning samaradorligi sezilarli darajada oshdi. O‘quvchilar uchun individual dasturlar, interaktivlik, bilimlarni monitoring qilish, avtomatik baholash, yangi metodlarning sinovdan o‘tkazilishi imkoniyatlarini yanada kengaytirdi. Shu sababli, kelajakda ta’lim sohasida sun’iy intellekt imkoniyatlaridan foydalanish nafaqat o‘qituvchi va o‘quvchi uchun qulayliklar, balki jamiyat taraqqiyoti uchun ham asosiy omil sifatida muhim bo‘lib qoladi.

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O‘SIMLIK BIOMASSASIDAN OLINGAN SORBENTGA CR (VI) IONLARI SORBSIYASI.

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Annotatsiya. Ushbu maqolada qishloq xo‘jaligining asosiy chiqindilari sholi, mosh, loviya va kungaboqar qobiqlardan sarbent olish tahlil qilinadi. Bunda chiqindilarning afzalliklari va kamchiliklari ko‘rib chiqiladi. Olingan sarbentlarning suv ifloslantiruvchi moddalarni zaharli metal ioni hisoblanagan dixramat ionini yutish miqdori aniqlangan hamda mavjud biosorbentlarga nsibatan solishtirilgan. Yutilgan dixramat ioni miqdorini hisobda aniq konsentratsiyali eritma konsentratsiyasini UV-1800 spektrofotometrdagi qiymatlari asosida kolibrofkalangan grafikdan foydalanilgan.

Kalit so‘zlar: Qishloq xo‘jaligi chiqindilari, sholi, loviya, mosh, kungaboqar, suvni tozalash.

Аннотация. В данной статье анализируется производство сорбентов из основных сельскохозяйственных отходов: рисовой, машевой, бобовой и подсолнечной шелухи. Рассматриваются преимущества и недостатки отходов. Определено количество поглощенного дихромат-иона, токсичного иона металла, полученными сорбентами и проведено сравнение с существующими биосорбентами. Количество поглощенного дихромат-иона рассчитывалось с использованием графика, откалиброванного на основе значений концентрации раствора с заданной концентрацией в спектрофотометре UV-1800.

Ключевые слова: Сельскохозяйственные отходы, рис, бобы, маш, подсолнечник, очистка воды.

Abstract. This article analyzes the production of sorbents from the main agricultural wastes of rice, mung, beans and sunflower husks. The advantages and disadvantages of the wastes are considered. The amount of absorption of dichromate ion, a toxic metal ion, by the obtained sorbents was determined and compared with existing biosorbents. The amount of absorbed dichromate ion was

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calculated using a graph calibrated based on the values of the concentration of the solution with a specific concentration in the UV-1800 spectrophotometer.

Keywords: Agricultural waste, rice, beans, mung beans, sunflower, water purification.

1.KIRISH.

So‘nggi yillarda sanoat korxonalarining suv havzalariga katta miqdorda ifloslantiruvchi moddalarni tashlashi suv resurslarining ifloslanishini jiddiy global muammoga aylantirdi[3,10]. Sanoat korxonalarining ortishi, aftomobilsozlik, konmetallurgiya zavodlarining ortishi va shu kabilar suvni ifloslanishida salmoqli o‘rin egallaydi. Ushbu holat inson salomatligi va atrof-muhit uchun sezilarli xavf tug‘dirib, suvni tozalashning samarali va barqaror texnologiyalarini ishlab chiqish zaruratini yuzaga keltirdi[2,3]. Suv va oqava suvlarni tozalashda qo‘llanilayotgan usullar orasida adsorbsiya texnologiyasi yuqori samaradorligi, moslashuvchanligi va iqtisodiy jihatdan maqsadga muvofiqligi sababli eng istiqbolli yondashuvlardan biri hisoblanadi[2,5]. Adsorbsiya jarayonida ifloslantiruvchi moddalar adsorbent material yuzasiga bog‘lanib, suv muhitidan samarali tarzda ajratib oladi[6]. An’anaviy adsorbent materiallar bilan solishtirilganda, biosorbentlar va yashil adsorbentlar qayta tiklanuvchi xomashyo manbalaridan olinishi, ekologik xavfsizligi va past tannarxi bilan ajralib turadi[2,6]. Biosorbentlar asosan o‘simlik asosidagi materiallar, qishloq xo‘jaligi chiqindilari hamda boshqa tabiiy biomassalardan tayyorlanadi[5,9]. Ushbu materiallar kimyoviy yoki termik modifikatsiya orqali yuqori adsorbsion qobiliyatga ega bo‘lib, og‘ir metallar, bo‘yoqlar va organik ifloslantiruvchi moddalarni samarali ushlab qolish imkonini beradi 1,5]. Atrof-muhitni ifloslantiruvchi moddalar, xususan, sanoat oqava suvlari tarkibidagi og‘ir metallar va toksik birikmalar suv ekotizimlari hamda inson salomatligi uchun eng xavfli omillardan biri bo‘lib qolmoqda[3,8]. Ushbu moddalar tabiiy suv manbalariga tushganda suv sifatini keskin yomonlashtiradi va uzoq muddatli ekologik oqibatlarga olib keladi[3]. Suv ifloslanishi tabiiy jarayonlar bilan bir qatorda antropogen faoliyat natijasida ham yuzaga keladi. Qishloq xo‘jaligida qo‘llaniladigan o‘g‘itlar va pestitsidlarning suv havzalariga oqib kirishi eutrofikatsiya jarayonlarini kuchaytiradi, sanoat chiqindilari esa og‘ir metallar va boshqa zaharli moddalar bilan ifloslanishga sabab bo‘ladi[3,10]. Shuningdek, noto‘g‘ri chiqindilarni yo‘q qilish va oqava suvlarni yetarli darajada tozalanmasligi patogen mikroorganizmlarning tarqalishiga olib keladi[2]. Suv ifloslanishini kamaytirish va nazorat qilish uchun biologik, fizik va kimyoviy usullar qo‘llaniladi. Biologik usullar organik moddalarni parchalaydi, kimyoviy usullar esa koagulyatsiya, flokulyatsiya va dezinfeksiya jarayonlarini o‘z ichiga oladi[10]. Zamonaviy texnologiyalar orasida membrana filtratsiyasi,

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fotooksidlanish va faollashtirilgan uglerod asosidagi adsorbsiya jarayonlari keng qo‘llanilmoqda[4,5]. So‘nggi yillarda qishloq xo‘jaligi chiqindilaridan tayyorlangan adsorbentlar suvni tozalash sohasida alohida e’tiborga sazovor bo‘lmoqda. Ushbu chiqindilar yuqori sirt maydoni va g‘ovakli tuzilishga ega bo‘lib, og‘ir metallar, bo‘yoqlar va organik ifloslantiruvchilarni samarali adsorbsiyalash imkonini beradi[5,9]. Bundan tashqari, agrochiqindilardan adsorbent sifatida foydalanish ekologik jihatdan xavfsiz va iqtisodiy samarali bo‘lib, qimmat sintetik adsorbentlarga munosib muqobil hisoblanadi[2,5]. Shu sababli, zamonaviy tadqiqotlar an’anaviy usullarning kamchiliklarini bartaraf etishga qaratilgan barqaror va samarali yechimlarni izlashga yo‘naltirilmoqda. Bu borada respublikamizda keng tarqalgan sholi, mosh, loviya va kungaboqar qobiqlari kabi qishloq xo‘jaligi chiqindilaridan foydalanish katta ilmiy va amaliy ahamiyatga ega[1,5]. Ushbu chiqindilar tarkibidagi sellyuloza gemisllyuloza va lignindan tashkil topgan bo‘lib, turli xil funksiyanal guruhlar: korbanil (-C=O), gidrosil (-OH) guruhlar mavjud. Ularni kimyoviy modifikatsiya orqali og‘ir metallar va boshqa ifloslantiruvchi moddalarni yuqori samaradorlik bilan bog‘lay oladigan adsorbsion materiallarga aylantirish imkonini beradi[1,7]. Mazkur yondashuv ikki tomonlama ekologik foyda keltiradi: bir tomondan, qishloq xo‘jaligi chiqindilarini qayta ishlash orqali atrof-muhitga tushadigan yukni kamaytiradi, ikkinchi tomondan esa import qilinadigan qimmat adsorbentlarga nisbatan arzon, mahalliy va barqaror muqobil yaratadi[5,9]. Ushbu maqolada yuqorida qayd etilgan agrochiqindilar asosida biosorbentlar olish usullari, ularning fizik-kimyoviy xossalari hamda suvni tozalashdagi samaradorligi qiyosiy tahlil qilinadi. Tadqiqotning asosiy maqsadi ifloslangan suv manbalarini tozalash uchun samarali, iqtisodiy jihatdan maqbul va ekologik toza texnologik yechim ishlab chiqishdan iborat[10].

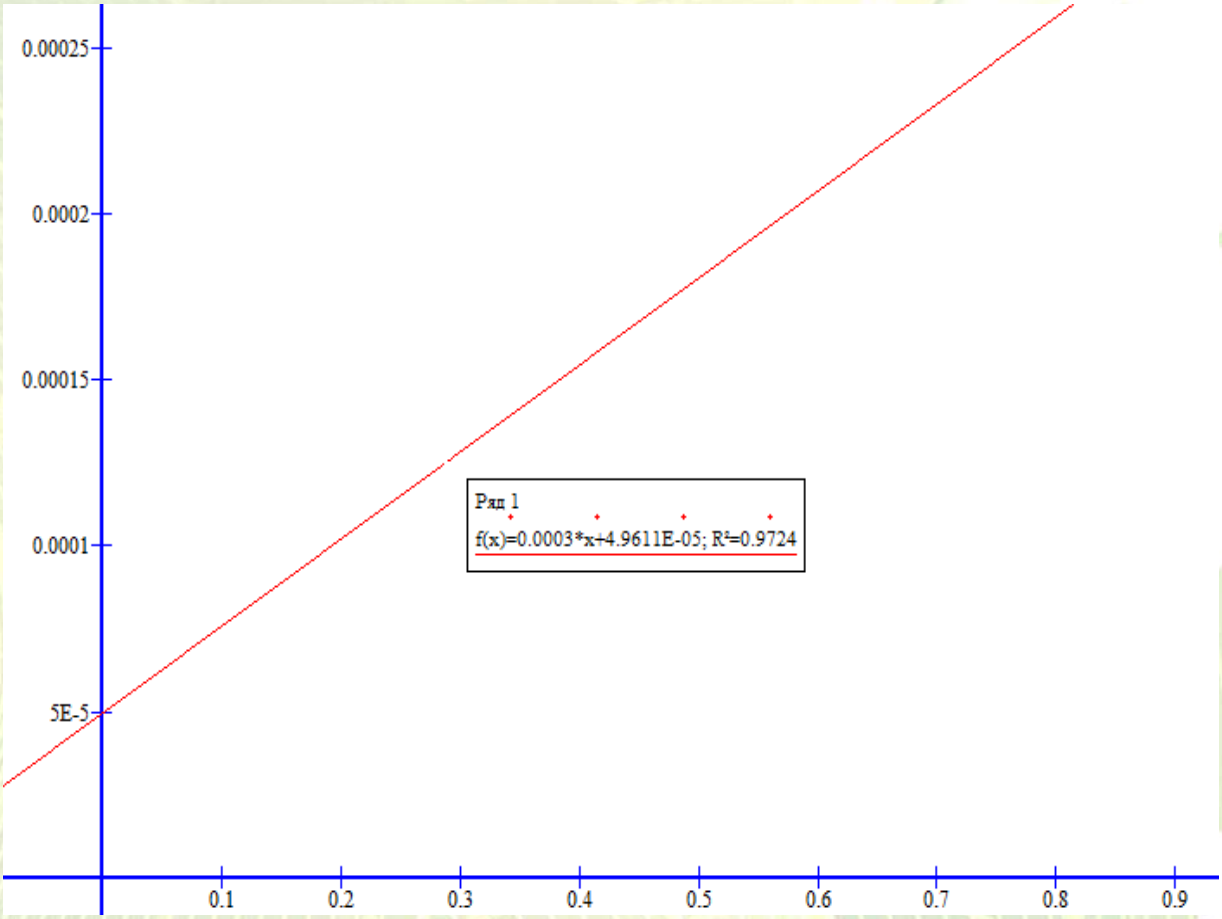
MATERALLAR. Sholi, mosh, loviya, kungaboqar qobiqlari. NaOH eritmasi, konsentrlanagan H_3PO_4, $K_2Cr_2O_7$ ning suvdagi turli xil konsentratsiyali eritmasi, distirlangan suv.

METODLAR. Respublikamizda yiliga millionlab tonna hosil bo‘ladigan sholi po‘chog‘i chiqindisidan yuqori qo‘shimcha qiymat yaratish, uni qayta ishlash orqali atrof-muhit yukini kamaytirish va tashqi mamlakatlardan keltiriladigan yuqori narxli sintetik adsorbentlar o‘rnini bosadigan barqaror, mahalliy ishlab chiqarilgan sorbent yaratish ushbu tadqiqotning asosiy maqsadlaridan biri edi. Tadqiqotimizda sholi po‘chog‘i asosida biosorbent tayyorlandi. Buning uchun tegirmonlardan yig‘ib olingan sholi po‘chog‘i mexanik aralashmalardan tozalandi va 3% li NaOH eritmasida faollashtirildi, so‘ngra neytral holatga kelguncha yuvishtirildi. Tayyor sholi po‘chog‘i 60°C da quritildi va 85% li H_3PO_4 konsentratli

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eritmasida 30 daqiqa davomida modifikatsiya qilindi. Hosil bo‘lgan mahsulot distillyangan suvda neytral holatgacha yuvish jarayonidan o‘tkazildi.

NATIJA. Olingan biosorbentga dixromat ionlarining sorbsiyasi o‘rganilganda, uning 216 mg/g sig‘imga ega ekanligi aniqlandi. Bu natija mavjud sintetik adsorbentlarga nisbatan yuqori samaradorlikni ko‘rsatdi (1-jadval). Dixramat ioni miqdorini aniqlashda dastlab aniq konsentratsiyali eritmalarning UV-1800 dagi spektrdagi nur sindirish ko‘rastgich qiymatlari asosida kalibrofkali grafik chizib olindi (1-rasm).



1-rasm. Kaliy dixramat eritmasi konsentratsiyasining nur sindirish ko‘rsatgichiga bog‘liqlik grafigi.

1-Jadval.

№	O‘simlik chiqindisi	Madifikator	$Cr_2O_7^{2-}$ ni yutgan miqdori (mg/g)	Adabiyot
1	Sholi qobigi‘i	H_3PO_4	216	Ushbu tadqiqot
2	Sholi qobigi‘i	NaOH bilan faollashtirish	86.4	Ushbu tadqiqot

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3	Sholi qobigi‘idan olingan sellyuloza	H_3PO_4 bilan aktivlashtirish	153.5	11
4	Mosh qobigi‘i	H_3PO_4 bilan aktivlashtirish	149.8	12
5	Mosh qobigi‘i	To‘g‘ridan-to‘g‘ri karbonizatsiya	68.5	13
6	Loviya qobigi‘i	$ZnCl_2$	185.2	14
7	Loviya qobigi‘i	H_2SO_4	98.3	15
8	Kungaboqar qobigi‘i	KOH bilan aktivlashtirish	210.4	16
9	Kungaboqar qobigi‘i	To‘g‘ridan-to‘g‘ri karbonizatsiya	91.7	17
10	Faollashtirilgan ko‘mir	An'anaviy savdo mahsuloti	110.2	18
11	Mosh qobigi‘i	$FeCl_3$ bilan modifikatsiya	178.3	19
12	Loviya qobigi‘i	KOH,bilan aktivlashtirish	162.7	20

Sholi qobig‘i ishqor bilan aktivlab distillangan suvda neytral xolatgacha yuvilganda uning dixramat ionlarini 86.4 mg/g yutgan bo‘lsa, fosfat kislota bilan modifikatsiyalangandan so‘ng esa 216 mg/gr ga oshdi . Bu H_3PO_4 bilan modifikatsiyaning biosorbentning sirt maydonini kengaytirishi va unga dixromat ionlari uchun qo‘shimcha bog‘lanish joylari yaratishi natijasidir. Shu bilan birga, ushbu biosorbentning yuqori samaradorligi va qayta tiklanuvchi xom ashyodan tayyorlanishi uni sanoat miqyosida suvni tozalash uchun ekologik toza va barqaror yechimga aylantirish imkoniyatini ochib beradi. Bundan tashqari, olingan biosorbent mavjud bisorbentlar bilan taqqoslaganda raqobatbardoshligini ifodalaydi.

XULOSA. Ushbu tadqiqot Respublikamizda keng tarqalgan sholi qobig‘i chiqindisidan yuqori samaradorlikka ega biosorbent olishning muvaffaqiyatli yo‘lini taklif qiladi. Olingan natijalar ushbu materialni suvni og‘ir metallardan tozalashda hamda arzon va ekologik toza texnologik yechim sifatida rivojlantirish uchun mustahkam asos yaratadi.

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SYNTHESIS OF N-(5-ETHYL-1,3,4-THIADIAZOL-2-YL)BENZAMIDE AND EVALUATION OF THE ANTI-TERMITE ACTIVITY OF 2-AMINO-5-ALKYL-1,3,4-THIADIAZOLE DERIVATIVES

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Abstract. This study investigated the synthesis of N-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide and evaluated the anti-termite activity of several 2-amino-5-ethyl-1,3,4-thiadiazole derivatives against worker termites. The biological activity of the compounds was assessed using filter paper treated with 0.02% aqueous solutions of the test substances. Each treatment was tested on 100 worker termites under laboratory conditions, and mortality was recorded from 3 to 14 days. Among the tested compounds, 2-amino-5-ethyl-1,3,4-thiadiazole showed the fastest effect, causing 100% mortality by day 10**,** whereas the other derivatives demonstrated a more prolonged toxic action. The synthesis of **N**-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide was optimized in different solvent media. The highest yield (94.4%**)** was obtained in acetone, while lower yields were recorded in tetrahydrofuran, chloroform, and acetonitrile. The results indicate that thiadiazole derivatives are promising candidates for developing effective and environmentally safer termiticidal agents.

Keywords: 1,3,4-thiadiazole derivatives; termiticidal activity; worker termites; N-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide; solvent optimization.

Аннотация. В данном исследовании изучался синтез N-(5-этил-1,3,4-тиадиазол-2-ил)бензамида и оценивалась противотермитная активность нескольких производных 2-амино-5-этил-1,3,4-тиадиазола против рабочих термитов. Биологическая активность соединений оценивалась с помощью фильтровальной бумаги, обработанной 0,02% водными растворами исследуемых веществ. Каждая обработка тестировалась на 100 рабочих термитах в лабораторных условиях, а смертность регистрировалась в течение 3–14 дней. Среди протестированных соединений 2-амино-5-этил-1,3,4-тиадиазол показал наиболее быстрый эффект, вызывая 100% смертность к 10-му дню, в то время как другие производные продемонстрировали более

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длительное токсическое действие. Синтез N-(5-этил-1,3,4-тиадиазол-2-ил)бензамида был оптимизирован в различных растворителях. Наибольший выход (94,4%) был получен в ацетоне, тогда как более низкие выходы были зафиксированы в тетрагидрофуране, хлороформе и ацетонитриле. Результаты показывают, что производные тиадиазола являются перспективными кандидатами для разработки эффективных и экологически безопасных средств против термитов.

Ключевые слова: производные 1,3,4-тиадиазола; термитоцидная активность; рабочие термиты; N-(5-этил-1,3,4-тиадиазол-2-ил)бензамид; оптимизация растворителя.

Annotatsiya. Ushbu tadqiqotda N-(5-etil-1,3,4-tiadiazol-2-il)benzamid sintezi o‘rganildi va bir nechta 2-amino-5-etil-1,3,4-tiadiazol hosilalarining ishchi termitlarga qarshi antitermit faolligi baholandi. Birikmalarning biologik faolligi sinov moddalarining 0,02% suvli eritmalari bilan ishlov berilgan filtr qog‘ozi yordamida baholandi. Har bir ishlov berish laboratoriya sharoitida 100 ta ishchi termitda sinovdan o‘tkazildi va o‘lim 3-14 kun ichida qayd etildi. Sinovdan o‘tgan birikmalar orasida 2-amino-5-etil-1,3,4-tiadiazol eng tez ta'sir ko‘rsatdi, 10-kunga kelib 100% o‘limga olib keldi, boshqa hosilalar esa uzoqroq toksik ta'sir ko‘rsatdi. N-(5-etil-1,3,4-tiadiazol-2-il)benzamid sintezi turli erituvchilarda optimallashtirildi. Eng yuqori hosil (94,4%) asetonda olingan, tetragidrofuran, xloroform va asetonitrilda esa pastroq hosil qayd etilgan. Natijalar shuni ko‘rsatadiki, tiadiazol hosilalari samarali va ekologik toza termitlarga qarshi vositalarni ishlab chiqish uchun istiqbolli nomzodlardir. Ushbu tadqiqotda 2-amino-5-etil-1,3,4-tiadiazol hosilalarining sintezi o‘rganildi va ularning ishchi termitlarga qarshi antitermit faolligi baholandi. Birikmalarning biologik faolligi sinov moddalarining 0,02% suvli eritmalari bilan ishlov berilgan filtr qog‘ozi yordamida baholandi. Har bir ishlov berish laboratoriya sharoitida 100 ta ishchi termitda sinovdan o‘tkazildi va o‘lim 3-14 kun ichida qayd etildi. Sinovdan o‘tgan birikmalar orasida 2-amino-5-etil-1,3,4-tiadiazol eng tez ta'sir ko‘rsatdi, 10-kunga kelib 100% o‘limga olib keldi, boshqa hosilalar esa uzoqroq toksik ta'sir ko‘rsatdi. N-(5-etil-1,3,4-tiadiazol-2-il)benzamid sintezi turli erituvchilarda optimallashtirildi. Eng yuqori natija atseton (94,4%) muhitida kuzatildi. Tetragidrofuran, xloroform va asetonitrilda esa pastroq unumni qayd etilgan. Natijalar shuni ko‘rsatadiki, tiadiazol hosilalari samarali va ekologik toza termitlarga qarshi vositalarni ishlab chiqish uchun istiqbolli nomzodlardir.

Kalit so‘zlar: 1,3,4-tiadiazol hosilalari; termitsid faolligi; ishchi termitlar; N-(5-etil-1,3,4-tiadiazol-2-il)benzamid; erituvchini optimallashtirish.

INTRODUCTION.

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Termites are among the most destructive cellulose-feeding insects in natural, agricultural, and urban environments, where they damage wood, plant-derived materials, and other cellulose-containing substrates [1, 10-15,16]. Modern termite management increasingly emphasizes bait-based strategies, because slow-acting toxicants may be transferred among workers through social interactions and feeding[8], thereby contributing to colony-level suppression rather than only rapid mortality of exposed individuals. Recent termite-control literature continues to describe baits as a major targeted control approach[5,6,8]. In the search for new biologically active agents, heterocyclic compounds occupy a prominent place because relatively small structural modifications can markedly alter their physicochemical and biological properties. Among them, 1,3,4-thiadiazole derivatives have attracted considerable attention due to their broad spectrum of biological activities [3], including pesticidal and insecticidal potential [2,4,7,9]. Reviews of this scaffold describe it as a versatile platform for the design of biologically active compounds and note its relevance in pesticide development. In the present study, attention was focused on 2-amino-5-ethyl-1,3,4-thiadiazole derivatives as potential anti-termite agents. According to the our experiments, several compounds were evaluated against worker termites using filter paper treated with 0.02% aqueous solutions, with mortality recorded over 3–14 days and corrected using Abbott's formula. The same study also examined the synthesis of N-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide in different solvent media in order to determine the most effective reaction conditions. Our data show that 2-amino-5-ethyl-1,3,4-thiadiazole produced the fastest mortality response, whereas the benzamide, toluenesulfonamide, and monochloroacetamide derivatives showed a more prolonged effect; in the synthesis section, acetone gave the highest product yield. Therefore, the aim of this work was to synthesize N-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide under different solvent conditions and to evaluate the anti-termite activity of selected 2-amino-5-ethyl-1,3,4-thiadiazole derivatives under laboratory conditions. The obtained results may contribute to the development of new thiadiazole-based compounds as promising candidates for environmentally safer termite management. 1,3,4-Thiadiazole derivatives are considered promising biologically active compounds due to their wide range of pesticidal and insecticidal properties. The search for new termiticidal agents based on heterocyclic compounds remains an important direction in the development of environmentally safer termite control strategies. In this context, 2-amino-5-ethyl-1,3,4-thiadiazole derivatives are of particular interest because structural modification of the amino group may influence both their biological activity and physicochemical properties. The present study was aimed at two main objectives:

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first, to investigate the synthesis of N-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide under different solvent conditions; and second, to evaluate the anti-termite activity of several 2-amino-5-ethyl-1,3,4-thiadiazole derivatives against worker termites.

MATERIALS AND METHODS.

Evaluation of anti-termite activity

The anti-termite activity of 2-amino-5-ethyl-1,3,4-thiadiazole derivatives was evaluated by determining the amount of filter paper consumed by termites when the compounds were offered as food. Filter paper pieces (2 × 2 cm) were soaked either in solutions of the test compounds or in distilled water in the control treatment. The treated filter papers were then placed into sterilized Petri dishes containing 100 worker termites. During the experiments, the Petri dishes were kept in a dark place. At scheduled observation times, the dishes were removed for recording the condition of the termites, the amount of filter paper consumed, and the numbers of live, paralyzed, and dead individuals. Throughout the experiment, the termites were supplied with distilled water. The tests lasted from 3 to 14 days. Both experimental and control treatments were performed in five replicates. Mortality percentages were calculated using Abbott's formula, taking into account mortality in the control group.

Test compounds and concentration

To study the termiticidal properties of the synthesized compounds, 100 termite individuals were used in each experiment. The compounds were dissolved in water to prepare 0.02% solutions, and their biological efficacy was then assessed under the same experimental conditions.

Synthesis of N-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide

Within the scope of the study, the acylation of the amino group of 2-amino-5-ethyl-1,3,4-thiadiazole was investigated in different solvent media. Benzoyl chloride was used as the acylating agent. The reaction was carried out in tetrahydrofuran, chloroform, acetonitrile, and acetone, and the effect of the reaction medium on product yield was comparatively analyzed.

RESULTS AND DISCUSSION.

Anti-termite activity of 2-amino-5-ethyl-1,3,4-thiadiazole derivatives

The results on the effect of 2-amino-5-ethyl-1,3,4-thiadiazole derivatives on the viability of worker termites are presented in Table 1. The compounds showed different levels of biological activity at a concentration of 0.02%. A 0.02% solution of compound I (2-amino-5-ethyl-1,3,4-thiadiazole) caused termite mortality of 59.9% on day 3, 90.3% on day 7, and 100.0% on day 10. A 0.02% solution of compound II, N-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide, caused termite mortality of 54.8% on day 3, 75.0% on day 7, 88.1% on day 10, and 97.9% on day

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14. A 0.02% solution of compound III, N-(5-ethyl-[1,3,4]thiadiazol-2-yl)-toluenesulfonamide, caused termite mortality of 49.2% on day 3, 70.4% on day 7, 82.5% on day 10, and 93.2% on day 14. A 0.02% solution of compound IV, N-(5-ethyl-1,3,4-thiadiazol-2-yl)monochloroacetamide, caused termite mortality of 35.0% on day 3, 73.0% on day 7, 85.9% on day 10, and 89.1% on day 14. Overall, the results show that all tested compounds exhibited anti-termite activity, although the rate and duration of their effects differed. Compound I acted faster and reached complete mortality by day 10, while compounds II, III, and IV showed prolonged effects over 14 days. According to your draft, this longer action may be important because a slower-acting bait has a greater chance of being distributed within the termite colony and eventually reaching the queen, thereby contributing to colony suppression.

Synthesis of N-(5-ethyl-1,3,4-thiadiazol-2-yl) benzamide in different solvents The solvent had a substantial effect on reaction efficiency.

In tetrahydrofuran, the reaction of 2-amino-5-ethyl-1,3,4-thiadiazole with equimolar benzoyl chloride in the presence of pyridine was first performed at room temperature for 1 hour and then at 55–65 °C for 2.5–3 hours. The product yield was 60%, indicating relatively low efficiency. In chloroform, the reaction was initially carried out at 0 °C for 1 hour and then at 55–60 °C for 2–3 hours. Under these conditions, the yield increased to 78.2%, although side reactions may still have occurred. In acetonitrile, reducing the reaction temperature to 75–80 °C and shortening the reaction time to 2–3 hours gave a yield of 86%, suggesting moderate efficiency but no clear specific advantage for this system. In acetone, the highest yield was obtained. The reaction started at 50–56 °C and was completed in a water bath over 2–3 hours. Under these conditions, the product yield reached 94.4%, making acetone the most effective medium among those tested.

Table-1.

Anti-termite activity of 2-amino-5-ethyl-1,3,4-thiadiazole derivatives at 0.02% concentration against worker termites

Compound	Chemical name	Mortality on day 3 (%)	Mortality on day 7 (%)	Mortality on day 10 (%)	Mortality on day 14 (%)
I	2-amino-5-ethyl-1,3,4-thiadiazole	59.9	90.3	100.0	—
II	N-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide	54.8	75.0	88.1	97.9

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III	N-(5-ethyl-[1,3,4]thiadiazol-2-yl)-toluenesulfonamide	49.2	70.4	82.5	93.2
IV	N-(5-ethyl-1,3,4-thiadiazol-2-yl)monochloroacetamide	35.0	73.0	85.9	89.1

Note. Each treatment was tested on 100 worker termites using 0.02% aqueous solutions; mortality was recorded over 3–14 days.

Table 2.

Effect of solvent on the synthesis yield of N-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide

Solvent	Reaction conditions	Yield (%)
Tetrahydrofuran	Room temperature, 1 h; then 55–65 °C for 2.5–3 h	60.0
Chloroform	0 °C, 1 h; then 55–60 °C for 2–3 h	78.2
Acetonitrile	75–80 °C for 2–3 h	86.0
Acetone	50–56 °C, water bath, 2–3 h	94.4

Identification and purity of the synthesized product

Thin-layer chromatography analysis of the products obtained by all methods showed the same retention factor, Rf = 0.51 in a benzene: acetone (2:1) solvent system, indicating that the products were chemically identical. Recrystallization from alcohol provided a highly pure material. In addition, IR spectroscopy revealed characteristic absorption bands of the amide group, confirming the expected monomeric structure of the synthesized compound.

CONCLUSION

The results demonstrated that 2-amino-5-ethyl-1,3,4-thiadiazole derivatives possess significant anti-termite activity against worker termites. At a concentration of 0.02%, all tested compounds caused substantial termite mortality, although their activity profiles differed in speed and persistence. Compound I produced the fastest mortality response, while compounds II, III, and IV showed longer-lasting effects, which may be advantageous for bait-based colony suppression. The solvent optimization study for the synthesis of N-(5-ethyl-1,3,4-thiadiazol-2-yl)benzamide showed that reaction yield depended strongly on the solvent medium. Among the solvents tested, acetone provided the best result, with a yield of 94.4%, and was therefore considered the most economically and technologically effective medium

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for synthesis. Further studies on structure–activity relationships are needed to clarify the mechanism of action of these compounds and to support the development of new, environmentally friendly termiticides based on thiadiazole derivatives.

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SANOAT OQOVA SUVLARINI TOZALASH JARAYONIDA HOSIL BO‘LADIGAN SHLAMLARNI QAYTA ISHLASH USULLARI

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Annotatsiya. Bugungi kunda ishlab chiqarish korxonalarining asosiy vazifalardan biri texnik va oqova suvlarni tozalab, texnologiyada aylanma suv sifatida foydalanish, kam chiqindili yoki chiqindisiz texnologiyalar yaratish, hosil bo‘ladigan chiqindilarni kompleks qayta ishlash va ulardan turli elementlar va boshqa foydali birikmalarni ajratib olish hisoblanadi.

Kalit so‘zlar: metallar, kimyoviy, sorbsiya, ekstraksiya, bug‘latish, chiqindi eritmalar, ion almashinish, elektrodializ, teskari osmos, ultrafiltratsiya, mishyak, selen, rux, palladiy, xrom, berilliy, qo‘rg‘oshin, simob, kobalt, nikel kadmiy, qo‘rg‘oshin, aluminiy, rux.

Аннотация. В настоящее время одной из основных задач промышленных предприятий является очистка технических и сточных вод с последующим их использованием в качестве оборотной воды в технологических процессах, создание малоотходных или безотходных технологий, комплексная переработка образующихся отходов, а также извлечение из них различных элементов и других полезных соединений.

Ключевые слова: металлы, химический, сорбция, экстракция, выпаривание, отходные растворы, ионный обмен, электродиализ, обратный осмос, ультрафильтрация, мышьяк, селен, цинк, палладий, хром, бериллий, свинец, ртуть, кобальт, никель, кадмий, свинец, алюминий, цинк.

Abstract. At present, one of the main tasks of industrial enterprises is the purification of technical and wastewater for their reuse as circulating water in technological processes, the development of low-waste or waste-free technologies, the integrated processing of generated wastes, and the extraction of various elements and other useful compounds from them.

Keywords: metals, chemical, sorption, extraction, evaporation, waste solutions, ion exchange, electrodialysis, reverse osmosis, ultrafiltration, arsenic, selenium, zinc, palladium, chromium, beryllium, lead, mercury, cobalt, nickel, cadmium, lead, aluminum, zinc.

KIRISH

Sanoat va maishiy oqova suvlarni qayta ishlash natijasida muallaq holdagi qattiq chiqindilarga boy bo‘lgan suspenziyalar va ularni suvsizlantirish natijasida

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shlamlar hosil bo‘ladi. Sanoat oqova suvlarini tozalash natijasida hosil bo‘ladigan cho‘kmalardan ayniqsa, kimyoviy va galvanik korxonalarda hosil bo‘ladigan shlamlardan rangli va noyob metallarning turli birikmalarini ajratib olishga ko‘pgina korxonalar e’tiborsiz qarashadi. Sanoatda chiqindi eritmalarni qayta ishlashda hosil bo‘lgan shlamlari tarkibidagi turli metallar birikmalarining miqdori asosan korxona quvvatiga va metallarni qoplash usullariga bog‘liq bo‘ladi.

Sanoat chiqindi shlamlarni chiqindixonalarga tashlash maxsus chiqindixonalarda o‘rnatilgan tartiblar asosida amalga oshiriladi. Sanoat korxonasi xududida esa bunday chiqindilarni vaqtincha saqlashga ruxsat etiladi, lekin bu xolda quyidagi shartlarga amal qilinishi kerak:

- havodagi zararli moddalarning miqdori ruxsat etilgan meyorlarning 30% dan oshmasligi kerak;

- zararli moddalarning yer osti suvlaridagi miqdori yer usti suvlarida ruxsat etilgan meyorlardan oshmasligi kerak;

- chiqindi saqlanadigan maydonlarning usti yopilgan bo‘lishi kerak.

Sanoat korxonalari chiqindilarining utilizatsiyasi rangli va boshqa metallarni ishlab chiqarishga qayta ishlash mumkin bo‘lgan birikma holida maksimal qaytarish va atrof muxitga zararli oqova suvlarning tashlanishini kamaytirish.

Sanoatda shlamlar asosan suyuq chiqindilardan iborat bo‘lgan detallarni yuvuvchi suvlar, ishlatilib bo‘lgan chiqindi eritmalar, ion almashinish, elektrodializ, teskari osmos, ultrafiltratsiya, sorbsiya, ekstraksiya, bug‘latish, shuningdek diafragmali elektroliz jarayonlarida hosil bo‘ladigan yuvuvchi suvlar hamda regeneratsiya qilish eritmalari va konsentratsiyalarini qayta ishlash natijasida hosil bo‘ladi.

Qattiq chiqindilar esa chiqindi suvlarni reagent usulida, elektrokoagulyatsiya, galvanokoagulyatsiya, elektroflotatsiya va to‘g‘ridan to‘g‘ri elektroliz qilish jarayonlarida hosil bo‘ladi.

Oqova suvlarni reagent usulida tozalash sanoatda keng qo‘llaniladi va bu usul og‘ir metall ionlarini: gidroksidlar, karbonatlar, ba’zan og‘ir metall sulfidlari, kalsiy, magniy va temir birikmalariga o‘tkazishga asoslangan.

Shlamlarni reagent usulida tozalanganda ularning tarkibidagi metallarning miqdori muayyan ishlab chiqarishda qo‘llaniladigan komponentlar, eritmalar va tozalash inshootlarida qo‘llaniladigan kimyoviy reaktivlarga bog‘liq.

Mavjud sanoat oqova suvlarini turli usullarda tozalash jarayonida hosil bo‘ladigan shlamlar tahlil qilinganda ular asosan havflilik darajasining 3-sinfiga (kam havfli) mansub ekanligi aniqlangan, lekin og‘ir metallarning miqdoriga qarab, havflilik darajasining (II) sinfiga (havfli) ham mansub bo‘lishi mumkin.

Sanoat chiqindixonalaridan og‘ir metallarning atrof-muhitga tarqalishi agar

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chiqindixona ochiq bo‘lsa shamol ta’sirida, yoki atmosfera yog‘inlari ta’sirida sodir bo‘lishi mumkin. Kislotali yomg‘irlar oxakli materiallarni, g‘isht, beton va metall konstruksiyalarning yemirilishiga olib keladi. Og‘ir metallarning birikmalari neytral muhitda amalda erimaydi, lekin kislotali muhitda eruvchan va faol ko‘rinishga o‘tadi va to‘siqlarning buzilishi natijasida atrof-muhitga tarqalishi mumkin. Chiqindixonalardagi komponentlarning yer osti suvlariga o‘tib ketish samarasi ularning maydalanish darajasi, havo xarorati, filtratning kislotaliligi va eruvchanlik ko‘paytmasi ortishi bilan ortadi.

Atmosfera va havoning ifloslanishiga qaraganda tuproqning ifloslanishi nisbatan havfli hisoblanadi, chunki tuproqdagi zararli komponentlarni ajratib olish juda murakkab hisoblanadi. Suvdagi ko‘pgina jonivorlar issiq qonli hayvonlarga qaraganda zaharli ta’sirlarga sezgir bo‘ladi. Lekin baliqlarni iste’mol qilish natijasida ulardagi oz miqdordagi zaharli moddalarning inson organizmida to‘planib borishi, hayot uchun havf tug‘diradi. Ko‘pgina kimyoviy moddalar inson organizmiga tushgach kanserogen, mutagen va teratogen ta’sirlar ko‘rsatishi mumkin. Mishyak, selen, rux, palladiy, xrom, berilliy, qo‘rg‘oshin, simob, kobalt, nikel konserogen ta’sir ko‘rsatsa, kadmiy, qo‘rg‘oshin, aluminiy, rux, litiylar terotogen va mutagen ta’sir ko‘rsatadi va oqova suvlarni mis, nikel, temir kabi og‘ir metallardan tozalash uchun opal-kristobalit minerallaridan va gips-metall tutgan sanoat chiqindilaridan olingan sorbentardan foydalanish maqsadga muvofiqdir. Bunda yuqoridagi metallarning salbiy ta’siri o‘sha paytda emas, ma’lum vaqtdan keyin, ba’zan o‘n yillardan keyin paydo bo‘lishi mumkin.

Monoshlamlarni, ya’ni tarkibida 1 ta metal bo‘lgan cho‘kmalarni qayta ishlash, murakkab tarkibli cho‘kmalarga qaraganda doim nisbatan oddiy va arzonroq bo‘ladi. Hosil bo‘ladigan cho‘kmalarni qayta ishlash yoki chiqindixonalarga tashlash muammosi, ushbu korxonada qayta ishlash texnologiyalarining va uni amalga oshirishga imkoniyatlarning mavjudligidan kelib chiqib amalga oshiriladi. Alohida olingan korxona uchun shlamlarni qayta ishlash bo‘limini qurish ko‘p hollarda iqtisodiy jihatdan o‘zini oqlamaydi, ajratib olinadigan komponentlari ko‘p bo‘lgan monoshlamlar bundan mustasno. Shuning uchun sanoat oqova suvlari cho‘kmalarini qayta ishlaydigan korxonalarni markazlashgan holda region yoki shahar bo‘yicha tashkil qilish tavsiya etiladi. Oqova suvlarni reagent usulida, flotatsiya, galvanokoagulyatsiya yoki elektrokoagulyatsiya usulida tozalash natijasida hosil bo‘lgan shlamlarda 95-99 % gacha suv bo‘ladi. Shuning uchun chiqindixona yoki qayta ishlash korxonalariga olib borishda transport harajatlarini kamaytirish maqsadida shlamlar suvsizlantiriladi, zichlanadi va ba’zan quritiladi.

Tabiiy atrof-muhitni qattiq sanoat chiqindilaridan himoya qilish usullari 3 ta

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asosiy guruhga bo‘linadi:

I – ko‘mish yoki uzoq muddat saqlash;

II – turli ishlab chiqarish tarmoqlarida foydali komponentlarini ajratib olmasdan utilizatsiya qilish usuli;

III – tozalash jarayonida hosil bo‘lgan cho‘kindilardan noyob komponentlarni regeneratsiya qilib olish.

I guruhga quyidagilar kiradi:

- shlamlarni og‘ir metallarning ferritlariga o‘tkazib, foydali qazilmalar qazib olishda hosil bo‘lgan karerlarga ko‘mish;
- shlamlarni xaritali ko‘mishlar.
- issiqlik elektr stansiyalaridagi kullar tashlanadigan chiqindixonalarda kul bilan qatlam-qatlam qilib ko‘mish.

II guruhga cho‘kindi va shlamlardan foydalanishning quyidagi usullari kiradi:

- beton va sementlar uchun faol mineral qo‘shimchalar, shuningdek keramzit graviya va g‘isht ishlab chiqarishda plastifikatsiyalovchi qo‘shimchalar sifatida;
- asfalt qoplamalari ishlab chiqarishda mineral to‘ldiruvchilarni faollashtiruvchi va plastifikatsiyalovchi qo‘shimchalar sifatida;
- oyna-keramikali kompozitsion materiallar, gips va dekorativ materiallar ishlab chiqarishda;
- pigmentlar ishlab chiqarishda;
- po‘lat ishlab chiqarishla legirlovchi qo‘shimcha sifatida;
- mineral o‘g‘itlar va ozuqa qo‘shimchalari ishlab chiqarishda.

III guruhga quyidagilar kiradi:

- pirometallurgiya usuli;
- metallarni ularning tuzlaridan ekstraksion, sorbsion va elektrokimyoviy va x.k. usullarda ajratib olishga bo‘linadigan gidrometallurgiya usullari.

Xavflilik darajasi 3-sinfga mansub bo‘lgan zararli sanoat chiqindilarini ko‘mib tashlashda ularning tarkibidagi zararli moddalarning atof-muhitga migratsiyasining oldi olingan bo‘lishi kerak. Ularni ko‘mish kotlovanlarda amalga oshiriladi, bunda zararli chiqindining eng yuqori qismi hudud sathidan kamida 2 metr past bo‘lishi kerak. Kotlovanlarning tagi tuproqni zichlab 2 m qalinlikda izolyatsiya qilinadi va ustidan suv o‘tkazmaydigan materiallar bilan qoplanadi.

Oqova suvlarni asosan reagent usulida tozalashda hosil bo‘ladigan shlamlardagi og‘ir metallarning gidroksidlari aralashmalarini shu metallarning ferritlariga o‘tkazish kimyoviy stabillash usullaridan biri hisoblanadi. Elektrokoagulyatsiya, galvanokoagulyatsiya va ferritizatsiya usullari yuqoridagi jarayonlarni o‘z ichiga olgan bo‘ladi. Elektrokoagulyatsiya, galvanokoagulyatsiyada temirning elektrokimyoviy erishi natijasida hosil

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bo‘ladigan, elektrogenerirlangan koagulyant temir II va temir III oksogidratlari suspenziyasi bilan qayta ishlanadi. Ferritlash usulida tozalanadigan eritma ma’lum nisbatlarda aralashtirilgan temir kuporosi, natriy ishqori va natriy nitratdan iborat, tarkibida temir bo‘lgan suspenziya bilan havo yordamida barbotajlash usulida 20 minutdan 1 soatgacha qayta ishlanadi. Bundan tashqari, ma’lum nisbatlarda olingan 2 va 3 valentli temir gidroksidlarini nitritlar bilan qayta ishlab, faol ferritlarni sintez qilish bilan ham amalga oshirish mumkin.

Metallarning ferritlar hosil qilish qobiliyati quyidagicha bo‘ladi: Cd < Zn < Co < Ni < Cu.

Yuqoridagi usullarda olingan ferritlar og‘ir metallarni samarali sorbsiya qiladi va ularga nisbatan ko‘p hajmda yutish qobiliyatiga ega. Temir kichik konsentratsiyalarda (1 g/l) pH ning keng diapazonlarida yetarli darajada magnit xossalariga ega bo‘lgan birikmalar hosil qiladi. Bir komponentli eritmalarga nisbatan bir vaqtning o‘zida bir necha metall ionlari tutgan eritmalarda, hamda pH ko‘tarilganda tozalash samarasi magnitlanuvchi mahsulotlar hosil bo‘lishi bilan birga oshadi. Ferrit usulida tozalashda mis pH>9 bo‘lgan qiymatlarda nisbatan faolligini ko‘rsatadi va yuqori magnit xususiyatlari bo‘lgan kristall modda ko‘rinishida ajratib olinadi.

Og‘ir rangli metallarning (nikel, mis, rux v.b.) ferritlari ularning gidroksidlaridan farq qilib, faqat suvda emas, balki kuchli ishqorlar va mineral kislotalarning suyultirilgan eritmalarida ham erimaydi, bu ularning kristall panjarasining (shpinelga o‘xshab) maxsus tuzilishga ega bo‘lganligi bilan asoslanadi. Ferritlarning kimyoviy inertligini hisobga olib, ularni foydali qazilmalarni o‘zlashtirishda bo‘shagan karerlarda uzoq vaqt saqlash mumkin.

Ferrit cho‘kindilari magnit xossalariga ega bo‘lganligi uchun, ulardan magnit moddalar va magnit defektoskopiya texnologiyalarida qo‘llanilishi mumkin. Ulardan suv yuzalarini neft qoldiqlaridan tozalaydigan uglerod-mineralli gidrofob sorbentlar tayyorlash mumkin.

Oqova suvlarni tozalashda hosil bo‘ladigan cho‘kmalar, shlamlarning qurilish materiallari ishlab chiqarishda va sanoatning boshqa tarmoqlarida doimiy qo‘llash uchun quyidagi shartlar bajarilishi kerak:

- ushbu shaharda yoki xududda mazkur chiqindini va uning tarkibidagi moddani doimiy ravishda ishlatadigan korxona bo‘lishi kerak;

- ishlab chiqarish yuqori texnik-iqtisodiy samaraga ega bo‘lishi kerak;

- chiqidining kimyoviy tarkibi kam o‘zgaruvchan bo‘lishi kerak (chiqindi faqat bitta korxonaniki bo‘lishi kerak);

- chiqindi asosida ishlab chiqarilgan mahsulot ekologik jihatdan havfsiz bo‘lishi kerak, shu bilan birga qurilish-texnik talablariga to‘liq javob berishi kerak.

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Bu talab mazkur shlamlar, galvanoshlamlardan qurilish materiallari ishlab chiqarishda asosiy talablardan hisoblanadi.

Og‘ir metallarning beton, asfalt va xatto keramikadan atrof-muhit omillari ta’sirida sizib chiqishi mumkinligi e’tiborga olinsa, ularni bog‘lovchi materiallar bilan qorishtirib utilizatsiya qilish har doim ham to‘g‘ri kelavermaydi. Galvanika ishlab chiqarish shlamlari asosida olingan qurilish materiallari gigienik baholash tizimi usulida taxlil qilinganda, bu betonlar atrofidagi havoda va yerda og‘ir metallarning miqdori gigienik meyorlardan yuqori chiqqanligi aniqlangan.

Shuning uchun galvanoshlamlar qo‘shib tayyorlangan asfalt-beton aralashmalarini bolalar va sport maydonchalari, davolanish va dam olish tashkilotlari yulaklari, hamda maydonlarini qoplash tavsiya etilmaydi. Har qanday asfalt-beton qorishmalarini tayyorlashda galvanoshlamlarning miqddori 1,6 % dan oshmasligi kerak. Bundan tashqari 5-8 yilda yul qoplamalari umalanadi va og‘ir metallar tuproqqa o‘tishi mumkin. Shuning uchun chiqindilarni bu yo‘nalishda qo‘llash uchun asosiy maqsad tayyorlangan materialning ekologik havfsizligini ta’minlashga qaratilgan bo‘lishi kerak. Galvanoshlamlarni qurilish materiallari olishda qo‘llashdan oldin termik ishlov berishgina ularning zararligini kamaytirishi mumkin. Shlamlarni 20-30 % suv qolguncha suvsizlantirilib, 200-1500^{0}S da qayta ishlansa, ularning tarkibidagi metallarning oksigidratlari va karbonatlari bog‘langan suvni yo‘qotib, gidroksidlarga qaraganda ancha barqaror va kamzaharli oksidlarga aylanadi. Olingan metall oksidllari kukunlarini issiqqa, atmosfera va kislotalar ta’siriga chidamli dekorativ tus beruvchi korroziyaga qarshi, himoya qatlamlari kompozitsiyalari olishda qo‘llaniladi. Shlamlarni kuydirishdan oldin 30-50 % gacha shixta tarkibiga qo‘shiladi, hosil bo‘lgan glazur dekorativ koshinlarga surkaladi. Shishasimon glazur qoplamalari tarkibida bir xil taqsimlangan pigment zararsiz bo‘lib, oziq-ovqat mahsulotlari bilan kontaktga yo‘l qo‘yiladi. Suvda eriydigan bo‘yoqlarga va ta’mirlash materiallariga qo‘shiladigan barqaror (mis, nikel, xrom fosfatlari kabi) pigmentlar ham xuddi shu usulda cho‘kmalarni fosfatlab olinadi.

Tarkibida metallar gidroksidlari ko‘p bo‘lgan shlamlarni shu metallarning oksidlariga o‘tkazish usuli lak-bo‘yoq ishlab chiqarishda qo‘llaniladi.

Oxirgi yilllarda sanoat oqova suvlarni tozalashdan chiqadigan shlamlarni, shu jumladan galvanoshlamlarni turli qurilish materiallari olishda qo‘llab ko‘rilgan va mahsulolarni ishlatish uchun o‘rnatilgan tartibda ruxsatnomalar olingan. Lekin shunga qaramasdan, hosil bo‘ladigan chiqindi shlamlarni qayta ishlash hajmi yetarli darajada katta emas. Bu quyidagi qator texnologik murakkabliklarga bog‘liq:

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- xatto bitta korxonadagi xom ashyoning kimyoviy va fazaviy tarkibining doyimiy emasligi;

- lak, bo‘yoq, pigmentlar ishlab chiqarishda tarkibida qum bo‘lgan shlamlarni qo‘llab bo‘lmasigi (oqova suvlarni qayta ishlanganda qo‘shiladigan oxakning tarkibida 5 % gacha qum buladi), chunki bu materiallarni ishlab chiqarishda zarrachalarning o‘lchamlari 40-60 mkm dan katta bo‘lmasligi kerak, qumning o‘lchami esa 1500 mkm ni tashkil etadi.

- yuqori xaroratda qayta ishlashda kalsiyli shlamlarni utilizatsiya qilib bo‘lmasligi, chunki bunda mahsulot tarkibida kalsiy oksidi hosil bo‘ladi va qurilish materiallarining mustahkamligi kamayadi va atmosfera yog‘inlari ta’sirida yemirilishiga olib keladi.

- bunday shlamlar kuydirilganda atmosferaga zaharli gazsimon va qattiq moddalar ajralib chiqadi.

Bunday shlamlarni utilizatsiya qilishning yana bir usullaridan biri ularni metallurgiya korxonalarida po‘latni legirlash uchun qo‘llashdir. Masalan, Rossiyaning Chuvashiya respublikasidagi korxonalardan biriga joriy qilingan texnologiya bo‘yicha galvanoshlamlarni 4-10 % gacha quritilib, 6% miqdorda koks va oxaktoshga qo‘shib, pechga yuklanadi. Bunda mis, nikel, xrom deyarli to‘liq, temir, marganes va vanadiy qisman po‘latga o‘tadi va uni legirlaydi, rux, alyumiyniy, kremniy va fosfor esa silikatlar, shpinellar va fosfatlar ko‘rinishida shlakka o‘tib, uni suyultirishda (razjijitel) katta rol o‘ynaydi. Bu usulning afzalligi oddiyligida va mavjud uskunalardan, ya’ni pechlardan foydalanish mumkin, kamchiligi esa shlam tarkibidagi noyob komponentlarni ajratib olib bo‘lmaydi, shuningdek chiqindi, shixta va olingan metallarni doimiy nazorat qilib turish kerak bo‘ladi.

Oqova suvlarni tozalashdan chiqadigan shlamlarni utilizatsiya qilishning yana bir usullari ularni mikroo‘g‘itlar, ozuqa konservantlari va qo‘shimchalari olish uchun qayta ishlashdir. Ma’lumki, o‘simliklar yaxshi rivojlanishi uchun ularga mis, rux, kobalt va boshqa turli metall ionlari kabi mikroelementlar kerak bo‘ladi. Mikroo‘g‘it chiqarish uchun 1 ta metall tutgan oqova suv kerak bo‘ladi, lekin deyarli barcha metallurgiya korxonalarida oqova suvlar aralashib ketadi va polimetalli chiqindi suvlarga aylanadi. Oqova suvlardan mikroo‘g‘itlar olish uchun korxonalardagi chiqindi suvlarni yig‘ishni tubdan o‘zgartirish kerak bo‘ladi va bu ancha moddiy sarflarga olib keladi.

Plastmassa va ular asosidagi buyumlar ishlab chiqaruvchi, shuningdek neftni qayta ishlash korxonalarida asosan oqova suvlar organik moddalar, xususan fenollar, formaldegidlar bilan ifloslanadi va ular turli usullarda tozalanadi. Bu turdagi ko‘pchilik korxonalar fenollar bilan ifloslangan oqova suvlarni muallaq

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holdagi yirikroq dispers qo‘shimchallardan tozalash uchun mexanik usullardan foydalanishadi. Boshqa mualliflar esa dastlabki tozalashdan o‘tgan suvlarni talab qilingan meyorlargacha tozalash uchun membrana va sorbsion usullardan foydalanishgan. So‘ngra fenol komplekslarini parchalash va fenol tutgan mayda dispers qo‘shimchalarni yo‘qotish uchun fizik-kimyoviy va kimyoviy usullar qo‘llaniladi. Ko‘p korxonalar bu chiqindi suvlarni chuqurroq tozalash, ya’ni fenol tutgan kolloid va erigan zararli birikmalardan tozalash uchun biologik usullarni qo‘llashadi. Biologik usulda tozalashdan oldin ko‘p korxonalar oqova suv tarkibidagi smolalar konsentratsiyasini 25-35 mg/l ga tushirish uchun tindirish, flotatsiya, filtrlash jarayonlarini qo‘llashadi, ba’zi korxonalar esa yanada chuqurroq tozalash uchun kvars qumidan iborat filtrlardan foydalanishadi.

Shunday korxonalar borki, fizik-kimyoviy regeneratsiya usullaridan bo‘lgan evaporatsiya, ekstraksiya usullarini qo‘llab, smolalar konsenratsiyasini 3-4 g/l gacha tushirishga erishishadi va fenollarni qayta ishlash uchun ajratib olishni ta’minlashadi.

Evaporatsiya jarayonida oqova suvdagi plastmassa chiqindilaridan tashqari krezollar, naftollar va karbon kislotalardan ham tozalanadi. Bunda bug‘ orqali haydalgan moddalar eritmadan ishqor yordamida (agar bu moddalar kuchsiz kislotali bo‘lsa) yoki kislota yordamida (agar kuchsiz asos xolatida bo‘lsa) ajratib olinadi. Evaporatsiya jarayonidan oldin oqova suvning kislotaliligini ko‘taruvchi, fenolllarning dissotsiatsialanishini kuchaytirib, ularning haydalishini kamaytiruvchi yoki fenol bilan birga haydalib, kislotaliligini kamaytiradigan va ishqorni neytrallab, fenolni yutolmaydigan qilib qo‘yishning oldini olish uchun, ularning tarkibidagi NH_3, H_2S, CO_2 lar ajratib olinadi. Oqova suvlarni evaporatsiya usulida fenoldan tozalash 80-90 % gacha samara beradi. Ba’zi korxonalar bu usulning uskuna ixchamligi, ishlatish oddiyligi va to‘liq avtomatlashtirish mumkinligi uchun qo‘llashadi.

Oqova suvlarni fenoldan tozalashning oxirgi bosqichi biologik usulda tozalash bo‘lib, u bir yoki ikki bosqichda olib boriladi va tozalash samarasi 99,1-99,8 % gacha yetadi.

Ko‘pchilik neftni qayta ishlash va plastmassa korxonalarida ekstraksion fenolsizlantirish qurilmasidan keyin suvdan fenolni ajratib olish uchun adsorbsiya usullarini qo‘llaydi, bunda sorbent sifatida faollantirilgan ko‘mir, koks, zollar, shlak va boshqalardan foydalanish mumkin. Bunda to‘yingan sorbent (masalan faollantirilgan ko‘mir) $+70^0$S xaroratdagi benzol bilan regeneratsiya qilinadi, fenol-benzol eritmasi ishqor bilan qayta ishlanadi va tozalangan benzolni yana regeneratsiya jarayoni uchun qo‘llashsh mumkin bo‘ladi. Regeneratsiya qilingan ko‘mirdan benzol suv bug‘i yordamida ajratib olinadi va ko‘mirni suvni tozalashda

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yana qayta qo‘llash imkoniyati yaratiladi. Bunda faollantirilgan ko‘mir ishtirokidagi adsorbsiya-desorbsiya jarayoni 15 martaga yetgach, ko‘mir $+800^0$S xaroratda, havosiz sharoitda regeneratsiya qilinadi. Oqova suvlarni organik qo‘shimchalardan tozalash bilan birga, qo‘llanilishi davomida organik moddalar bilan to‘yingan faollantirilgan ko‘mirdan iborat adsorbentlarni biologik usulda regeneratsiya qilish usullari ustida ham izlanishlar olib borishgan.

Agar oqova suvlar tarkibida fenoldan tashqari rodanidlar va sianidlar bo‘lsa, biologik usulda tozalash bir necha bosqichda olib boriladi: birinchi bosqichda oqova suv fenol strukturasini buzuvchi bakteriyalar yordamida fenoldan tozalanadi, ikkinchi bosqichda rodanid strukturasini buzuvchi bakteriyalar yordamida rodanid va sianidlardan tozalanadi, uchinchi bosqichda esa oqova suvlar talab qilingan meyorlargacha tozalanadi.

Yuqorida keltirilgan turli tarkibli sanoat oqova suvlarini utilizatsiya qilish resurs tejamkor texnologiyalarga kirmaydi, chunki bu yerda ko‘p rangli og‘ir metallar texnologik siklga qaytarilmaydi, ulardan boshqa birikmalar olinib, asosiy bo‘lmagan soxalarda qo‘llaniladi. Lekin bu yerda o‘ta zaharli bo‘lgan og‘ir metallar tutgan oqova suvlar va chiqindi eritmalar zarasizlantiriladi yoki utilizatsiya qilinib, atrof-muhitga ta’siri kamaytiriladi.

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СОВРЕМЕННЫЕ ПОДХОДЫ К ПОВЫШЕНИЮ ЭНЕРГОЭФФЕКТИВНОСТИ ЭЛЕКТРОМЕХАНИЧЕСКИХ СИСТЕМ ПРИ ПЕРЕМЕННЫХ ТЕХНОЛОГИЧЕСКИХ РЕЖИМАХ

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Аннотация. В статье представлен аналитический обзор современных научных исследований, посвящённых повышению энергоэффективности электромеханических систем (компрессоров, вентиляторов и насосных агрегатов), функционирующих в условиях переменных технологических нагрузок. Рассматриваются классические и современные методы регулирования, применение частотно-регулируемых приводов, интеллектуальные алгоритмы управления, а также цифровые технологии в рамках концепции Индустрия 4.0. Проведён анализ преимуществ адаптивных стратегий управления и определены перспективные направления дальнейших исследований. Предоставлены методы для повешения энергоэффективности электромеханических систем авторов разных стран, также результаты исследовании в многопрофильной больнице Сеула (Южная Корея) измеренные в реальных условиях эксплуатации, выбрав системы частотно-регулируемого привода (ЧРП) и вакуумного регулирования (ВП) [12].

Ключевые слова: энергоэффективность, электропривод, электромеханические системы, энергосбережение режимы работы электромеханических систем.

Annotation. The article presents an analytical review of modern scientific research devoted to improving the energy efficiency of electromechanical systems (compressors, fans and pumping units) operating under variable technological loads. Classical and modern control methods, the use of variable frequency drives, intelligent control algorithms, as well as digital technologies within the framework of the Industry 4.0 concept are considered. The advantages of adaptive management strategies are analyzed and promising areas of further research are identified. Methods for measuring the energy efficiency of electromechanical systems from different countries are provided, as well as the results of a study at a multidisciplinary hospital in Seoul (South Korea), measured under real operating conditions by selecting variable frequency drive (VFD) and vacuum control (VP) systems [12].

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Keywords: energy efficiency, electric drive, electromechanical systems, energy saving, operating modes of electromechanical systems.

Annotatsiya. Maqolada o‘zgaruvchan texnologik yuklamalar sharoitida ishlaydigan elektromexanik tizimlarning (kompressorlar, ventilyatorlar va nasos agregatlari) energiya samaradorligini oshirishga bag‘ishlangan zamonaviy ilmiy tadqiqotlarning tahliliy sharhi keltirilgan. Rostlashning klassik va zamonaviy usullari, chastotaviy rostlanadigan yuritmalarni qo‘llash, intellektual boshqarish algoritmlari, shuningdek, Sanoat 4.0 konsepsiyasi doirasidagi raqamli texnologiyalar ko‘rib chiqiladi. Adaptiv boshqaruv strategiyalarining afzalliklari tahlil qilingan va keyingi tadqiqotlarning istiqbolli yo‘nalishlari aniqlangan. Turli mamlakatlar mualliflarining elektromexanik tizimlarining energiya samaradorligini oshirish usullari, shuningdek, Seuldagi (Janubiy Koreya) ko‘p tarmoqli shifoxonada chastota bilan boshqariladigan yuritma (CHBY) va vakuumli boshqarish (VB) tizimlarini tanlab, haqiqiy ish sharoitlarida o‘lchangan tadqiqot natijalari keltirilgan [12].

Kalit so‘zlar: energiya samaradorligi, elektr yuritma, elektromexanik tizimlar, energiya tejamkorligi, elektromexanik tizimlarning ish rejimlari

ВВЕДЕНИЕ.

В настоящее время реализуется широкий комплекс стратегических, политических, технических и организационных мероприятий, направленных на расширение применения низкоуглеродных источников энергии. Тем не менее, несмотря на предпринимаемые на глобальном уровне усилия, значительная часть промышленных предприятий продолжает функционировать на основе использования органического топлива. Такая модель производства неизбежно сопровождается отрицательным воздействием на окружающую среду и способствует усилению процессов изменения климата и деградации природных экосистем. В связи с этим одним из ключевых направлений решения данной проблемы является поиск эффективных способов снижения энергопотребления [11].

Электромеханические системы, такие как компрессоры, вентиляторы и насосы, составляют основу энергетической инфраструктуры промышленных предприятий. На их долю приходится до 60–70 % общего потребления электроэнергии [1, 6]. Особенно значительным является энергопотребление систем сжатого воздуха и вентиляционных установок, где традиционные методы управления часто оказываются недостаточно эффективными [2, 3]. В современных промышленных условиях быстро изменяющиеся технологические процессы, параметрическая неопределённость и значительная изменчивость нагрузок требуют внедрения адаптивных и

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интеллектуальных систем управления. В соответствии с концепцией Индустрии 4.0, цифровизация производства и интеграция киберфизических систем, промышленного Интернета вещей (IIoT), технологий анализа больших данных и искусственного интеллекта создают возможности для повышения энергоэффективности электромеханических систем и обеспечения их интеллектуального и гибкого функционирования [4, 7].

Классические современные методы регулирования. Повышение эффективности использования электроэнергии может обеспечиваться не только за счёт совершенствования конструкции электроприводов. Даже технически высокоразвитые приводы могут работать неэффективно при изменении условий их эксплуатации. В процессе функционирования асинхронных приводов нередко наблюдаются существенные изменения режимов работы, что обусловлено технологическими требованиями, воздействием климатических факторов, а также различными условиями окружающей среды. Энергоэффективное регулирование производительности и режимов работы оборудования является важным направлением целенаправленных исследований. Основное внимание в таких исследованиях уделяется изменению угловой скорости двигателя, однако значительное число работ также посвящено вопросам рационального распределения нагрузки, управлению крутящим моментом, а также совершенствованию пусковых режимов и других методов повышения эффективности работы приводов [11].

В 2018 году группа исследователей предложила метод энергоэффективного управления режимами работы электроприводов асинхронных двигателей с регулируемой скоростью, применяемых в насосах, компрессорах и вентиляторах. Результаты исследования показали, что использование насосов с регулируемым расходом позволяет снизить потребление электроэнергии судовым оборудованием до 60 % при уменьшении скорости движения судна[12]. Традиционные методы регулирования производительности компрессоров и вентиляторов включают схемы «нагрузка–разгрузка», дросселирование и использование ресиверов. Основные недостатки этих методов:

значительные переходные потери энергии [5];

повышение износа оборудования;

нестабильность при переменных нагрузках;

увеличение удельного энергопотребления на 5–15 % [1, 3].

Эти ограничения стимулируют разработку методов плавного и адаптивного регулирования, особенно для условий переменных нагрузок.

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Частотно-регулируемые приводы (VFD) и энергосбережение. Одним из самых эффективных способов повышения энергоэффективности является применение частотно-регулируемых приводов (VFD). Согласно законам подобия для механических систем, мощность потребления пропорциональна кубу скорости вращения:

$$P \sim n^3,$$

где (P) — потребляемая мощность, (n) — скорость вращения [2, 3, 5].

Снижение скорости вращения на 20 % может снизить энергопотребление почти на 50 %, что подтверждается экспериментальными исследованиями винтовых и поршневых компрессоров [2, 3, 4].

Регулирование производительности — это метод, который помогает компрессору регулировать производительность машины в соответствии с рабочей нагрузкой по требованию. В открытой литературе наиболее распространенными методами регулирования производительности в объемных компрессорах являются бесступенчатое регулирование и регулирование скорости вращения. Принцип бесступенчатого управления заключается в задержке времени закрытия всасывающего клапана путем подачи внешней силы (обычно гидравлической силы), что позволяет избыточной жидкости выходить из рабочей камеры. Другой часто используемый метод регулирования производительности — регулирование скорости, при котором рабочая скорость регулируется приводом с регулируемой скоростью в ответ на изменение рабочей нагрузки [2].

Для вентиляторных систем применение VFD также показывает значительное сокращение энергии без потери технологической производительности. Системы ОВК на основе переменного объема воздуха (VAV) обычно применяются в больницах, где они реагируют на нагрузки отопления и охлаждения отдельно, с различными графиками работы для каждой зоны. Система VAV может адекватно реагировать на внутренние и наружные нагрузки кондиционирования воздуха, поддерживая комфортные условия внутри помещений. Многопрофильной больнице Сеула (Южная Корея) при сравнении результатов исследования, измеренные в реальных условиях эксплуатации, выбрав системы частотно-регулируемого привода (ЧРП) и вакуумного регулирования (ВП): наиболее эффективные методы управления воздушным потоком для вентиляторов в системах переменного расхода воздуха (VAV). По сравнению с другими системами ОВК, такими как системы постоянного объема воздуха (CAV) и фанкойлы, система VAV обеспечивает гибкое реагирование на частичные нагрузки, уменьшает размер

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основного воздуховода и мощность вентилятора, а также экономит годовое потребление энергии как минимум на 11,5% [5, 9].

Таблица 1

Сравнительный анализ методов регулирования

Метод	Экономия энергии	Сложность внедрения	Гибкость
Нагрузка–разгрузка	0–8 % [1, 5]	низкая	низкая
Дросселирование	5–10 % [5]	низкая	средняя
VFD	20–35 % [2, 3, 5]	средняя	высокая
MPC и ИИ	30–45 % [7, 10]	высокая	очень высокая

Математическое моделирование и оптимизация. Современные исследования сосредоточены на разработке математических моделей электромеханических систем, учитывающих нелинейность характеристик оборудования и ограничения по давлению, расходу и мощности. Алгоритмы оптимального управления, предиктивные модели и методы машинного обучения используются для минимизации энергопотребления в условиях переменных нагрузок. На этапе разработки системы математическое моделирование представляет собой практичный и ресурсосберегающий метод, позволяющий адекватно описывать термодинамические процессы, протекающие в рабочем цикле машины, и осуществлять прогноз её энергетических и эксплуатационных характеристик [2, 4, 7].

Цифровые двойники и аналитические модели позволяют прогнозировать нагрузку, адаптивно корректировать рабочие параметры и снижать износ оборудования, что важно для интеграции энергоменеджмента. Применение насосных установок способствует повышению энергоэффективности отдельных элементов электропривода. В проведённом анализе авторы отмечают несколько основных направлений повышения энергоэффективности приводов насосных агрегатов с асинхронными двигателями. К ним относятся: корректный выбор номинальной мощности асинхронного двигателя и насоса в соответствии с рабочими условиями, а также регулирование скорости вращения насоса посредством использования частотно-регулируемого электропривода. [13]. На ряде горнодобывающих предприятий с целью повышения энергоэффективности вентиляционных систем были внедрены электроприводы с регулируемой скоростью вращения, работающие от сети среднего напряжения. Применение таких приводов позволяет адаптировать режим работы вентиляционного

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оборудования к фактическим условиям эксплуатации и тем самым снизить энергопотребление. [14]. Цифровые двойники и аналитические модели позволяют прогнозировать нагрузку, адаптивно корректировать рабочие параметры и снижать износ оборудования, что важно для интеграции энергоменеджмента.

Наиболее эффективные решения. Регулирование скорости вращения двигателя (частотно-регулируемый привод)

Изменение скорости электродвигателя в зависимости от нагрузки позволяет адаптировать работу оборудования (насосов, вентиляторов, компрессоров) к текущим технологическим требованиям и значительно снизить энергопотребление[2,3,5,12,13].

Рациональное распределение нагрузки между приводами Балансировка нагрузки между несколькими агрегатами позволяет снизить потери энергии. Например, использование энергии перегрузки одного пресса для питания другого может уменьшить энергопотребление до 36 %.[14].

Регулирование крутящего момента двигателя Управление моментом с помощью преобразователей напряжения или специальных алгоритмов позволяет обеспечить энергоэффективный режим работы асинхронных двигателей при нагрузках ниже номинальных[13, 15].

Энергоэффективное управление током *двигателя* Регулирование тока позволяет снизить потери в электрической машине и обеспечить оптимальные условия работы привода при изменяющихся нагрузках[12].

Бессенсорное управление скоростью двигателя. Использование алгоритмов управления без датчиков скорости обеспечивает симметричный и сбалансированный режим работы двигателя во всём диапазоне скоростей, что повышает его энергоэффективность[16]

Оптимизация магнитного потока асинхронного двигателя. Регулирование магнитного потока на основе минимизации потерь или управления потреблением энергии позволяет значительно уменьшить потери при работе двигателя на малых нагрузках[21].

Компенсация реактивной мощности и повышение коэффициента мощности. Применение систем компенсации реактивной мощности уменьшает потери энергии, снижает потребление реактивной мощности и повышает коэффициент мощности электропривода. Применение указанных методов способствует существенному снижению энергопотребления электромеханических систем при функционировании в условиях переменных режимов работы [22].

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ЗАКЛЮЧЕНИЕ. Обзор литературы показывает, что повышение энергоэффективности электромеханических систем в условиях переменных технологических режимов является актуальной научной задачей. Благодаря большому количеству научных публикаций направление исследований, посвящённое совершенствованию режимов работы электроприводов посредством регулирования магнитного потока и скорости вращения, получило значительное развитие и сформировалось как самостоятельная область научных исследований. [2,3,5,12,13,21]. К наиболее энергоэффективным режимам работы электроприводов относятся режимы, основанные на регулировании скорости вращения, рациональном распределении нагрузки, управлении крутящим моментом и током двигателя, оптимизации магнитного потока, а также компенсации реактивной мощности. Применение указанных методов способствует существенному снижению энергопотребления электромеханических систем при функционировании в условиях переменных режимов работы. [12].

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ПРОЕКТИРОВАНИЕ ТЕХНОЛОГИЧЕСКОЙ ОСНАСТКИ ДЛЯ МЕХАНИЧЕСКОЙ ОБРАБОТКИ ДЕТАЛЕЙ МАШИНОСТРОЕНИЯ

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Аннотация. В статье рассматриваются вопросы проектирования технологической оснастки, применяемой при механической обработке деталей машиностроения. Показана роль технологической оснастки в обеспечении точности обработки, повышении производительности и улучшении условий труда. Рассмотрен пример разработки специального приспособления – кондуктора для сверления отверстия в детали типа «втулка» с использованием системы автоматизированного проектирования КОМПАС-3D. В результате проектирования была создана трехмерная модель приспособления, выполнены рабочие чертежи и составлена спецификация элементов конструкции.

Ключевые слова: машиностроение, технологическая оснастка, кондуктор, сверление, САПР, 3D-моделирование, КОМПАС-3D.

Abstract. The article discusses the issues of designing technological fixtures used in the machining of machine-building parts. The role of technological fixtures in ensuring machining accuracy, increasing productivity and improving working conditions is shown. An example of designing a special fixture – a jig for drilling a hole in a “bushing” type part using the KOMPAS-3D computer-aided design system is considered. As a result of the design process, a three-dimensional model of the jig was created, working drawings were developed and a specification of the structural elements was compiled.

Keywords: mechanical engineering, technological fixture, jig, drilling, CAD, 3D modeling, KOMPAS-3D.

Annotatsiya. Maqolada mashinasozlik qismlarini mexanik ishlov berishda qo‘llaniladigan texnologik jihozlarni loyihalash masalalari ko‘rib chiqiladi. Texnologik jihozlarning ishlov berish aniqligini ta’minlash, unumdorlikni oshirish va mehnat sharoitlarini yaxshilashdagi roli ko‘rsatilgan. KOMPAS-3D avtomatlashtirilgan loyihalash tizimidan foydalangan holda "vtulka" tipidagi detalda teshik ochish uchun maxsus moslama - konduktorni ishlab chiqish misoli

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ko‘rib chiqilgan. Loyihalash natijasida moslamaning uch o‘lchamli modeli yaratildi, ishchi chizmalari bajarildi va konstruksiya elementlarining spetsifikatsiyasi tuzildi.

Kalit so‘zlar: mashinasozlik, texnologik jihozlash, o‘tkazgich, burg‘ulash, SAPR, 3D-modellashtirish, KOMPAS-3D.

ВВЕДЕНИЕ.

Современное машиностроительное производство характеризуется высоким уровнем автоматизации и постоянным совершенствованием технологических процессов. Важную роль в повышении эффективности производства играет технологическая оснастка, обеспечивающая точное базирование и надежное закрепление заготовок при обработке. Она оказывает значительное влияние на точность обработки, производительность оборудования и качество продукции. В современных условиях особое значение имеет применение систем автоматизированного проектирования, позволяющих сократить время разработки и повысить точность проектных решений.

ОСНОВНАЯ ЧАСТЬ

Технологическая оснастка в различных отраслях промышленности является важным элементом технологической системы, обеспечивающим гибкость производства и высокое качество продукции. Конструктивное разнообразие оснастки определяет уровень специализации её производителей и возможности её применения в технологических процессах.

Современное производство требует выпуска большого количества высококачественной продукции при минимальных затратах. Особенно это актуально для машиностроения, которое играет ключевую роль в техническом развитии всех отраслей экономики. Достижение этих целей обеспечивается эффективным использованием оборудования, совершенствованием организации труда и внедрением передовых технологий.

Интенсификация машиностроительного производства связана с модернизацией средств производства, внедрением научно-технических достижений, подготовкой выпуска новых видов продукции и совершенствованием технологической оснастки.

Большинство деталей невозможно изготовить без применения технологической оснастки, которая используется для установки, базирования и крепления заготовок. Технологическая оснастка подразделяется на группы: специальную и универсальную [2]. Специальная проектируется и изготавливается в том случае, если невозможно применить универсальную

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оснастку. Специальная оснастка предназначена для изготовления определенного изделия или для выполнения нескольких операций. При разработке технологического процесса документально определяется (по каталогам, классификаторам и картотеке оснастки и т.д.), применялась ли необходимая оснастка ранее, если нет, то разрабатывается техническое задание и оформляется заказ на ее проектирование и изготовление

Решение задач, поставленных перед машиностроителями, связано с необходимостью проектирования и внедрения прогрессивной технологической оснастки для гибких производственных систем. Правильно спроектированная и изготовленная технологическая оснастка является высокоэффективным средством повышения производительности автоматизированного оборудования, обеспечения требуемой точности изделий, снижения их себестоимости, облегчения и повышения безопасности труда рабочих [1].

На основании широкого и повсеместного использования средств технологической оснастки, позволяющих расширить и актуализировать номенклатуру выпускаемой продукции, обучение системе их проектирования является крайне важной и актуальной задачей.

Рассмотрим этапы проектирования технологической оснастки по моделированию проектируемой оснастки

В качестве проектируемой технологической оснастки принимаем специальное приспособление для сверления отверстия диаметром в 4 мм в детали «Втулка» (рис. 1). В процессе проектирования разработаем кондуктор для сверления и зенкерования отверстия в теле детали, создадим сборочный чертеж.

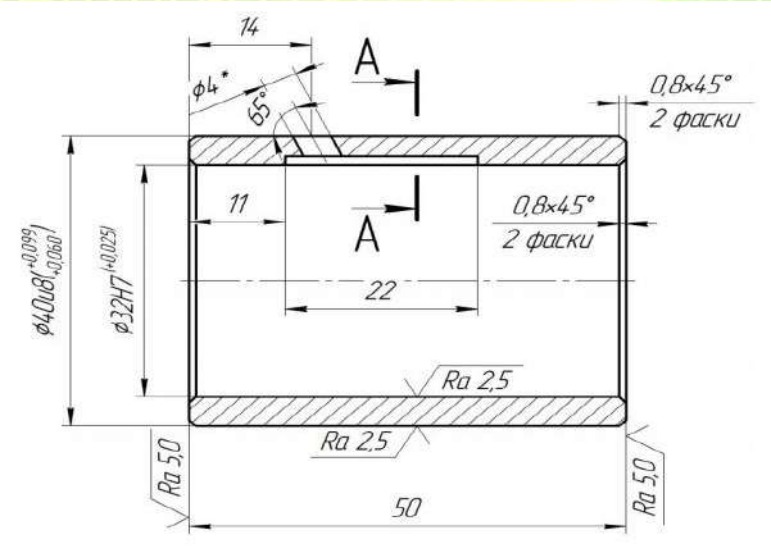


Рис. 1. Обрабатываемая деталь (втулка)

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Разработка схемы установки заготовки представлена на рисунках 2, 3.С целью обеспечить заданную точность обработки примем схему базирования [3], изображенную на рисунке 3.

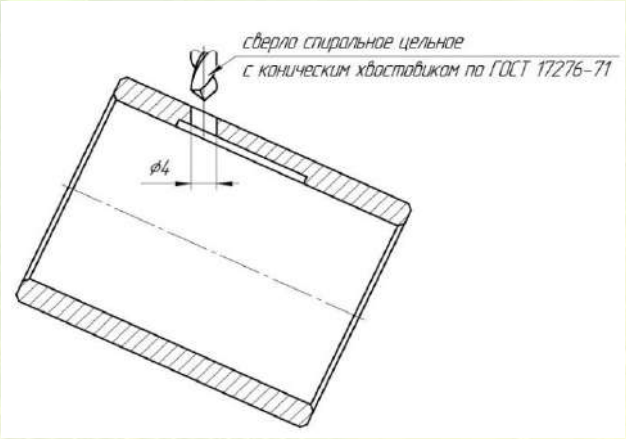


Рис. 2. Операционный эскиз

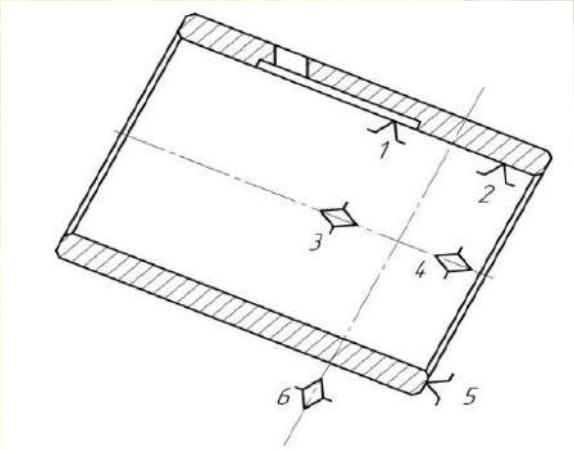


Рис. 3. Теоретическая схема базирования:
1,2,3,4 - направляющие явные базы; 5 — установочная явная база; 6 — опорная скрытая база

С целью обеспечить заданную точность обработки примем схему базирования [3], изображенную на рисунке 3

Разработка эскиза приспособления для сверления и зенкерования отверстия в детали представлена на рисунке 4.

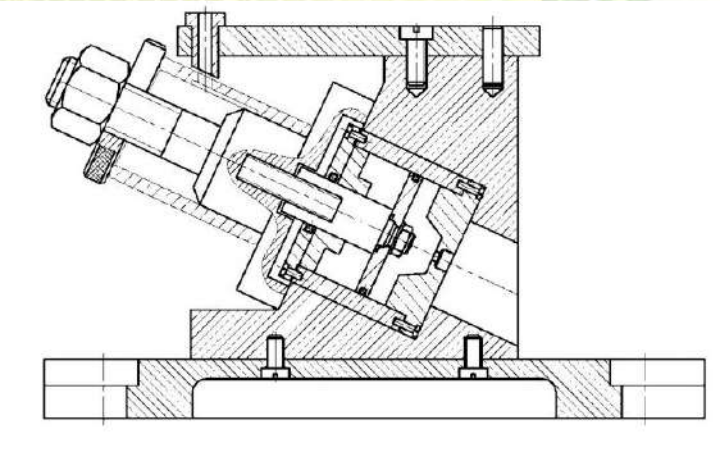


Рис. 4. Кондуктор для сверления и зенкерования отверстия

Далее выполнены в КОМПАС-3D трехмерные модели проектируемой оснастки в соответствии с разработанными эскизными конструктивными решениями (рис. 5).

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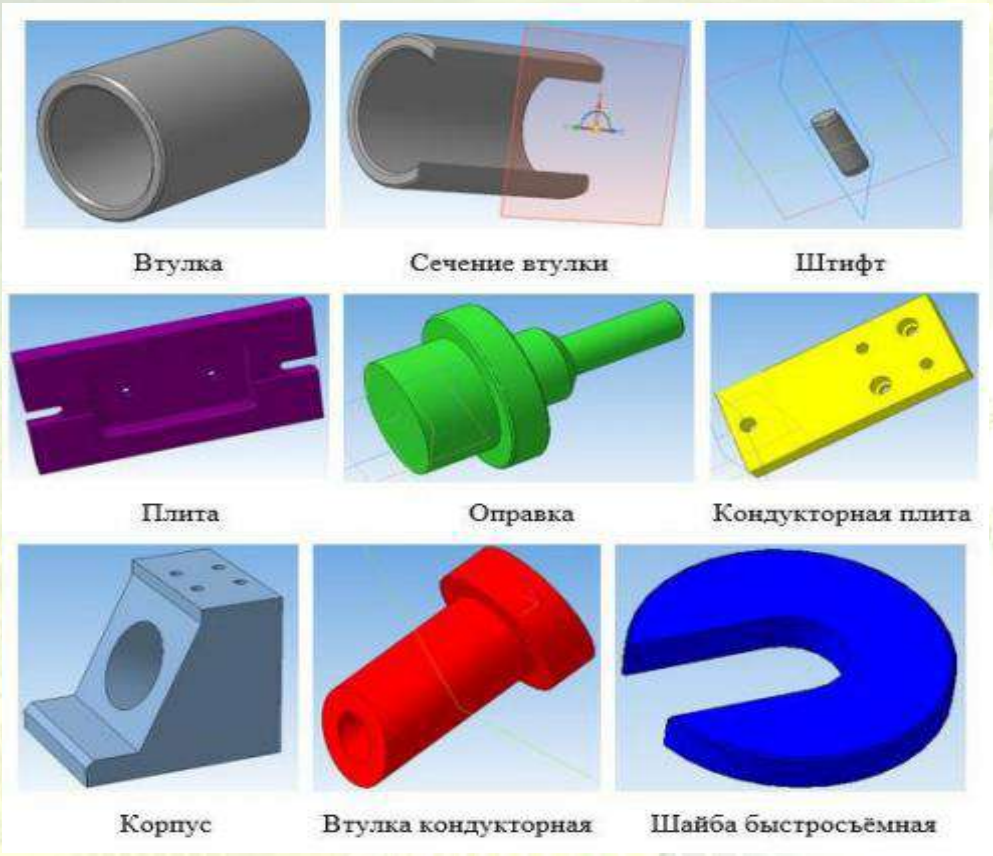


Рис. 5. 3D-модели проектируемой оснастки

Далее производиться конструктирование модели технологической оснастки для сверления отверстия Ø 4мм — кондуктора.

В данной статье было произведено проектирование специального приспособления, предназначенного для сверления отверстия в детали типа «втулка». С помощью компьютерной системы трехмерного параметрического проектирования КОМПАС-3D была создана 3D модель кондуктора и выполнены рабочие чертежи.

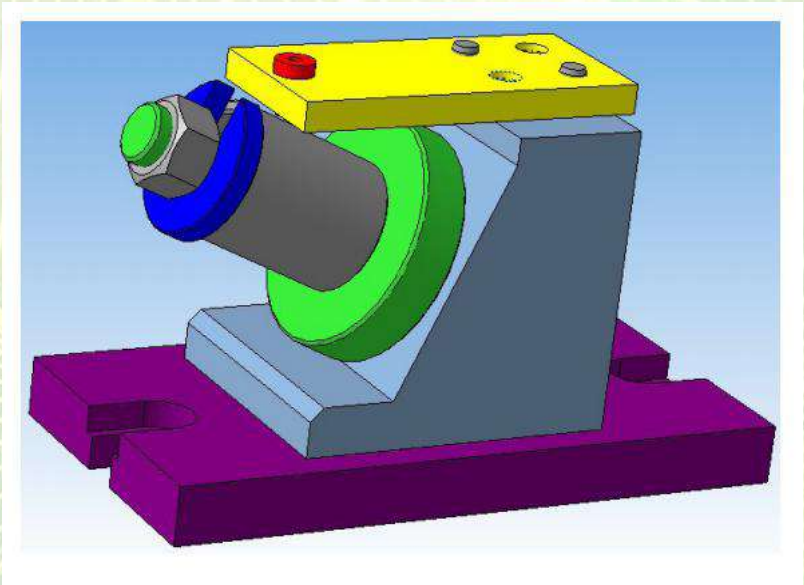


Рис. 6. 3D-модель кондуктора

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Применение станочных приспособлений позволяет:

- надежно базировать и закреплять обрабатываемую деталь с сохранением ее жесткости в процессе обработки;
- стабильно обеспечивать высокое качество обрабатываемых деталей при минимальной зависимости качества от квалификации рабочего;
- повысить производительность и облегчить условия труда в результате механизации приспособлений;
- расширить технологические возможности используемого оборудования базирования [2].

ЗАКЛЮЧЕНИЕ

Проектирование технологической оснастки играет важную роль в обеспечении эффективности и качества машиностроительного производства. Использование современных систем автоматизированного проектирования позволяет значительно сократить сроки разработки, повысить точность конструкторских решений и улучшить качество технологического оснащения.

Развитие цифровых технологий и внедрение инновационных методов проектирования создают новые возможности для совершенствования технологических процессов и повышения конкурентоспособности промышленной продукции

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ОСОБЕННОСТИ СОВМЕСТНОГО ИСПОЛЬЗОВАНИЯ И ЭЛЕКТРОМАГНИТНОЙ СОВМЕСТИМОСТИ СИСТЕМ ПРЯМОЙ СВЯЗИ МЕЖДУ КОСМИЧЕСКИМИ СТАНЦИЯМИ ПОДВИЖНОЙ СПУТНИКОВОЙ СЛУЖБЫ И ПОЛЬЗОВАТЕЛЬСКИМ ОБОРУДОВАНИЕМ IMT (DC-MSS-IMT)

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Аннотация. В данной статье рассматриваются особенности совместного использования радиочастотного спектра и обеспечения электромагнитной совместимости (ЭМС) систем прямой связи между космическими станциями подвижной спутниковой службы (DC-MSS) и пользовательским оборудованием международных мобильных телекоммуникаций (IMT). Актуальность исследования обусловлена стремительным развитием спутниковых и наземных телекоммуникационных технологий, а также возрастающей плотностью использования радиочастотного ресурса, что приводит к необходимости эффективного управления интерференцией и координации работы различных систем связи. В работе проведён анализ характеристик сигналов DC-MSS и IMT, включая параметры излучения, частотные диапазоны, уровни мощности и особенности распространения радиоволн. Особое внимание уделено вопросам взаимных помех, возникающих при одновременной эксплуатации данных систем, а также оценке их влияния на качество предоставляемых услуг связи. Рассматриваются модели распространения радиосигналов, методы расчёта зон покрытия и интерференционных областей, а также критерии допустимого уровня помех в соответствии с международными стандартами и рекомендациями. В статье также исследуются существующие подходы к обеспечению электромагнитной совместимости, включая пространственное, частотное и временное разделение ресурсов, использование адаптивных алгоритмов управления мощностью, применение современных технологий кодирования и модуляции, а также методы фильтрации и подавления помех. Приводятся результаты моделирования различных сценариев совместной работы систем DC-MSS и IMT, позволяющие определить оптимальные условия их функционирования без существенного ухудшения качества связи. Кроме того, рассматриваются вопросы нормативно-правового регулирования использования радиочастотного спектра, а также роль международных организаций в разработке рекомендаций по обеспечению совместимости

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спутниковых и наземных систем связи. В заключении формулируются практические рекомендации по повышению эффективности совместного использования спектра, снижению уровня взаимных помех и обеспечению устойчивой работы систем DC-MSS и IMT в условиях растущей нагрузки на радиочастотный ресурс.

Ключевые слова: электромагнитная совместимость, радиочастотный спектр, спутниковая связь, DC-MSS, IMT, интерференция, пользовательское оборудование, космические станции, управление помехами, моделирование радиосигналов, частотное распределение, телекоммуникационные системы, качество связи, стандарты связи.

Annotatsiya. Mazkur maqolada kosmik stansiyalar o‘rtasida to‘g‘ridan-to‘g‘ri aloqa tizimlari (DC-MSS) hamda xalqaro mobil telekommunikatsiya (IMT) foydalanuvchi qurilmalari o‘rtasida radiochastota spektridan birgalikda foydalanish va elektromagnit moslashuv (EMM) masalalari ko‘rib chiqiladi. Tadqiqotning dolzarbligi sun’iy yo‘ldosh va yer usti telekommunikatsiya texnologiyalarining jadal rivojlanishi hamda radiochastota resursidan foydalanish zichligining ortib borishi bilan izohlanadi. Bu esa interferensiyani samarali boshqarish va turli aloqa tizimlari faoliyatini muvofiqlashtirish zaruratini yuzaga keltiradi. Tadqiqotda DC-MSS va IMT signallarining asosiy xususiyatlari, jumladan, nurlanish parametrlari, chastota diapazonlari, quvvat darajalari va radio to‘lqinlarning tarqalish xususiyatlari tahlil qilinadi. Shuningdek, ushbu tizimlarning bir vaqtning o‘zida ishlashi natijasida yuzaga keladigan o‘zaro xalaqitlar va ularning aloqa sifatira ta’siri baholanadi. Radioto‘lqinlar tarqalish modellari, qamrov hududlarini aniqlash usullari hamda interferensiya zonalarini hisoblash yondashuvlari yoritiladi. Maqolada elektromagnit moslashuvni ta’minlashning zamonaviy usullari, jumladan, chastota, vaqt va makon bo‘yicha resurslarni ajratish, quvvatni moslashuvchan boshqarish algoritmlarini qo‘llash, zamonaviy modulyatsiya va kodlash texnologiyalaridan foydalanish, shuningdek, xalaqitlarni filtrlash va kamaytirish usullari ko‘rib chiqiladi. Turli ssenariylar asosida olib borilgan modellashtirish natijalari tizimlarning optimal ishlash sharoitlarini aniqlash imkonini beradi. Bundan tashqari, radiochastota spektridan foydalanishni tartibga solishning huquqiy asoslari va xalqaro tashkilotlarning bu boradagi roli ham tahlil qilinadi. Xulosa qismida spektrdan samarali foydalanish, o‘zaro xalaqitlarni kamaytirish va tizimlarning barqaror ishlashini ta’minlash bo‘yicha amaliy tavsiyalar berilgan.

Kalit so‘zlar: elektromagnit moslashuv, radiochastota spektri, sun’iy yo‘ldosh aloqasi, DC-MSS, IMT, interferensiya, foydalanuvchi qurilmalari, kosmik

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stansiyalar, xalaqitlarni boshqarish, radioto‘lqinlarni modellashtirish, chastota taqsimoti, telekommunikatsiya tizimlari, aloqa sifati, aloqa standartlari.

Abstract. This paper examines the features of spectrum sharing and electromagnetic compatibility (EMC) of direct communication systems between mobile satellite service (DC-MSS) space stations and International Mobile Telecommunications (IMT) user equipment. The relevance of this study is driven by the rapid development of satellite and terrestrial telecommunication technologies, as well as the increasing load on the radio-frequency spectrum, which requires effective interference management and coordination among different communication systems. The study analyzes the signal characteristics of DC-MSS and IMT, including emission parameters, frequency bands, power levels, and radio-wave propagation features. Special attention is paid to mutual interference arising during the simultaneous operation of these systems and its impact on the quality of communication services. The paper considers radio-signal propagation models, methods for determining coverage and interference zones, and permissible interference level criteria in accordance with international standards. Modern approaches to ensuring EMC are also explored, including spatial, frequency, and temporal resource separation, application of adaptive power control algorithms, use of advanced coding and modulation methods, and interference filtering and suppression techniques. Results of modeling various scenarios of DC-MSS and IMT system co-existence are presented, enabling the determination of optimal operating conditions. Additionally, regulatory and legal aspects of radio-frequency spectrum use are discussed, along with the role of international organizations in developing recommendations to ensure compatibility between satellite and terrestrial communication systems. The paper concludes with practical recommendations for improving spectrum utilization efficiency and reducing mutual interference levels.

Keywords: electromagnetic compatibility, radio-frequency spectrum, satellite communication, DC-MSS, IMT, interference, user equipment, space stations, interference management, radio-signal modeling, frequency allocation, telecommunication systems, quality of service, communication standards.

ВВЕДЕНИЕ.

Современная индустрия беспроводной связи находится на пороге фундаментальной трансформации, связанной с интеграцией наземных сетей подвижной связи (IMT) и космических систем. Концепция прямой связи между спутниками подвижной спутниковой службы (ПСС) и немодифицированным пользовательским оборудованием (UE), получившая в документах Международного союза электросвязи (МСЭ) обозначение DC-

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MSS-IMT, рассматривается как ключевой элемент архитектуры сетей пятого (5G) и шестого (6G) поколений. Основная цель этой интеграции заключается в обеспечении повсеместного покрытия и устранении «цифрового разрыва» в районах, где развертывание наземной инфраструктуры экономически нецелесообразно или технически невозможно, включая удаленные сельские зоны, морские акватории и зоны стихийных бедствий.

Регуляторная база для развития этой технологии была заложена на Всемирной конференции радиосвязи 2023 года (ВКР-23). Резолюция 253 (ВКР-23) инициировала исследования по пункту 1.13 повестки дня ВКР-27, который предполагает рассмотрение возможных новых распределений ПСС в диапазоне частот от 694/698 МГц до 2,7 ГГц.5 Эти исследования направлены на поиск технических и операционных мер, гарантирующих, что спутниковые станции не будут создавать недопустимых помех существующим наземным службам, имеющим первичный статус, и не будут требовать защиты от них.1 Важность этих исследований обусловлена тем, что предлагаемые диапазоны уже крайне плотно используются наземными сетями IMT, системами общественной безопасности (PPDR), радиоастрономией и правительственными службами.

Техническая реализация DC-MSS-IMT сталкивается с необходимостью гармонизации частотных планов, определенных в Рекомендации МСЭ-Р M.1036. Исторически спутниковые и наземные системы развивались в изолированных частотных сегментах: ПСС в L-диапазоне (1,5/1,6 ГГц) или S-диапазоне (2 ГГц), а наземные сети - в широком спектре от 700 МГц до 3,5 ГГц и выше.8 Новая модель предполагает использование спутниками частот, традиционно выделенных для наземной подвижной связи, что классифицируется текущим Регламентом радиосвязи как «несоответствующее использование спектра» при отсутствии соответствующих межгосударственных соглашений и регуляторных рамок.

МЕТОДОЛОГИЯ.

Переход к массовому коммерческому использованию DC-MSS-IMT требует детального анализа агрегированных помех, возникающих при работе крупных группировок спутников на низких околоземных орбитах (LEO). Операторы, такие как SpaceX, AST SpaceMobile и Lynk Global, уже продемонстрировали возможность установления голосовых вызовов и передачи данных с использованием обычных смартфонов, что подтверждает жизнеспособность технологии, но одновременно усиливает обеспокоенность

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традиционных операторов связи по поводу деградации качества обслуживания в их сетях.

Ключевым драйвером внедрения спутниковой составляющей в экосистему IMT стала работа консорциума 3GPP над стандартами неназемных сетей (Non-Terrestrial Networks, NTN). Начиная с Release 17, в спецификации были внесены изменения, позволяющие адаптировать протокол 5G New Radio (NR) для работы в условиях космического сегмента.4 Эти изменения критически важны для компенсации двух основных физических факторов: огромных задержек распространения сигнала (до 540 мс для GEO и 10–50 мс для LEO) и значительного доплеровского сдвига частоты, вызванного движением спутника со скоростью около 7,5 км/с.

Результаты и обсуждение.

Архитектура системы DC-MSS-IMT включает два основных типа организации спутниковой полезной нагрузки, каждый из которых накладывает свои ограничения на сценарии электромагнитной совместимости.

Рабочая группа 4C МСЭ-Р определила список приоритетных диапазонов для исследований совместимости, основываясь на расположении каналов IMT в Рекомендации M.1036.

Таблица 1

Список приоритетных диапазонов для исследований совместимости

Диапазон (МГц)	Наземное использование	Критические факторы совместимости
700 / 800 / 900	Основа покрытия LTE/5G, ТВ-вещание (ниже 694 МГц).	Риск помех для цифрового телевидения (DTT) и систем PPDR.
1427–1518 (L-band)	Дополнительный нисходящий канал (SDL) в Европе.	Защита пассивных служб (радиоастрономия) в полосе 1400–1427 МГц.
1920–1980 / 2110–2170	Основные полосы 3G/4G/5G (FDD).	Соседство с глубоким космосом (SRS) в 2110–2120 МГц и ПСС в 2170–2200 МГц.

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2300–2400	Широкополосный доступ, телеметрия.	Исключен из вариантов ПСС в Европе из-за чувствительности авиационной телеметрии.
2500–2690	Высокая емкость сетей IMT.	Защита радиоастрономии в смежной полосе 2690–2700 МГц.

Исследования электромагнитной совместимости (ЭМС) для DC-MSS-IMT базируются на анализе четырех основных векторов помех. Геометрия этих сценариев уникальна тем, что источник помех (спутник) находится на большой высоте и имеет зону видимости, охватывающую тысячи квадратных километров, что делает невозможным применение традиционных методов территориального разнесения.

Помехи на линии «космос-земля» (нисходящая линия).

В этом сценарии спутник ПСС передает сигнал на смартфон, который может быть принят наземными приемниками как мешающий сигнал.

Спутник -> Базовая станция IMT: Агрегированная мощность от всех спутников созвездия, работающих в той же полосе частот, повышает уровень шума на входе приемника БС. Это приводит к сокращению радиуса соты и снижению пропускной способности в восходящем канале наземной сети.

Спутник -> Наземное пользовательское оборудование: Хотя антенны смартфонов имеют низкое усиление, массовое присутствие спутников создает фоновое излучение, которое может влиять на качество приема в наземных сетях, особенно на границах зон обслуживания.

Помехи на линии «земля-космос» (восходящая линия)

Здесь источником помех выступает смартфон, работающий в режиме спутниковой связи.

UE ПСС -> Спутник другой системы: Если смартфон передает сигнал в сторону спутника на частотах, используемых другой спутниковой системой, это может вызвать деградацию канала этой системы.

UE ПСС -> Наземная базовая станция: В случае использования смежных каналов внеполосные излучения (OOBE) смартфона могут мешать приему сигналов от других абонентов наземной сети на ближайших базовых станциях.

Особую сложность представляют трансграничные сценарии. Спутниковые лучи неизбежно пересекают государственные границы, что требует разработки строгих технических мер для защиты наземных сетей соседних стран, которые могут не давать разрешения на использование

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данных частот спутниковыми операторами. Также критически важным является обеспечение защиты наземных систем в исключительных экономических зонах (EEZ) и на судах (MCV).

Методология исследований совместимости: MCL и Монте-Карло

Для оценки вероятности возникновения помех и определения допустимых уровней излучения применяются две основные методологии, закрепленные в отчетах МСЭ-Р.

Метод минимальных потерь связи (MCL). MCL представляет собой детерминистический подход, при котором рассматривается наихудший сценарий (worst-case). Предполагается, что мешающий передатчик и жертва находятся на минимально возможном расстоянии, а их антенны ориентированы друг на друга с максимальным усилением.

Применение: Используется для первичной оценки необходимости защитных интервалов и определения зон отчуждения. Например, расчеты MCL для полосы 5 ГГц показывают, что совместное использование спектра RLAN и спутниковыми системами возможно только при соблюдении строгих ограничений по мощности.

Недостатки: Часто дает избыточно пессимистичные результаты, так как вероятность совпадения всех наихудших условий крайне мала.

Статистическое моделирование Монте-Карло (SEAMCAT). Этот метод является более современным и точным для анализа динамических систем, таких как DC-MSS-IMT. С помощью программного обеспечения SEAMCAT моделируются тысячи случайных состояний системы («снимков»), в каждом из которых положение спутников, абонентов и параметры распространения радиоволн меняются в соответствии с заданными функциями распределения.

Применение: Оценка вероятности того, что уровень помехи превысит установленный порог защиты в течение определенного процента времени (например, 1% или 5%).

Результаты: Исследования в WP 4C показали, что учет агрегированной помехи от нескольких спутниковых систем является обязательным, так как в зоне видимости наземной станции может одновременно находиться до нескольких десятков активных спутников разных операторов.

Для корректного моделирования используются рекомендации МСЭ-Р по распространению радиоволн, такие как P.452 (для наземных трасс) и специфические модели для спутниковых каналов, учитывающие потери в теле пользователя, затенение зданиями и поглощение в атмосфере.

Критерии защиты и пределы плотности потока мощности (PFD)

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Результатом исследований совместимости является определение численных критериев защиты, которые не должны нарушаться спутниковыми системами. Основным критерием является отношение мощности помехи к мощности собственного теплового шума приемника (I/N).

Таблица 2

Критерии защиты и пределы плотности потока мощности (PFD)

Объект защиты	Критерий I/N (дБ)	Обоснование
Сети IMT (общий случай)	-6 дБ / -10 дБ	Допускается снижение пропускной способности на 5–10%.
Спутниковые сети (ПСС/ФСС)	-12.2 дБ	Соответствует увеличению эквивалентной шумовой температуры на 6% ($\Delta T/T$).
Радиоастрономия (RAS)	-15 дБ … -20 дБ	Чрезвычайно высокая чувствительность к любым внешним излучениям.
Авиационная телеметрия	-6 дБ	Критически важная служба для безопасности полетов.

Для практического регулирования эти критерии переводятся в пределы плотности потока мощности (PFD) на поверхности Земли. PFD — это количество энергии, приходящееся на единицу площади в определенной полосе частот (обычно дБВт/м²/МГц).

Исследования совместного использования и совместимости DC-MSS-IMT находятся в активной фазе. Техническая осуществимость прямой связи спутник-смартфон доказана, однако ее массовое внедрение зависит от способности регуляторов найти компромисс между инновациями и защитой существующих служб. На текущем этапе исследований установлено, что традиционные подходы к оценке одиночных помех утрачивают актуальность, в связи с чем возникает необходимость применения статистического моделирования для анализа агрегированных помех от мега-созвездий спутников. В области регулирования параметров излучения отмечается, что статичные ограничения мощности (PFD-маски) требуют

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замены на углозависимые модели, учитывающие характеристики наземных антенн систем IMT.

Кроме того, дальнейшее развитие стандартов 3GPP (начиная с Rel-19 и последующих релизов) должно предусматривать внедрение более эффективных механизмов управления помехами, включая координацию в реальном времени между спутниковыми и наземными системами планирования радиочастот. При этом следует учитывать, что в отдельных регионах некоторые диапазоны радиочастот, например диапазон 2,3 ГГц в Европе, вероятно, останутся недоступными для спутниковой компоненты вследствие строгих требований по обеспечению безопасности.

ЗАКЛЮЧЕНИЕ.

В данной статье рассмотрены особенности совместного использования и электромагнитной совместимости систем прямой связи между космическими станциями подвижной спутниковой службы (DC-MSS) и пользовательским оборудованием IMT. Проведен анализ потенциальных источников электромагнитных помех, а также факторов, влияющих на качество передачи данных и надежность связи в условиях совместного спектра частот.

Результаты исследования показали, что успешная интеграция DC-MSS и IMT-оборудования требует точного соблюдения нормативов по уровню радиопомех и разработку совместимых протоколов взаимодействия. Использование методов частотного планирования, фильтрации сигналов и координации между операторами позволяет существенно снизить вероятность взаимных помех и повысить эффективность использования спектра.

Кроме того, выявлено, что совместное функционирование систем возможно только при комплексном подходе, включающем технические, организационные и регуляторные меры. Применение предложенных рекомендаций позволит не только обеспечить надежную связь между космическими и наземными компонентами, но и повысить общую пропускную способность и качество услуг для конечного пользователя.

Таким образом, исследование подчеркивает важность системного подхода к обеспечению электромагнитной совместимости и рационального использования спектра для устойчивого развития спутниковой и мобильной связи в условиях роста требований к качеству и объему передаваемой информации.

В целом, дальнейшее развитие концепции DC-MSS-IMT связано с формированием так называемого «интеллектуального спектра», в рамках

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которого спутниковые и наземные сети будут функционировать как единая скоординированная система, обеспечивающая устойчивую связь в любой точке мира без взаимных помех. Период до 2027 года рассматривается как ключевой этап в формировании данной технологической парадигмы.

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QOG‘OZ ICHLAB CHIQARISH KORXONALARINI OQAVA SUVLARNI TOZALASHDA DISPERS KOLLOID SISTEMA HOSIL QILISH MEXANIZMI VA SAMARADORLIGI

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Annotatsiya. Koagulyantlar sifatida suvni tozalash uchun ishlatiladigan temir va alyuminiy tuzlari suv tarkibidagi muallaq moddalar va bakteriyalarni olib yuradigan flokulyant cho‘kindi hosil qilish uchun. Alyuminiy va temir o‘z ichiga olgan koagulyantlar mamlakatimizda va xorijda eng ko‘p qo‘llaniladi. Sellyuloza-qog‘oz ishlabchiqarish korxonalarini suvni koagulyant qo‘shib tozalash, asosan, suvning loyqaligiga va tarkibidagi organik moddalar miqdoriga qarab belgilanadi.

Kalit so‘zlar: koagulyantlar, alyuminiy, temir, oqova suvlar, sulfat, sanoat suvlari, xomashyo, qog‘oz , sellyuloza suvning loyqaligi, organik moddalar.

Аннотатция. Соли железа и алюминия, используемые в качестве коагулянтов при очистке воды, способны гидратироваться с образованием хлопьевидного осадка, переносящего в воду взвешенные вещества и бактерии. Коагулянты, содержащие алюминий и железо, получили наибольшее распространение в нашей стране и за рубежом. Очистка воды добавлением коагулянта на определяется в зависимости от мутности воды и количества органических веществ в ней.

Ключевые слова: атомные электростанции, сточные воды, котельная вода, техническая вода, сырье,

Abstract. Iron and aluminum salts used as coagulants for water treatment are able to hydrate to form a flocculent sediment that carries suspended matter and bacteria in the water. Coagulants containing aluminum and iron are the most widely used in our country and abroad. Treatment of water by adding coagulant in thermal power plants is mainly determined depending on the turbidity of water and the amount of organic substances in it.

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Keywords: nuclear power plants, waste water, boiler water, process water, raw materials,

KIRISH.

Tabiiy va sanoat chiqindi suvlarini koagulyantlar va flokulyantlardan foydalangan holda muallaq va kolloid dispers moddalardan tozalash muammosi yopiq suv aylanishi bilan texnologik sxemalarni yaratish va amalga oshirish tufayli mineral xomashyoni kompleks qayta ishlash, suv resurslarini sezilarli darajada ko‘paytirish, xo‘jalik faoliyatiga suv ta'minotining yangi manbalarini jalb qilish masalasini oqilona hal qilish imkonini berdi. [1-7]

Suvni muallaq moddalardan tozalashda zarrachalarning kichik o‘lchamlari va tizimning yuqori agregatsiya va cho‘kindi barqarorligi tufayli katta qiyinchiliklar paydo bo‘ladi. [8-9] Bu jarayonlarning kuchayishiga ko‘p hollarda koagulyantlar va flokulyantlar va ayniqsa ularning aralashmalari ta'sirida agregatlardagi zarrachalarning kattalashishi hisobiga erishish mumkin. Yana samaraliroq yangi koagulyantlardan foydalanish, dispers tizimlarning fazalarini maksimal darajada ajratishga yordam beruvchi ratsional texnologik sxemalarni ishlab chiqish, reagentlar tannarxini va sarfini kamaytirish dolzarb va muhim muammolardir.

Natijalar. Koagulyantlar sifatida suvni tozalash uchun ishlatiladigan temir va alyuminiy tuzlari suv tarkibidagi muallaq moddalar va bakteriyalarni olib yuradigan flokulyant cho‘kindi hosil qilish uchun hidratsiyaga qodir. Alyuminiy o‘z ichiga olgan koagulyantlar mamlakatimizda va xorijda eng ko‘p qo‘llaniladi. Buning uchun ishlatiladigan alyuminiy sulfat, asosan, qimmatbaho reagent bo‘lgan alyuminiy gidroksiddan olinadi.

Sellyuloza-qog‘oz ishlabchiqarish korxonalarini suvni organik va noorganiklar koagulyant qo‘shib tozalash, asosan, suvning loyqaligiga va tarkibidagi organik moddalar miqdoriga qarab belgilanadi.

TAJRIBA QISM. Suv namunalarini sintez qilib olingan maxaliy xom ashyolardan olingan biz tomonimizdan olingan bir yillik va ko‘p yillik sholi, qamish,somon b poyasi terak daraxtidan olingan texnik liglindan olingan natriy karboksil liglindan flokulyant sifatida foydalanib xar xil miqdorda qo‘shildi.

1-Jadval

T/r	Harorat	10 % li $FeCl_3$	10 % $CaOH_2$	pH	Na-KL
1	25^0C	0,8 ml	15 tomchi	8,0	0.5 ml
2	25^0C	0,8 ml	17 tomchi	8,2	0.6 ml
3	25^0C	0,8 ml	19 tomchi	8,5	0.8ml

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4	25^0C	0,8 ml	36 tomchi	9.0	0.9 ml
5	25^0C	0,8 ml	38 tomchi	9,5	5 ml
6	25^0C	0,8 ml	40 tomchi	8,5	5 ml
7	26^0C	0,8 ml	30 tomchi	10,5	8 ml

1 litrli 6 dona bonkaga chiqindi suvi quyib unga 40 ml dan 10 % li $CaOH_2$ va 10 % li $FeCl_3$ 0,2 ml dan qo`shildi hona harorati 30^0C.

2-Jadval

T/r	**Harorat**	**10 % li $FeCl_3$**	**10 % $CaOH_2$**	**PH**	**Na-KL 0,20 %**
1	30^0C	0,4 ml	40 ml	10	0,3 ml
2	30^0C	0,4 ml	40 ml	10	0,3 ml
3	30^0C	0,4 ml	40 ml	10	0,3 ml
4	30^0C	0,4 ml	40 ml	10	0,3 ml
5	30^0C	0,4 ml	40 ml	10	0,3 ml
6	30^0C	0,4 ml	40 ml	10	0,3 ml



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1-Rasm Koagulyatsiya jarayoni (Natriy Karboksil Lignin bilan)

Suvdagi kolloid zarrachalar

▼

Elektrostatik neytrallanish

(-COO^- guruhlari kolloidlarni neytrallashtiradi)

▼

Van der Waals kuchlari

(Zarrachalar fizikaviy tortish orqali birlashadi)

▼

Flokk hosil bo‘lishi

(Yirik, zich, barqaror xlopalar)

▼

Gravitatsiya ta’sirida cho‘kish

(Suv tozalandi, xlopalar cho‘kdi)

Tajriba natijalari shuni ko‘rsatadiki, natriy karboksil lignin samarali tabiiy koagulyant sifatida dispers tizimdagi kolloid zarrachalarni agregatsiyalash va xlopalar hosil qilishda yuqori samaradorlikka ega. Ushbu modda o‘zining anionli funksional guruhlari orqali suvdagi zarralar bilan elektrostatik va van-der-Vals kuchlari orqali o‘zaro bog‘lanadi, natijada zich, barqaror va tez cho‘kadigan xlopalar hosil bo‘ladi.

Optimal pH va lignin dozasi sharoitida hosil bo‘lgan flokklar gravitatsiya ta’sirida tez cho‘kadi, bu esa koagulyatsiya jarayonining samaradorligini oshiradi.

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Shuningdek, ligninning tabiiy polimer tuzilishi flokklarning mexanik mustahkamligini ta’minlaydi va jarayon davomida parchalanishni kamaytiradi.

3-Jadval

2026 YIL 20-YANVAR KUNGI LABORATORIYA BO`YICH ILMIY LABORATORIYASIDA FILTIR ORQALI OLINGAN SUVLARDAN OLINGAN MA`LUMOTLAR

T/r	pH ko`rsatgichi	Umumiy qattiqlik mmol ekv/l	Ca^{+2} mmol ekv/l	Mg^{+2} mmol ekv/l
1	11,21	9,275	9,175	0,1
2	11,07	7,225	7,075	0,15
3	11,78	26,62	26,32	0,3
4	11,64	18,725	18,7	0,025
5	10,91	635	6,1	0,25
6	11,24	8,625	8,55	0,075

Koagulyatsiya orqali suvni tozalashning ijobiy va salbiy tomonlari

Koagulyatsiya yordamida suvni tozalash bir qator afzalliklarga ega:

- Samaradorlik. Tozalash sifati haqiqatan ham yuqori: suv engilroq va butunlay shaffof bo‘ladi.
- Usul shartlarga mos kelmaydi: harorat, suv tarkibi, uning kislotalilik darajasi (odatda neytral pH talab qilinadi).
- Ushbu texnologiya yordamida suvni tozalashning arzonligi. Boshqa mexanik va reaktiv usullarga qaraganda arzonroq.

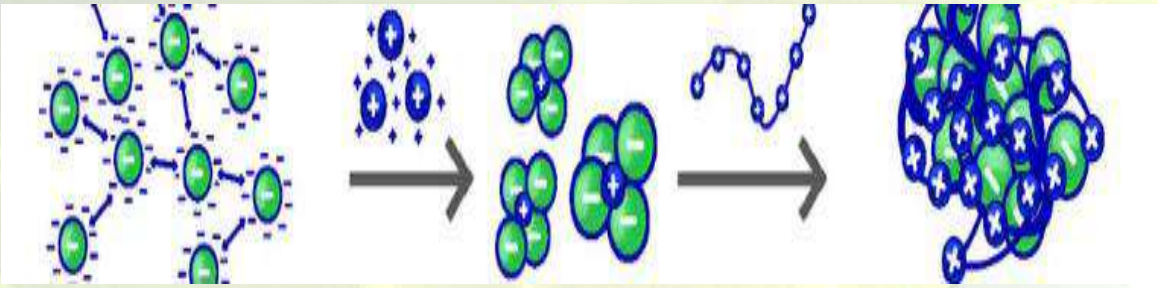
Usulning kamchiliklari:

- Jarayonning tezligi va yakuniy tozalash darajasi bog‘liq bo‘lgan dozani majburiy aniq hisoblash.
- Ikkilamchi chiqindilarni olib tashlash uchun filtrlash zarurati - cho‘kma parchalari.
- Koagulyatsiyani o‘z-o‘zini boshqarish bilan bog‘liq muammolar. Ushbu sohada maxsus bilim va tajribasiz uyda suvni tozalash deyarli mumkin emas.

FLOKULYATSIYA

Agar tozalashdan keyin koagulyatsion suyuqlik hali ham cho‘kmaydigan va mexanik filtrlashdan o‘tmaydigan kichik qo‘shimchalarni o‘z ichiga olsa, flokulyatsiya amalga oshiriladi. Bu hosil bo‘lgan yoriqlar bir-biriga yopishib kattaroq zarrachalar - flokulalar hosil qilish jarayonining nomi. Ularni olib tashlash osonroq, ular cho‘kma idishining pastki qismida tezroq joylashadi yoki filtr materialida saqlanadi.

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Flokulyantlarning vazifasi koagulyatsiyani kuchaytirish, ya'ni uning ta'sirini kuchaytirish, kichik zarralar orasidagi aloqalarni mustahkamlashdir. Bu moddalar makromolekulalar zanjiri shakliga ega chiziqli polimerlardir. Flokulyantlar organik, tabiiy va noorganikdir.

Tabiiy flokulyantlar guruhiga mevali va rezavorli keklar, oqsil asosli xamirturushlar, kraxmallar kiradi. Flokulyatsiya jarayonini qo‘zg‘atuvchi organik moddalar anion poliakrilamid va uning ba'zi sopolimerlari, shuningdek, katyonik birikmalardir. Noorganik flokulyantlardan biri natriy silikat bo‘lib, u erimaydigan tuzlar bilan kremniy kislotasiga sintez paytida faollashadi.

Ba'zida koagulyantlar oldindan kiritilmasdan suspenziyalarni yopishtirish va kattalashtirish uchun flokulyantlar qo‘llaniladi. Va bu yechim bir qator afzalliklarga ega:

- hosil bo‘lgan cho‘kindi miqdorining kamayishi, bir vaqtning o‘zida olib tashlash osonroq bo‘lgan katta yoriqlar sonini ko‘paytirish;
- kichikroq hajmdagi reagentlarni qo‘shganda ham eritmalarni barqarorlashtirish;
- qattiq fazani suyuqlikdan tez ajratish;
- keng pH diapazonida ishlash qobiliyati;
- temir ionlari yoki boshqa metallar bilan koagulyatsiyalangan eritmalarning mineralizatsiyasining yo‘qligi;
- eritmaning dastlabki kislotalilik darajasini saqlab turish.

XULOSA. Tajribalar shuni ko‘rsatdiki, koagulyant sifatida alyuminiy va temir sulfat birikmalari sanoat oqova suvlarini tozalashda samarali hisoblanadi.

Natriy karboksil liglindan flokulyant sifatidan foydanilganda sintetik polimer flokulyanlardan cho‘kma yirikligi va kaogulyasiya vaqti qisqaligini .

Shu bilan birga, temir va alyuminiy xloridlari asosidagi koagulyantlardan foydalanish qattiq sorbentlarga nisbatan bir qator afzalliklarga ega.

Alyuminiy-temir koagulyantlar aluminosilikat rudalarini sulfat kislota va xlorid kislota bilan reaksiyaga kiritish orqali osonlik bilan olinadi va eritma shaklida bevosita tozalash uchun ishlatilishi mumkin.

Chuqur suvni tozalash uchun suvni tozalashning kombinatsiyalangan sxemalarini qo‘llash maqsadga muvofiqdir. Birinchidan, suvni koagulyant bilan tozalang, so‘ngra qattiq adsorbentlardan foydalaniladi.

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Ilmiy tatqiqot ishlari davom etmoqda chiqindi suvlarni samarali tozalashi uchullari va tabiy flakulyatlar ustida izlanish kata yordam bergan Toshkent kimyo texnologiya ilmiy tatqiqot institutigan minadorchilik bildirib qolamiz.

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ISOLATION OF BIOLOGICALLY ACTIVE COMPOUNDS FROM ALOE VERA BIOMASS AND THEIR APPLICATION IN ECOLOGICAL SYSTEMS

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Abstract. Aloe vera is recognized as a significant medicinal plant due to its rich content of biologically active compounds. This study focuses on the chemical profile of Aloe vera, its bioactive constituents, and the methodologies employed for their extraction. Specifically, extraction techniques targeting polysaccharides, flavonoids, phenolic compounds, and other bioactive molecules present in Aloe vera leaves were examined. The findings indicate that extracts from Aloe vera exhibit notable antioxidant, antibacterial, and regenerative effects. These compounds have diverse applications across pharmaceutical, cosmetic, food, and environmental technology sectors. The results further suggest promising potential for scalable extraction and effective utilization of natural bioactive substances derived from Aloe vera.

Keywords: Aloe vera, biologically active compounds, polysaccharides, extraction methods, antioxidant properties, medicinal plants.

Annotatsiya. Aloe vera o‘z tarkibida biologik faol birikmalarning boyligi sababli muhim dorivor o‘simlik sifatida e’tirof etiladi. Ushbu tadqiqot Aloe vera ning kimyoviy tarkibi, uning biofaol komponentlari hamda ularni ajratib olish usullarini o‘rganishga bag‘ishlangan. Xususan, Aloe vera barglarida mavjud polisaxaridlar, flavonoidlar, fenolik birikmalar va boshqa biofaol moddalarning ekstraksiyasi usullari tahlil qilindi. Olingan natijalar Aloe vera ekstraktlari sezilarli darajada antioksidant, antibakterial va regenerativ xususiyatlarga ega ekanligini ko‘rsatdi. Ushbu birikmalar farmatsevtika, kosmetika, oziq-ovqat va ekologik texnologiyalar sohalarida keng qo‘llanilish imkoniyatiga ega. Tadqiqot natijalari Aloe vera asosidagi tabiiy biofaol moddalarning sanoat miqyosida samarali ajratib olinishi va amaliy qo‘llanilishi istiqbolli ekanligini ko‘rsatadi.

Kalit so‘zlar: Aloe vera, biologik faol birikmalar, polisaxaridlar, ekstraksiya usullari, antioksidant xususiyatlar, dorivor o‘simliklar.

Аннотация. Алоэ вера признано важным лекарственным растением благодаря высокому содержанию биологически активных соединений. Данное исследование посвящено изучению химического состава Aloe vera,

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его биоактивных компонентов, а также методов их извлечения. В частности, были рассмотрены методы экстракции полисахаридов, флавоноидов, фенольных соединений и других биоактивных веществ, содержащихся в листьях Aloe vera. Полученные результаты показали, что экстракты Aloe vera обладают выраженными антиоксидантными, антибактериальными и регенеративными свойствами. Эти соединения находят широкое применение в фармацевтической, косметической, пищевой и экологической отраслях. Результаты исследования также свидетельствуют о перспективности масштабируемого извлечения и эффективного использования природных биоактивных веществ, полученных из Aloe vera.

Ключевые слова: Aloe vera, биологически активные соединения, полисахариды, методы экстракции, антиоксидантные свойства, лекарственные растения.

INTRODUCTION.

In recent years, there has been growing interest in the extraction of biologically active compounds from medicinal plants, primarily due to their application in pharmaceutical and biotechnological domains. Naturally derived bioactive substances are valued for their environmental compatibility, biological efficacy, and positive impacts on human health. Hence, advancing technologies to isolate novel biologically active compounds from plant sources holds considerable scientific and applied relevance. Aloe vera (Aloe barbadensis Miller) represents a prominent example of such a plant, widely recognized in traditional and modern medicine. The leaves contain a complex mixture including polysaccharides, vitamins, minerals, enzymes, and phenolic compounds, which collectively contribute to antioxidant, anti-inflammatory, antibacterial, and regenerative functions. The majority of these bioactive components are localized within the leaf gel and can be extracted through various methods. Contemporary approaches often utilize aqueous and alcoholic solvents, ultrasound-assisted extraction, and supercritical fluid techniques, facilitating efficient recovery with improved yields. Products derived from Aloe vera are extensively incorporated in pharmaceuticals, dietary supplements, cosmetics, and environmental remediation technologies. Consequently, a thorough investigation into extraction processes and a broader evaluation of application potential remain pivotal objectives. This study aims to analyze extraction technologies for Aloe vera's bioactive compounds and assess their prospective uses in pharmaceutical and environmental fields.

RESEARCH METHODOLOGY. Mature Aloe vera leaves (Aloe barbadensis Miller) served as the primary material for this investigation. Initial assessment of morphological parameters and external characteristics was

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conducted through visual inspection. Prior to experimental procedures, leaves were rinsed with distilled water to eliminate dust and surface impurities. The study utilized reagents including distilled water, ethanol (96%), methanol, the DPPH reagent (2,2-diphenyl-1-picrylhydrazyl), microbiological media, and standard bacterial strains. Analytical tools and equipment comprised a spectrophotometer, ultrasonic extractor, laboratory dryer, and precision balances.

Method for Obtaining Aloe vera Extract. The internal gel from Aloe vera leaves was carefully separated and homogenized into a uniform mass. This gel was further processed with a grinder to produce a homogeneous suspension. Extraction was performed using both aqueous and ethanol-based solvents under controlled conditions: solvent-to-material ratio of 10:1, temperature maintained between 45 and 50 °C, extraction duration of 2 to 3 hours, and stirring speed at 200 rpm. Upon completion of extraction, the solution underwent filtration, followed by concentration through vacuum evaporation techniques to yield the final extract.

RESEARCH RESULTS AND THEIR DISCUSSION.

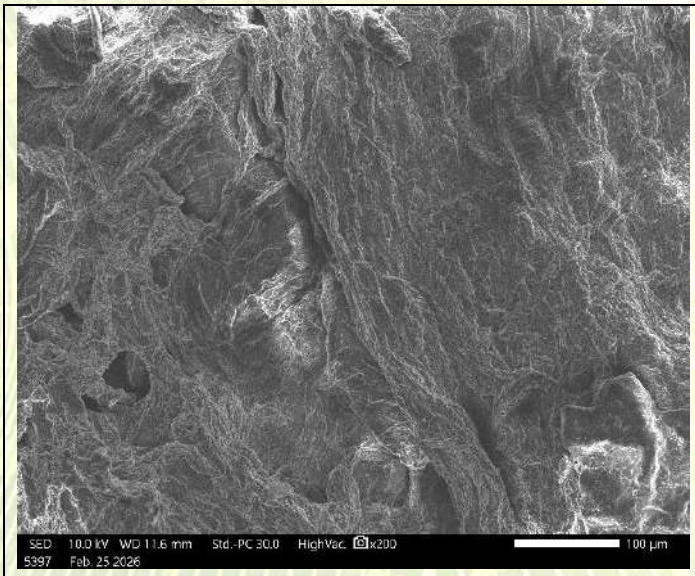


Figure 1. SEM microstructure of an Aloe vera-based biomaterial (×200 magnification). The SEM image reveals an uneven, layered, and fibrous microstructure of the material surface. The structure contains interconnected fibrillar elements, indicating that the biomaterial has a natural polysaccharide-based composition. The surface irregularity suggests the presence of an active surface area suitable for adsorption processes.

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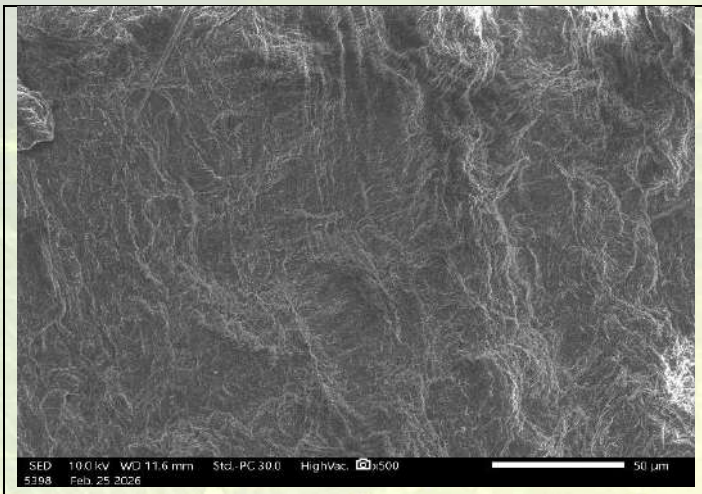


Figure 2. SEM image of the biopolymer matrix (×500 magnification). The image shows the formation of microchannels and a fibrous branched structure on the material surface. Such a microstructural configuration facilitates mass transfer and diffusion processes. This condition may enhance the adsorption and biological activity properties of the material.

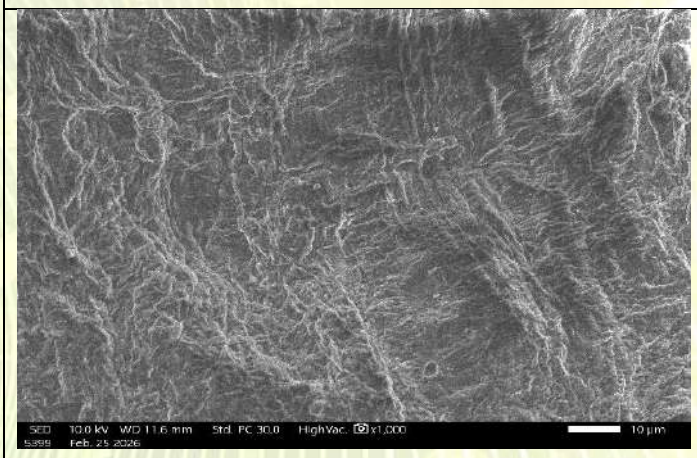


Figure 3. Fibrous microstructure of the biomaterial (×1000 magnification). SEM analysis shows the presence of clearly visible microfibers on the material surface. The fibers are interconnected, forming a three-dimensional structure. Such a structure enhances the mechanical strength and active surface area of the biomaterial.

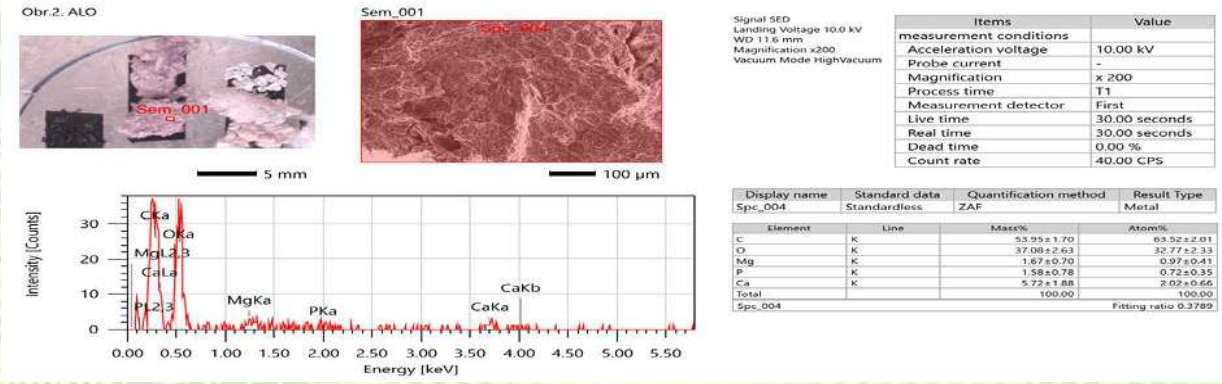


Figure 4. SEM image and EDS elemental analysis of the Aloe vera-based sample, showing the surface morphology and elemental composition of the material (×200 magnification).

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The SEM image reveals that the surface of the Aloe vera-based sample presents an irregular and fibrous microstructure. The observed layered and fibrillar features suggest a composition primarily based on natural polysaccharides. This microstructural arrangement likely enhances the material's surface area, thereby facilitating adsorption processes. EDS spectral analysis identifies carbon (C), oxygen (O), phosphorus (P), magnesium (Mg), and calcium (Ca) as the principal elements. Quantitative data indicate that carbon accounts for 53.95 wt.% and oxygen for 37.08 wt.%, consistent with an organic biopolymeric framework. The detection of calcium and magnesium implies the presence of mineral constituents or inorganic compounds of biological origin, while phosphorus is presumably associated with phosphate compounds inherent to the plant biomaterial. Collectively, SEM–EDS results suggest the Aloe vera-based material comprises a complex microstructure integrating an organic polymeric matrix with mineral components. This structural complexity potentially broadens the scope of its application in adsorption, biological, and environmental technologies.

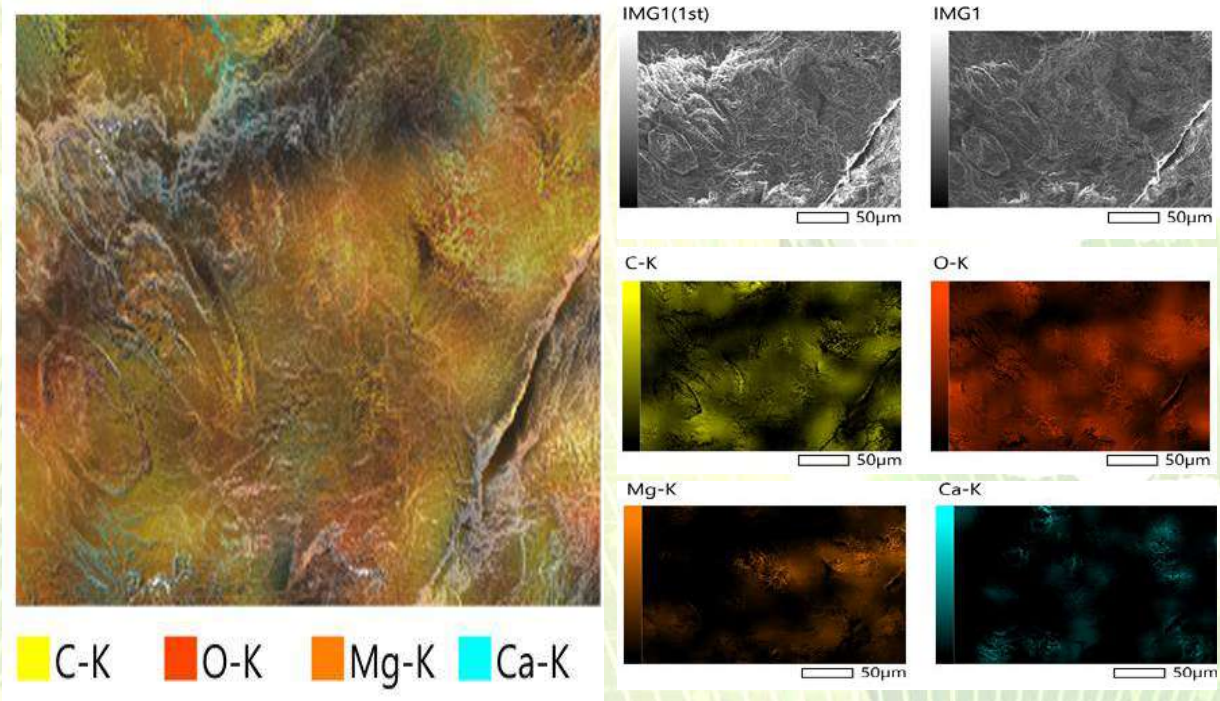


Figure 5. SEM–EDS elemental mapping and microstructure of the surface of the Aloe vera-based biomaterial.

Figure 5 illustrates the SEM image alongside EDS elemental mapping of the Aloe vera-based biomaterial's surface. The images confirm a surface characterized by unevenness, fibrous texture, and layered morphology, which suggests an elevated surface area conducive to adsorption. Elemental mapping identifies carbon, oxygen, magnesium, and calcium as predominant elements. Carbon and oxygen display a widespread and relatively uniform distribution over the surface, corroborating the organic polysaccharide-based nature of the material. In contrast,

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magnesium and calcium are localized in specific regions, pointing to the incorporation of mineral or inorganic components derived from plant biomass. The heterogeneous distribution of these elements may influence the physicochemical characteristics of the biomaterial, with implications for its adsorption capacity and catalytic behavior. Overall, SEM–EDS elemental mapping supports the conclusion that the Aloe vera-derived biomaterial features a heterogeneous microstructure composed of an organic biopolymer matrix interspersed with mineral phases, underscoring its suitability for applications in environmental remediation, adsorption technologies, and biotechnology.

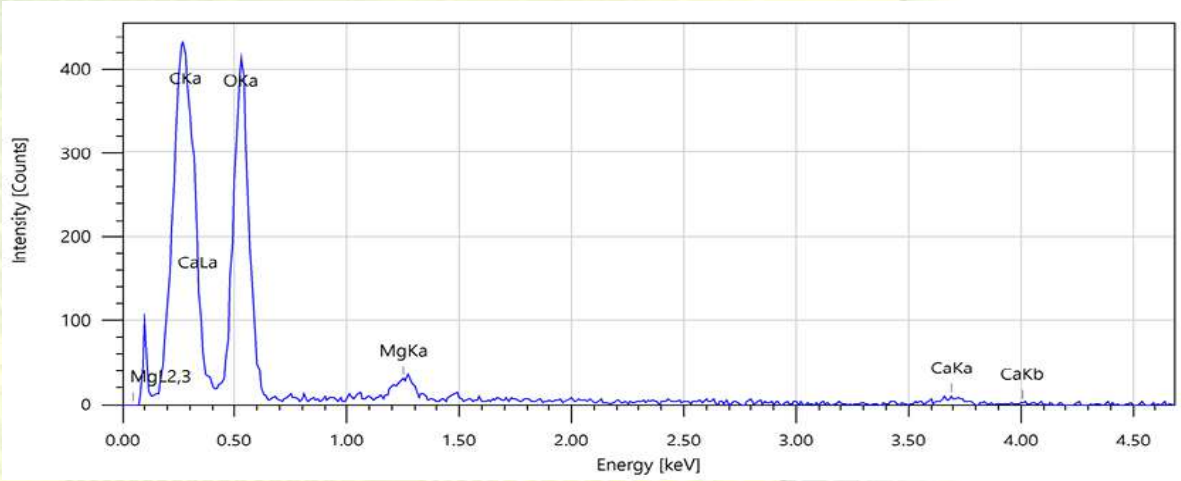


Figure 6. EDS spectrum and elemental composition analysis of the Aloe vera-based sample.

Energy-dispersive X-ray spectroscopy (EDS) analysis revealed that the primary elements present in the sample are carbon (C), oxygen (O), magnesium (Mg), and calcium (Ca). The spectrum exhibited the most intense peaks corresponding to C Kα and O Kα, suggesting that the sample predominantly comprises organic biopolymer constituents. This observation aligns with the known composition of Aloe vera, which is characterized by a high content of polysaccharides and other organic molecules. Furthermore, the detection of Mg Kα as well as Ca Kα and Ca Kβ peaks points to the presence of mineral elements within the biomaterial. These elements likely originate from intrinsic mineral components naturally found in the plant tissue or possibly from inorganic compounds absorbed by the biomass. Collectively, the EDS data confirm that the Aloe vera-derived material possesses a chemically complex matrix containing both organic constituents (carbon and oxygen) and inorganic mineral elements (magnesium and calcium). Such a composition may have a favorable impact on the material's biological activity and adsorption capabilities.

CONCLUSION. In this study, the microstructural features and elemental composition of an Aloe vera-derived biomaterial were characterized using

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scanning electron microscopy (SEM) and EDS techniques. The findings demonstrated that the surface morphology of the material is heterogeneous, exhibiting fibrous and porous characteristics. This microstructure enhances the surface area and thus may facilitate the adsorption of various substances. SEM imaging further revealed fibrillar and laminar features indicative of a biopolymer scaffold originating from plant biomass. Detailed high-magnification observations confirmed the presence of microvoids and fibrous domains on the surface. Elemental mapping showed a uniform distribution of carbon and oxygen throughout the material, underscoring its polysaccharide-rich organic nature. The co-localization of magnesium and calcium suggests that mineral components are also integrated within the matrix. These results indicate that the Aloe vera-based biomaterial consists of a hybrid organic–mineral framework, where its extensive surface area and intricate microstructure could be critical for adsorption and biological interactions. Consequently, this material merits consideration for potential applications in environmental remediation, adsorption technologies, biotechnology, and pharmaceutical fields. Future research should aim to elucidate the physicochemical properties more thoroughly and explore broader practical uses across various industrial and environmental contexts.

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SOG‘LIQNI SAQLASHDA SINTETIK MA'LUMOTLARNI YARATISH USULLARI

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Annotatsiya. Ushbu tadqiqot ishida sog‘liqni saqlash sohasida sintetik ma’lumotlarni yaratish usullari, ularning qo‘llanilishi va samaradorligi tahlil qilinadi. Zamonaviy raqamli tibbiyot tizimlarida ma’lumotlar hajmining ortib borishi bilan birga, maxfiylik va ma’lumotlar yetishmovchiligi muammolari dolzarb ahamiyat kasb etmoqda. Shu nuqtai nazardan, sintetik ma’lumotlar sun’iy intellekt modellarini o‘qitish uchun muqobil va xavfsiz yechim sifatida qaraladi. Tadqiqotda turli xil ma’lumot turlari jadval, tasvir, vaqtli qatorlar va omiks ma’lumotlari asosida sintetik ma’lumotlarni generatsiya qilish metodlari ko‘rib chiqilgan. Ular statistik, mashinali o‘rganish va chuqur o‘rganish yondashuvlari asosida tahlil qilingan. Natijalar shuni ko‘rsatadiki, chuqur o‘rganishga asoslangan usullar yuqori samaradorlikka ega bo‘lib, ayniqsa GAN modellar keng qo‘llanilmoqda. Shuningdek, sintetik ma’lumotlar yordamida bemor maxfiyligini saqlagan holda, tibbiy tadqiqotlar samaradorligini oshirish, sun’iy intellekt modellarining aniqligini yaxshilash va sog‘liqni saqlash tizimlarida innovatsion yechimlarni joriy etish imkoniyati mavjud.

Kalit so‘zlar: sintetik ma’lumotlar, sog‘liqni saqlash, sun’iy intellekt, chuqur o‘rganish, ma’lumotlar maxfiyligi, GAN modellari

Аннотация. В данной работе рассматриваются методы генерации синтетических данных в сфере здравоохранения, а также анализируется их эффективность и области применения. В условиях стремительного роста объёмов медицинских данных особую актуальность приобретают вопросы конфиденциальности и ограниченного доступа к данным. В этом контексте синтетические данные выступают в качестве безопасной альтернативы для обучения моделей искусственного интеллекта. В исследовании проанализированы методы генерации синтетических данных для различных типов данных: табличных, изображений, временных рядов и омикс-данных. Методы классифицированы на статистические, машинного обучения и глубокого обучения. Полученные результаты показывают, что методы глубокого обучения, особенно основанные на GAN, обладают высокой эффективностью. Использование синтетических данных позволяет повысить

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точность моделей, обеспечить конфиденциальность пациентов и ускорить развитие медицинских исследований.

Ключевые слова: синтетические данные, здравоохранение, искусственный интеллект, глубокое обучение, конфиденциальность данных, GAN модели

Abstract. This study explores methods for generating synthetic data in the healthcare domain, along with their applications and effectiveness. With the rapid growth of medical data, issues such as data privacy and limited accessibility have become increasingly important. In this context, synthetic data emerges as a secure alternative for training artificial intelligence models. The research examines various data types, including tabular, image, time-series, and omics data, and analyzes generation methods based on statistical, machine learning, and deep learning approaches. The results indicate that deep learning-based methods, particularly Generative Adversarial Networks (GANs), demonstrate high performance. The use of synthetic data enables improved model accuracy, preservation of patient privacy, and acceleration of innovation in healthcare systems.

Keywords: synthetic data, healthcare, artificial intelligence, deep learning, data privacy, GAN models

1. KIRISH

Elektron sog‘liqni saqlash qaydlari (EHR), taqiladigan sog‘liqni saqlash qurilmalari, genomik ketma-ketlik, tibbiy tasvirlash, mobil sog‘liqni saqlash ilovalari va teletibbiyot kabi raqamli sog‘liqni saqlash texnologiyalarining jadal o‘sishi har kuni ulkan hajmdagi ma’lumotlar ishlab chiqarilishiga olib kelmoqda. Ushbu ma’lumotlar ilg‘or tahlil va sun’iy intellekt (AI) yordamida sog‘liqni saqlash natijalarini sezilarli darajada yaxshilashi mumkin [1,2]. Biroq, bemor ma’lumotlarining nozik (maxfiy) tabiati ulardan foydalanish imkoniyatini cheklaydi va tadqiqot hamda ishlanmalar jarayonida jiddiy to‘siqlarni keltirib chiqaradi [3–5].

Sintetik ma’lumotlar — bu shaxslarning kimligini xavf ostiga qo‘ymasdan, real dunyo ma’lumotlariga taqlid qila oladigan, sun’iy ravishda yaratilgan ma’lumotlardir. Shunday qilib, sintetik ma’lumotlar AQShdagi "Sog‘liqni saqlash sug‘urtasining harakatchanligi va hisobdorligi to‘g‘risida"gi qonun (HIPAA) yoki Yevropadagi "Ma’lumotlarni himoya qilish umumiy reglamenti" (GDPR) kabi qoidalarga muvofiq, bemor maxfiyligini saqlagan holda sog‘liqni saqlash ma’lumotlarining boy imkoniyatlaridan foydalanishning noyob usulini taklif etadi.

Sog‘liqni saqlashda sintetik ma’lumotlarning qiymati juda katta ahamiyatga ega. Sintetik ma’lumotlardan sun’iy intellekt modellarining samaradorligini oshirish, simulyatsiya qilingan klinik sinovlar orqali dori-darmonlarni yaratishni

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tezlashtirish, mavjud ma’lumotlarni to‘ldirish va ma’lumotlar hajmini oshirish orqali ulardan foydalanish imkoniyatini yaxshilash hamda shaxsni aniqlash mumkin bo‘lgan har qanday ma’lumotdan (PPI) qochgan holda asl ma’lumotlarni takrorlash orqali maxfiylikni himoya qilishda foydalanish mumkin [6–10].

Shunday qilib, sintetik ma’lumotlar nafaqat bemor anonimligini ta’minlaydi, balki tadqiqotchilarga ma’lumotlar mavjudligi bilan bog‘liq to‘siqlarni yengib o‘tishga imkon beradi, bu esa ularga bemorlarning shaxsini oshkor qilish xavfisiz keng ko‘lamli tajribalar va simulyatsiyalar o‘tkazish imkonini beradi. Bundan tashqari, sintetik ma’lumotlar turli populyatsiyalar bo‘ylab AI modellarining umumlashish qobiliyatini (generalizability) yaxshilash uchun yanada xilma-xil va ochiq ma’lumotlarni ishlab chiqishga yordam beradi. Bu, ayniqsa, ma’lumotlar zararli tarafkashliklar (masalan, yosh, irq, jins) kontekstida bir tomonlama yoki yetarli darajada ifodalanmagan holatlarda juda muhimdir; bunda sintetik ma’lumotlarni yaratishdan ushbu muammolarni yumshatish metodologiyasi sifatida foydalanish mumkin.

Sintetik ma’lumotlar AI modellarini o‘qitishda real ma’lumotlarning o‘rnini bosuvchi vosita bo‘lib xizmat qilishi mumkin. Ammo biz sintetik ma’lumotlarni qanday yaratishimiz mumkin? Sintetik ma’lumotlar o‘xshash xususiyatlarga ega yangi ma’lumot nuqtalarini yaratish uchun real ma’lumotlarning statistik xususiyatlarini aniqlash orqali yaratilishi mumkin. Adabiyotlarga ko‘ra, yuqori sifatli sintetik jadval, tasvir, radiomika, vaqtli qatorlar va omiks ma’lumotlarini yaratish uchun turli xil usullar taklif qilingan bo‘lib, ular quyidagicha toifalanadi:

Biroq, maxfiylik muhim omil bo‘lib, u faqat ma’lumotlarning haqqoniyligi (fidelity) bilan kafolatlanmaydi. Shu maqsadda, ma’lumotlarni himoya qilish bo‘yicha eng yaxshi amaliyotlar, shaxsni aniqlash imkoniyatini (identifiability) baholashning aniqroq standartlari va maxfiylikni ta’minlagan holda innovatsiyalarni rag‘batlantirish uchun mutanosib tartibga solish yondashuvlari qabul qilinishi kerak. Shunday qilib, yuqori sifatli sintetik ma’lumotlarning mavjudligi tadqiqotchilarga ko‘p modalli AI modellarini ishlab chiqish imkonini beradi. Bundan tashqari, sintetik ma’lumotlar real ma’lumotlar to‘plamlarida tez-tez uchramaydigan murakkab bemor ssenariylarini simulyatsiya qilish imkonini beradi, shu orqali sog‘liqni saqlash tizimlarining kam uchraydigan, ammo o‘ta muhim holatlarga qarshi mustahkamligini oshiradi. Bundan tashqari, sintetik ma’lumotlardan foydalanish orqali tadqiqotchilar ko‘p modalli ma’lumotlarni birlashtirish va tahlil qilish jarayonida yuzaga keladigan ko‘plab logistik va etik to‘siqlarni chetlab o‘tishlari mumkin, bu esa tadqiqot sur’atini tezlashtiradi. Oxir-oqibat, sintetik ma’lumotlardan foydalanish shaxsiy ma’lumotlar maxfiyligining qat’iy standartlariga rioya qilgan holda, davolash samaradorligini va bemor

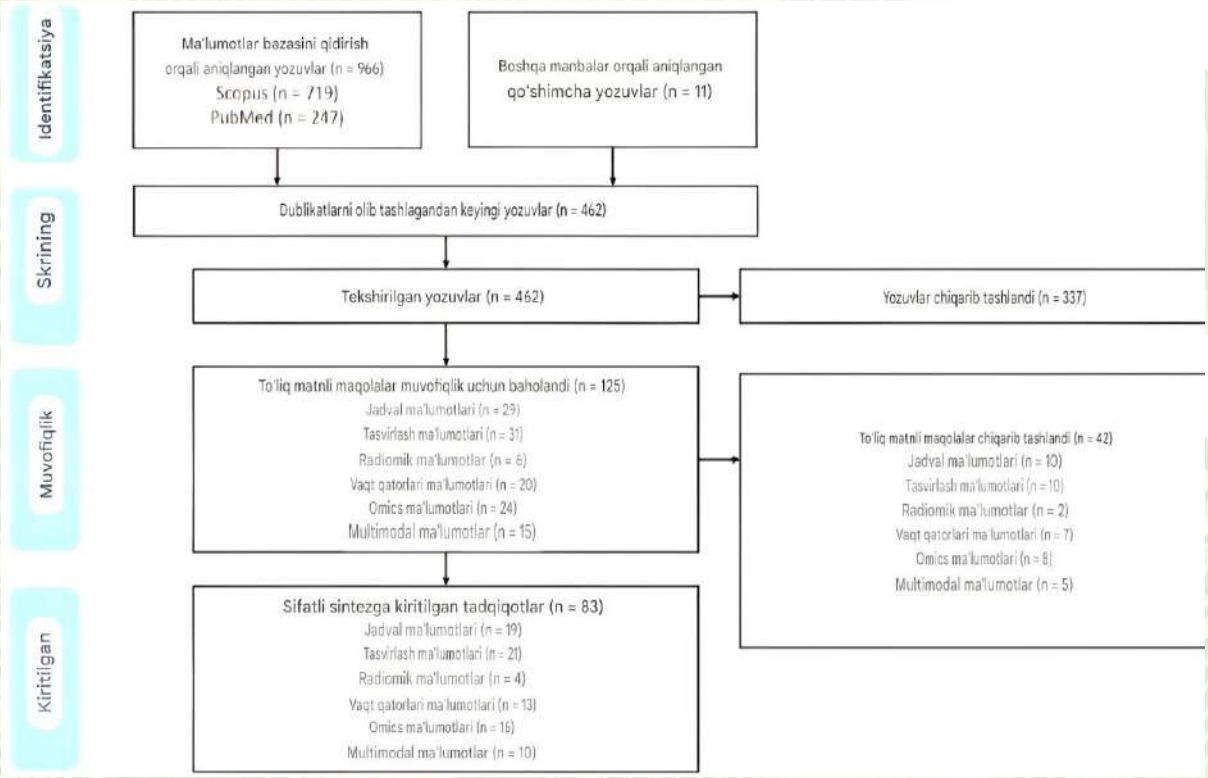
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natijalarini yaxshilab, shaxsiylashtirilgan tibbiyotni sezilarli darajada rivojlantirishi mumkin.

Ushbu sharhning maqsadi — innovatsiyalarni rag‘batlantirish va turli sog‘liqni saqlash sohalaridagi umumiy muammolarni yanada samarali hal qilish, shuningdek, maqsadli tibbiy tadqiqotlar va amaliyotda sintetik ma’lumotlarning ta’sirini yaxshilash uchun sintetik ma’lumotlarni yaratish metodologiyalari, kodlar va sintetik ma’lumotlarga ega ochiq manbali repozitoriylarni har tomonlama tahlil qilishdan iborat. Ushbu sharhning asosiy maqsadlari quyidagilardan iborat:

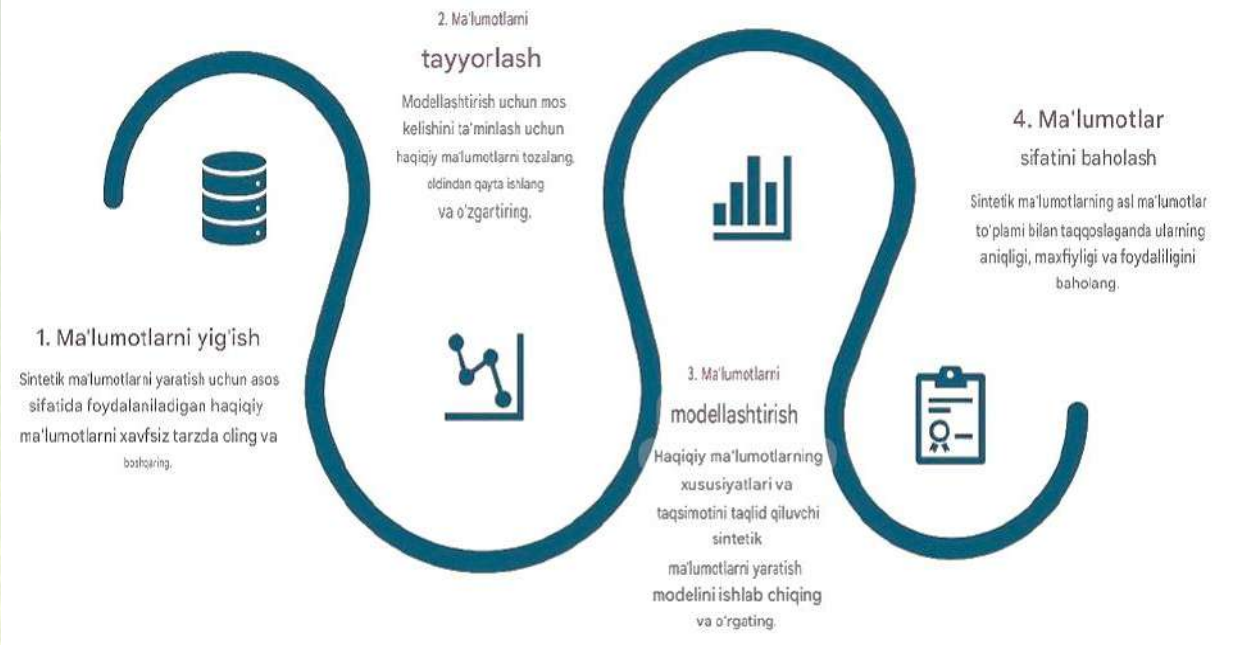
2. METODLAR

2.1. Ko‘rib chiqish jarayoni Biz sog‘liqni saqlashda sintetik ma’lumotlarni yaratish texnologiyalarining turli xil qo‘llanilish holatlarini mustahkam mavzuviy tahlil qilishni ta’minlash maqsadida, yuqori sifatli taqriz qilinadigan jurnallar va xalqaro konferensiyalarga asoslangan PubMed va Scopus ma’lumotlar bazalari bo‘yicha mavjud adabiyotlarning tizimli sharhini o‘tkazdik. Bizning tahlilimiz beshta asosiy ma’lumot turiga qaratilgan: jadval ma’lumotlari, tasviriy ma’lumotlar, radiomika ma’lumotlari (tasvirga asoslangan miqdoriy xususiyatlar), vaqtli qatorlar ma’lumotlari va omiks ma’lumotlari. Shuningdek, ko‘p modalli (multimodal) sintetik ma’lumotlarni yaratishning maxsus holatlari ham o‘rganildi.



1-rasm. Tizimli ko‘rib chiqish uchun PRISMA oqim diagrammasi; bunga ma’lumotlar bazalarini qidirish, saralangan annotatsiyalar soni va olingan to‘liq matnlar kiradi.

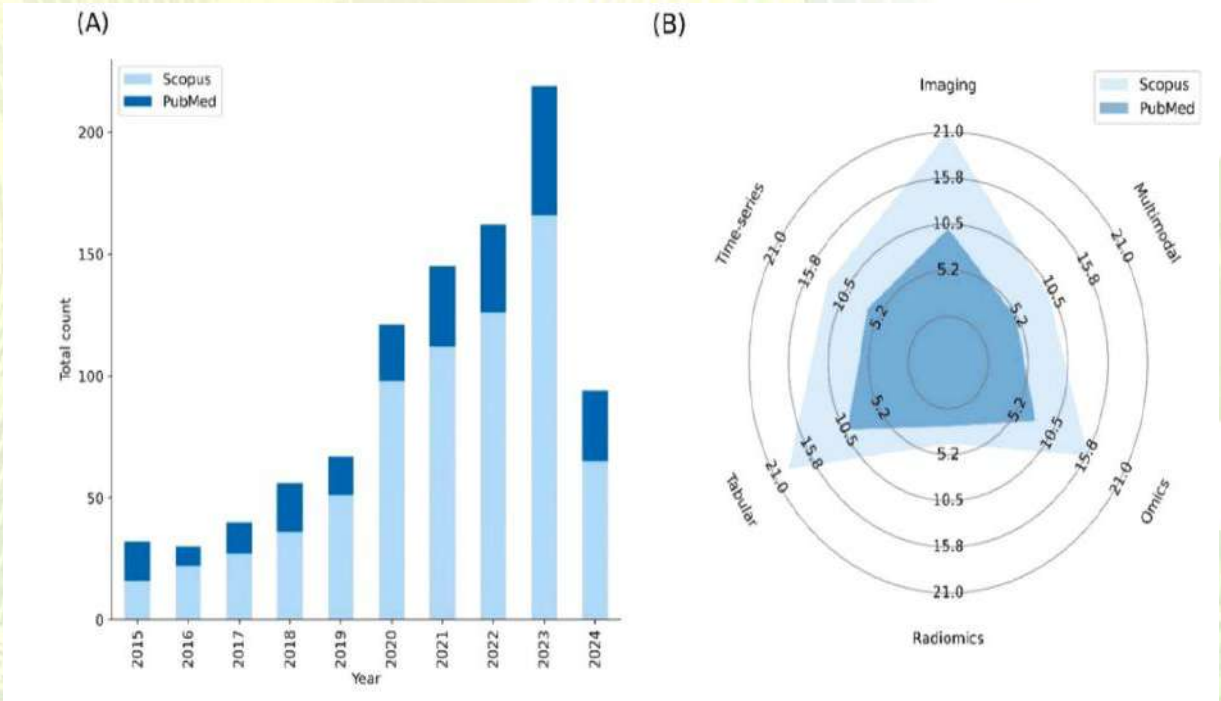
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2-rasm. Sintetik ma’lumotlarni yaratish ish jarayonining to‘rtta bosqichi

3. NATIJALAR

3.1. Sohadagi tendensiyalarning qisqacha mazmuni



3-rasm. Quyidagilarning umumiy tavsifi: (A) PubMed va Scopus ma'lumotlar bazalari bo‘yicha sog‘liqni saqlash sohasida sun'iy ma'lumotlarni yaratishga oid tadqiqotlarning yillik umumiy soni; (B) PubMed va Scopus ma'lumotlariga ko‘ra, turli xil ma'lumot turlari (beshta asosiy ma'lumot turi va multimodal ma'lumot holatlari) bo‘yicha tadqiqotlarning yakuniy soni.

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1-Jadval

Yo‘nalish	Eng yuqori ko‘rsatkich	Ulushi
Asosiy usul	Deep Learning (Chuqur o‘rganish)	**72.6%**
Asosiy til	Python	**75.3%**

Shuningdek, bir nechta DL yondashuvlarining kombinatsiyasidan iborat bo‘lgan Konvolyutsion neyron tarmoqlari ansambli (Ensemble of CNNs) tasvirlardagi "taqsimotdan tashqari" (out-of-distribution) obyektlarni aniqlash imkoniyatini oshiradi, bu esa ishonchli tibbiy tashxis qo‘yish uchun juda muhimdir. Xuddi shunday, Normallashtiruvchi oqimlar (Normalizing Flows) kompyuter tomografiyasi (KT) ma’lumotlarini olish va rekonstruksiya qilishdagi anomaliyalar ta’sirini kamaytirish, aniqroq va barqaror tasvirlarni ta’minlash uchun qo‘llanilgan.

Nihoyat, tadqiqotchilarga turli xil tibbiy tasvirlar (jumladan, mammografiya, bosh miya MRT, endoskopiya, ko‘krak qafasi rentgenogrammasi, yurak MRT va ko‘krak bezi DCE-MRT) bilan ishlash, ularni yaratish va ulardan foydalanish imkonini beruvchi **medigan** deb nomlangan Python kutubxonasi ishlab chiqilgan. Ushbu kutubxona tarkibida bir nechta oldindan o‘qitilgan (pre-trained) GAN-ga asoslangan modellar (CT-GAN, WGAN, SinGAN, PGGAN, FastGAN, pix2pix) mavjamud.

Asosiy tushunchalar:

- **PET reconstruction:** PET skaneridan olingan xom ma'lumotlarni tushunarli tasvirga aylantirish jarayoni.
- **Vision Transformers:** Tasvirlarni tahlil qilishda "diqqat" (attention) mexanizmidan foydalanuvchi yangi avlod modellari.
- **Out-of-distribution:** Model o‘rgatilgan ma'lumotlar to‘plamiga kirmaydigan, kutilmagan yoki noodatiy holatlar.
- **Medigan:** Tibbiy sun'iy tasvirlar bilan ishlash uchun maxsus yaratilgan ochiq manbali vosita.

Sun’iy tasviriy ma’lumotlarning aniqligi (fidelity) va sifatini baholashda keng qo‘llaniladigan metrikalar qatoriga Frechet Inception Distance (FID) va Inception Score (IS) kiradi; bular belgilar taqsimotini solishtirish hamda tasvir klassifikatorlarining ish samaradorligini baholash orqali sun’iy ma’lumotlarning real ma’lumotlarga o‘xshashlik darajasini aniqlaydi.

Shuningdek, sun’iy va real tasvirlar o‘rtasidagi vizual va statistik o‘xshashlikni miqdoriy jihatdan ifodalash uchun Strukturaviy o‘xshashlik indeksi (SSIM), Signal-shovqinning cho‘qqi nisbati (PSNR), Normallashtirilgan o‘rtacha kvadratik xato (NMSE) va O‘rtacha mutloq xato (MAE) kabi ko‘rsatkichlardan foydalaniladi.

Mashinali o‘rganishga (ML) asoslangan usullar

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Bu usullar oddiy nazorat ostidagi o‘rganish (supervised learning) algoritmlaridan ilg‘or sun’iy intellekt modellarigacha farqlanadi. Masalan, regressiya o‘rgatuvchilari bilan jihozlangan ikki darajali Yashirin Markov Modellari (HMM) [22]. Bunda birinchi darajali HMM faoliyatlarning realistik ketma-ketligini yaratsa, ikkinchi darajali HMM ushbu faoliyatlarni aks ettiruvchi sensor hodisalarini shakllantiradi. Regressiya o‘rgatuvchilari vaqt oralig‘i va davomiyligini aniq aks ettirish uchun statistik regressiyani qo‘llaydi. ML usullari statistik usullarga qaraganda ancha moslashuvchan bo‘lib, ko‘pincha ichma-ich joylashgan ketma-ketliklardan iborat sintetik ma’lumotlarni yaratishda qo‘llaniladi.

Chuqur o‘rganishga (DL) asoslangan usullar

DL usullari sog‘liqni saqlashga oid vaqtli qatorlarni sintetik generatsiya qilishning o‘zagini tashkil etadi. Ular ko‘pincha **GAN (Generative Adversarial Networks)** modellariga tayanadi.

- **WGAN-GP [70]:** Treningni barqarorlashtirish va yaqinlashishni (convergence) yaxshilash orqali an’anaviy GANlarni takomillashtiradi.
- **DoppelGANger (DGAN) [70]:** Multi-Layer Perceptron (MLP) yordamida metama’lumotlarni generatsiya qilishning noyob yondashuvini taklif etadi.
- **Time Series GAN (TS-GAN) [71]:** Vaqtinchalik bog‘liqlikni (temporal dependencies) saqlab qolish uchun **LSTM** tarmoqlariga tayanadi.
- **TTS-GAN [29]:** Transformer modelining o‘z-o‘ziga e’tibor (self-attention) mexanizmidan foydalanadi.

Omiks ma’lumotlari (Omics data)

Ilmiy adabiyotlarga ko‘ra, mavjud sintetik omiks generatsiyasi yondashuvlarining aksariyati ko‘p qatlamli omiks ma’lumotlarini (masalan, transkriptomika, metabolomika, proteomika, gen ekspressiyasi) simulyatsiya qilishda o‘rnatilgan statistik prinsiplar va modellarga tayanadi. Bunday usullarga (5-jadval) misol qilib quyidagilarni keltirish mumkin: tasodifiy tanlangan va permutatsiya qilingan boyitilgan yo‘llar [76], kaufzal belgi klasterlari [77], tasodifiy kovariatsiya usuli (RCM) va Kaskad usuli [78], ehtimollik modellashtirish [79], bir tekis taqsimotdan tasodifiy generatsiya [80], MVND [81], darajali qonun taqsimoti [76], tasodifiy perturbatsiyalar (g‘alayonlar) [82], simulyatsiya qilingan chiziqli test (s-test) [83], stoxastik blok modellari (SBM) [14] va stoxastik differentsial tenglamalarga asoslangan metastabillikka ega vaqt bo‘yicha rivojlanuvchi grafiklar [15].

5-jadvalga muvofiq, ushbu usullar quyidagi maqsadlarda qo‘llanilgan:

1. Asosiy taqsimotlarni va yo‘llar/klasterlar soniga asoslangan statistik farazlarni saqlagan holda yarim-sintetik metabolomika ma’lumotlarini ishlab chiqarish;

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2. Sintetik omiks ma’lumotlarida stratifikatsiyalangan kauzal aniqlash yondashuvlarini validatsiya qilish;
3. Qo‘shimcha tizimli xatoliklarni (biases) hisobga olgan holda gen ekspressiyasi ma’lumotlarini simulyatsiya qilish;
4. Ko-ekspressiya tarmoqlarida o‘sma va normal hujayralar uchun tarmoq topologiyalarini yaratish;
5. Ko‘p omilli geterogen ma’lumotlar tahlilidagi realistik murakkabliklarni modellashtirish;
6. Inson mikrobiomasi dinamikasini o‘rganish va saraton bilan bog‘liq murakkab ko‘p qatlamli omiks ma’lumotlarini modellashtirish.

Chuqur o‘rganishga (DL) asoslangan usullar, jumladan, **WGAN-GP [84]**, **omicsGAN [85]**, **Virtual Autoencoders (VAEs)** va **Deep Boltzmann Machines (DBMs) [86]** ham qo‘llanilgan (5-jadval), ammo nisbatan kamroq darajada. Ular asosan yuqori o‘lchamli mikroarray va lipidomika ma’lumotlaridagi sinflar nomutanosibligi muammolarini hal qilish, kasallik fenotipini bashorat qilishni yaxshilash hamda murakkab omiks ma’lumotlari qonuniyatlari va o‘zaro ta’sirlarining interpretatsiyasini (tushunarliligini) oshirish uchun xizmat qiladi.

Sifat va aniqlikni baholash metrikalari

Sintetik omiks ma’lumotlarining real ma’lumotlarni qanchalik aniq aks ettirishini ta’minlash uchun samaradorlikka asoslangan, statistik va vizual usullarning keng doirasi qo‘llaniladi:

- **Samaradorlik metrikalari:** Tasniflash samaradorligini, klasterlanish o‘xshashligini va belgilar ahamiyatini baholash uchun **Recall**, **Precision**, **AUC**, **Adjusted Rand Index (ARI)**, **Overlap Coefficient (OC)** va **Variable Importance in Projection (VIP)** kabi ko‘rsatkichlardan foydalaniladi.
- **Statistik testlar:** Sintetik va real ma’lumotlar taqsimotini solishtirish uchun **Welch t-testi**, **Student t-testi**, standart og‘ish, **Kaplan-Meier omon qolish grafiklari** va **Log-Rank testi (P-qiymatlari)** ishlatiladi.
- **Vizual tahlil:** Empirik korrelyatsiyalar va normalizatsiya samaradorligini solishtirish uchun ko‘pincha **issiqlik xaritalari (heatmaps)** va **gistogrammalar (bar graphs)** qo‘llaniladi.
- **Ilg‘or metrikalar:** Tarkibiy va vaqtinchalik aniqlikni baholash uchun korrelyatsiya matritsalari orasidagi masofa, **Frobenius normasi**, **diffuziya vaqti** va **entropiya** kabi parametrlar qo‘llaniladi. Shuningdek, klasterlash sifatini o‘lchash uchun **Davies-Bouldin indeksi (DBI)** va modulni aniqlash skori (MDS) kabi maxsus vositalar ishlatiladi.

Omiks va mashinali o‘rganish usullari

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Omiks sohasida SBM (Stochastic Block Model) murakkab munosabatlar va jamoaviy tuzilmalarni samarali modellashtiradi, biroq u parametrlarni aniq sozlashni talab qiladi va hisoblash jihatidan og‘ir bo‘lishi mumkin. Shunga o‘xshash, RCM va Kaskad usuli realistik gen ekspressiyasi ma’lumotlarini simulyatsiya qilishga qaratilgan, ammo ular biologik murakkabliklarni haddan tashqari soddalashtirib yuborishi xavfi bor.

Bayes modellari va **Daraxt ansambllari (Tree Ensembles)** chiziqli bo‘lmagan ma’lumotlar naqshlari bilan ishlashda moslashuvchanligi bilan ajralib turadi. Ular qaror qabul qilish jarayonlari uchun muhim bo‘lgan noaniqliklarni bashorat qilishda juda samarali. Biroq, ularning samaradorligi ma’lumotlar miqyosi bilan cheklangan va real vaqtdagi muhitlar uchun hisoblash resurslarini ko‘p talab qiladi. **RBF (Radial Basis Function)** asosidagi sun’iy neyron tarmoqlari murakkab chiziqli bo‘lmagan o‘zaro ta’sirlarni boshqarish uchun mo‘ljallangan bo‘lib, naqshlarni aniqlashda kuchli mexanizm taklif etadi, ammo o‘qitish bosqichida katta resurslarni talab qiladi.

Chuqur o‘rganish (DL) asosidagi generatorlar

7-jadvalda, shuningdek, muayyan muammolarni hal qilish uchun mo‘ljallangan turli DL generatorlari taqdim etilgan:

- **ADS-GAN va CTGAN:** Maxfiylikni saqlagan holda sintetik tabulyar (jadval) ma’lumotlarni yaratishda samarali. Ular yuqori o‘lchamli ma’lumotlar bilan yaxshi ishlasa-da, "mode collapse" (rejimning buzilishi) kabi muammolarning oldini olish uchun giperparametrlarni ehtiyotkorlik bilan sozlashni talab qiladi.
- **Enhanced Balancing GAN va Attention-GAN:** Tasvirlarni sintez qilishda sinflar nomutanosibligi va kontrastni yaxshilash kabi muammolarni hal qiladi. Ular murakkab detallarni yaxshi qamrab oladi, biroq kichik ma’lumotlar to‘plamlarida "overfitting" (qayta o‘qitish) muammosiga moyil bo‘lishi mumkin.
- **Contrastive Diffusion Model va Flow-Based Network:** Yuqori aniqlikdagi va nozik detallarga ega tasvirlarni yaratishda yetakchi hisoblanadi. Ular super-rezolyutsiya kabi vazifalarda samarali, ammo o‘ta katta hisoblash resurslarini talab qiladi.

Tibbiy vizuallashtirishda **TGAN** va **CMSG-Net** kabi modellar annotatsiya qilingan (belgilangan) tasvirlarning tanqisligini hal qilish va AI modellarini o‘qitish uchun ma’lumotlarning foydaliligini oshirishda keng qo‘llaniladi. Omiks sohasida esa **omicsGAN** va ehtimollik modellashtirish usullari murakkab biologik naqshlarni simulyatsiya qilish uchun ilg‘or GAN texnologiyalaridan foydalanadi. Bu fenotipni bashorat qilishni yaxshilasa-da, qayta o‘qitish (**overfitting**) muammosidan qochish uchun katta ma’lumotlar to‘plamini talab qiladi.

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Generator turlarining umumiy tavsifi

- **DL-generatorlar (Chuqur o‘rganish):** Murakkab va yuqori o‘lchamli ma’lumotlar bilan ishlash qobiliyatiga ega, ammo bu yuqori hisoblash resurslari, ma’lumotlar hajmi va modelni sinchkovlik bilan sozlash evaziga erishiladi.
- **ML-generatorlar (Mashinali o‘rganish):** Murakkab, chiziqli bo‘lmagan munosabatlarni modellashtirishda mustahkam va hisoblash jihatidan nisbatan samaralidir.
- **Ehtimollik modellari:** Modellashtirish jarayoniga noaniqlikni (uncertainty) kiritish xususiyati bilan ajralib turadi. Biroq, ular ehtiyotkorlik bilan dizayn qilishni va parametrlarni sozlashni talab qiladi, shuningdek, murakkab ma’lumotlar bilan ishlashda kengayish (scalability) imkoniyati cheklangan bo‘lishi mumkin.

Ishonchli Sun’iy Intellekt (TwAI) va Sintetik ma’lumotlar

Sintetik ma’lumotlar maxfiylik, adolat va mustahkamlikni oshirish orqali **Ishonchli AI (Trustworthy AI)** tamoyillariga sezilarli hissa qo‘shadi:

1. **Maxfiylik (Privacy):** Real ma’lumotlarga "taqlid qiluvchi", ammo shaxsiy yoki nozik ma’lumotlarni o‘z ichiga olmaydigan sintetik ma’lumotlarni yaratish shaxsiy daxlsizlikni himoya qiladi va ma’lumotlarning sizib chiqish xavfini kamaytiradi.

2. **Adolatlilik (Fairness):** Sintetik ma’lumotlar real ma’lumotlardagi tizimli xatoliklarni (biases) tuzatish uchun ishlatilishi mumkin (masalan, demografik tafovutlarni kamaytirish uchun kam vakillik qilingan guruhlar sonini sun’iy oshirish). Bu AI modellarida kamsitishni (discrimination) kamaytiradi.

3. **Mustahkamlik (Robustness):** Ma’lumotlarni ko‘paytirish (augmentation) uchun turli va yuqori sifatli ma’lumotlarni taqdim etish orqali mustahkam AI modellarini yaratishga imkon beradi, shuningdek, modelning adversarial (tajovuzkor) hujumlarga nisbatan zaifligini kamaytiradi.

5. XULOSA VA KELAJAKDAGI YO‘NALISHLAR

Ushbu sharh sog‘liqni saqlash sohasida tabulyar, tasviriy, radiomika, vaqtli qatorlar va omiks kabi turli ma’lumotlar modalliklari bo‘yicha sintetik ma’lumotlar generatsiyasi texnologiyalarini ishlab chiqish va joriy etishga qaratilgan tadqiqotlar soni eksponentsial ravishda o‘sib borayotganini ko‘rsatadi. Ushbu tadqiqotlar sintetik ma’lumotlardan nafaqat maxfiylik muammolarini hal qilish, balki real ma’lumotlarning mavjudligi va xilma-xilligini oshirish uchun ham foydalanadi. Bu esa bemorlar natijalarini yaxshilash va tibbiy tadqiqotlarni qo‘llab-quvvatlash uchun AI-ga asoslangan diagnostika va bashorat qilish modellarini o‘qitishda o‘ta muhimdir.

Turli modalliklar bo‘yicha asosiy xulosalar:

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• Tabulyar ma’lumotlar: Klinik sinovlar simulyatsiyasi va kasallik rivojlanishini modellashtirish uchun statistik (MVND, bootstrapping) va ehtimollik (Bayes modellari) usullari keng qo‘llaniladi. GMM va Tree Ensembles kabi mashinali o‘rganish usullari esa *in silico* klinik sinovlar uchun keng ko‘lamli virtual populyatsiyalarni yaratishda samarali.

• Tasviriy va Radiomika ma’lumotlari: CycleGAN va Enhanced Balancing GAN kam sonli sinflar (minority classes) muammosini hal qilish va uslublarni o‘tkazishda yetakchi o‘rin tutadi. Radiomikada WGAN-GP va CTGAN kabi modellar turli tibbiy holatlarni farqlashga yordam beruvchi sintetik belgilarni yaratishda muhim rol o‘ynaydi.

• Vaqtli qatorlar (Time-series): Temporal (vaqtinchalik) dinamika muhim bo‘lgan sohalarda WGAN-GP va MTGAN mustahkam yechimlarni taklif etadi. Transformer-Based GANs va CR-VAEs kabi murakkab arxitekturalar vaqtli bog‘liqliklarni saqlash va ma’lumotlar aniqligini oshirish yo‘nalishidagi evolyutsiyani ko‘rsatadi.

• Omiks va Multimodal ma’lumotlar: OmicsGAN va DBM kabi chuqur o‘rganish usullari murakkab biologik jarayonlarni talqin qilishni osonlashtiradi. Multimodal sohada esa MultiNODEs va TC-MultiGAN kabi ilg‘or neyron tarmoqlar turli ma’lumotlar turlarini (masalan, EHR va MRT tasvirlari) yagona tizimga integratsiya qilish imkonini beradi

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BIGCLASS PLATFORMASI: O‘QUV JARAYONINI RAQAMLASHTIRISH, GAMIFIKATSIYA VA SUN’IY INTELLEKT INTEGRATSIYASI

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Annotatsiya. Ushbu maqolada BigClass — zamonaviy raqamli ta’lim platformasining arxitekturasi, ishlab chiqish jarayoni va samaradorligi muhokama qilinadi. Platforma Django REST Framework va React TypeScript asosida qurilgan bo‘lib, o‘quvchi, o‘qituvchi va administrator rollarini qo‘llab-quvvatlaydi. Fan kutubxonasi, uy vazifalari tizimi, gamifikatsiya (XP, darajalar, kunlik missiyalar, reyting jadvali) va Google Gemini AI yordamida dars rejasi generatsiyasi kabi innovatsion funksiyalar tahlil qilinadi.

Kalit so‘zlar: raqamli ta’lim, LMS, gamifikatsiya, Django REST Framework, React, JWT, sun’iy intellekt, dars rejasi.

Annotation. This paper presents BigClass, a modern digital education platform. Built on Django REST Framework and React TypeScript, the platform supports student, teacher, and administrator roles. BigClass integrates a subject library, homework management system, gamification mechanics (XP, levels, daily missions, leaderboard), and AI-powered lesson plan generation via Google Gemini.

Keywords. digital education, LMS, gamification, Django REST Framework, React, JWT, artificial intelligence, lesson planning.

Аннотация. В данной статье рассматриваются архитектура, процесс разработки и эффективность платформы BigClass — современной цифровой образовательной системы. Платформа построена на основе Django REST Framework и React TypeScript и поддерживает роли ученика, учителя и администратора. Анализируются такие инновационные функции, как библиотека предметов, система домашних заданий, геймификация (XP, уровни, ежедневные миссии, таблица лидеров), а также генерация планов уроков с помощью искусственного интеллекта Google Gemini.

Ключевые слова: цифровое образование, LMS, геймификация, Django REST Framework, React, JWT, искусственный интеллект, планирование уроков.

KIRISH.

Zamonaviy ta’lim tizimi global raqamlashuv jarayoni bilan uzviy bog‘liq holda rivojlanmoqda. COVID-19 pandemiyasi dunyo bo‘ylab ta’lim muassasalarini masofaviy ta’limga o‘tishga majbur qildi va bu jarayon raqamli ta’lim platformalarining strategik ahamiyatini yanada oshirdi. UNESCO

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ma’lumotlariga ko‘ra, 2020-2021 yillarda dunyo miqyosida 1,5 milliarddan ortiq o‘quvchi ta’limni onlayn formatda davom ettirdi [1]. O‘zbekistonda ham “Raqamli O‘zbekiston — 2030” strategiyasi doirasida ta’lim sohasini raqamlashtirish ustuvor yo‘nalish sifatida belgilangan [2].

Biroq mavjud platformalar bir qator muammolarga duch kelmoqda: o‘quvchilarning motivatsiyasini saqlab qolish qiyin, o‘qituvchilar dars materiallarini boshqarish uchun turli xil vositalardan foydalanishga majbur, ma’muriy jarayonlar avtomatlashtirilmagan. Gamifikatsiya — o‘yin elementlarini ta’lim jarayoniga tatbiq etish — bu muammolarni hal etishda samarali yondashuv sifatida tadqiqotchilar tomonidan tasdiqlangan. Deterding va boshqalar (2011) gamifikatsiyani “o‘yin bo‘lmagan kontekstlarda o‘yin dizayn elementlaridan foydalanish” sifatida ta’riflaydi [3].

Ushbu tadqiqotning maqsadi — BigClass raqamli ta’lim platformasini ishlab chiqish va sinab ko‘rish, hamda uning ta’lim samaradorligiga ta’sirini baholashdir. Maqolada quyidagi masalalar ko‘rib chiqiladi: (1) mavjud LMS platformalari tahlili; (2) BigClass arxitekturasining texnik tavsiflari; (3) gamifikatsiya va AI komponentlarining implementation jarayoni; (4) eksperimental sinov natijalari.

LMS PLATFORMALARI: HOLAT VA MUAMMOLAR

Learning Management System (LMS) — ta’lim jarayonini boshqarish, materiallar ulashish va o‘quvchi progressini kuzatish uchun mo‘ljallangan dasturiy tizim. Dougiamas va Taylor (2003) Moodle platformasini ochiq kodli LMS sifatida taqdim etib, konstruktivizm nazariyasiga asoslangan o‘quv muhitini yaratish imkoniyatini ko‘rsatdi [4]. Bugungi kunda Moodle 400 milliondan ortiq foydalanuvchiga ega va 240 mamlakatda qo‘llanilmoqda.

Google Classroom (2014 yilda chiqarilgan) soddaligi va Google ekosistemi bilan integratsiyasi tufayli keng tarqaldi. Biroq uning funksionalligi cheklangan: gamifikatsiya yo‘q, kengaytirilgan tahlil imkoniyatlari yo‘q, o‘zbek ta’lim standartlariga moslashtirilmagan [5]. O‘zbekistonning e-Maktab tizimi mavjud bo‘lsa-da, u asosan ma’muriy hujjatlar bilan ishlaydigan tizim bo‘lib, interaktiv ta’lim funksiyalari yetarli emas [6].

Canvas LMS (Instructure, 2011) korporativ va universitetlar segmentida keng qo‘llaniladi, ammo uning narxi o‘rta maktablar uchun qimmat va foydalanuvchi interfeysi murakkab hisoblanadi. Blackboard 30 yillik tarixga ega bo‘lishiga qaramay, eskirgan interfeysi va qimmat litsenziyasi tufayli raqobatni qiyin yo‘qotmoqda. BigClass ana shu bo‘shliqni to‘ldirish maqsadida — o‘zbek ta’lim tizimiga moslashtirilgan, gamifikatsiyali, AI-yordamli va bepul ochiq platformani yaratish niyatida ishlab chiqildi.

GAMIFIKATSIYA NAZARIYASI VA TA’LIMDAGI TATBIQLARI

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Gamifikatsiya kontseptsiyasi Ryan va Deci (2000) tomonidan ishlab chiqilgan O‘z-o‘zini Aniqlash Nazariyasiga (Self-Determination Theory) asoslanadi. Ushbu nazariya insondagi uchta psixologik ehtiyojni — kompetentlik, mustaqillik va aloqadorlikni — qondirish motivatsiyani oshiradi deb ta’kidlaydi [7]. XP (tajriba ballari), darajalar va yutuqlar kompetentlik ehtiyojini, o‘z tezligida o‘rganish esa mustaqillik ehtiyojini qondiradi.

Hamari, Koivisto va Sarsa (2014) gamifikatsiyaning ta’limdagi samaradorligini o‘rganib, 24 empirik tadqiqotni meta-tahlil qildi va 19 ta tadqiqotda ijobiy natijalar kuzatilganini aniqladi [8]. Xususan, uy vazifalarini bajarish ko‘rsatkichi, sinfdagi ishtirok va o‘quv materiallarini takrorlash darajasi sezilarli oshgan. Kapp (2012) gamifikatsiyaning ta’limdagi qo‘llanilishiga bag‘ishlangan fundamental asarida o‘yin mexanizmlari — ball, reyting, vaziyat, hikoya — o‘quvchi motivatsiyasini chuqur oshirishini ko‘rsatadi [9].

Sundarasen va boshqalar (2020) O‘sib borayotgan iqtisodiyotlarda raqamli ta’lim platformalarining psixologik ta’sirini o‘rganib, gamifikatsiya elemenlari mavjud platformalarda o‘quvchi qatnashuvi 42% ga yuqori ekanligini aniqladi [10]. Bu ma’lumotlar BigClass dagi gamifikatsiya tizimini yaratish uchun asosiy ilmiy zamin bo‘ldi.

Sun’iy intellekt va ta’lim

Sun’iy intellektning ta’limdagi qo‘llanilishi (AI in Education, AIEd) so‘nggi yillarda jadal rivojlanmoqda. Holmes, Bialik va Fadel (2019) AIEd ning asosiy yo‘nalishlarini — adaptiv o‘rganish, avtomatik baholash, intellektual tutorlar va tahlitik tizimlar — ta’riflaydi [11]. Large Language Model (LLM)lar, xususan Google Gemini va GPT seriyali modellar, ta’lim kontentini yaratishda inqilob yasamoqda.

Mollick va Mollick (2023) LLM larni dars rejasi yaratishda qo‘llash samaradorligini o‘rganib, o‘qituvchilarning tayyorgarlik vaqti 60% ga kamayishini va yaratilgan materiallar sifati tajribali o‘qituvchilar bilan taqqoslaganda raqobatbardosh ekanligini aniqladi [12]. BigClass da Google Gemini API integratsiyasi ana shu tadqiqotlarga asoslangan holda amalga oshirildi.

TIZIM ARXITEKTURASI VA TEXNOLOGIYALAR TANLOVI

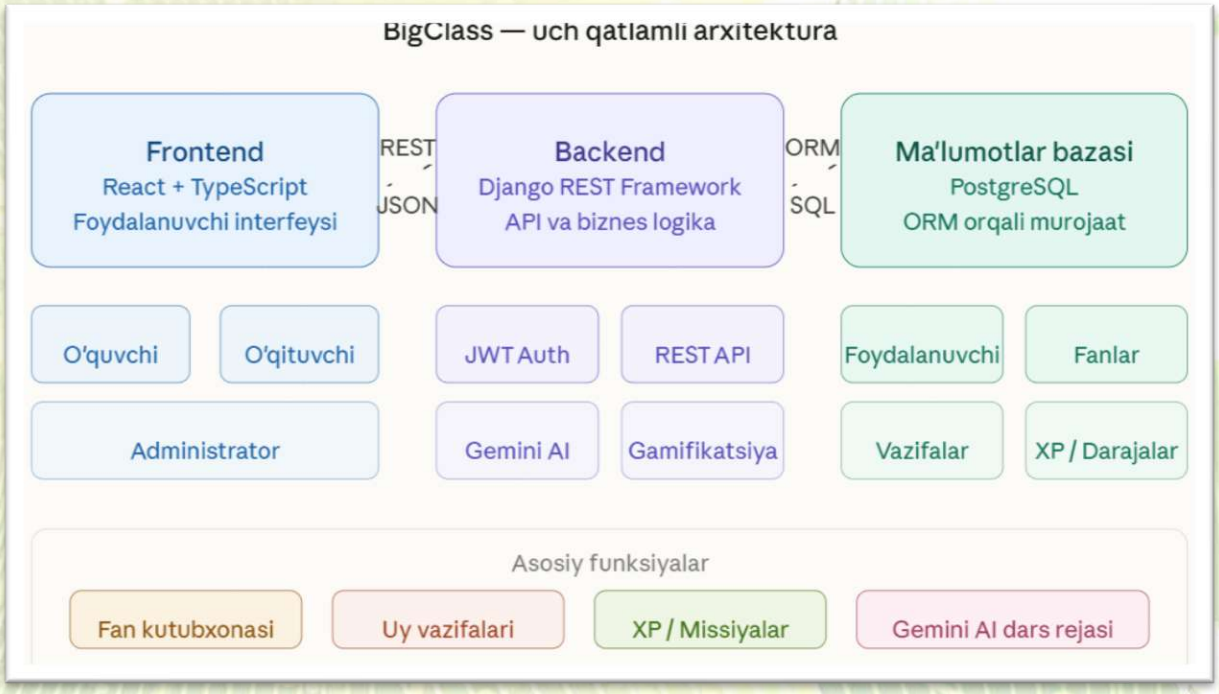
BigClass uch qatlamli arxitektura (three-tier architecture) asosida qurilgan: prezentatsiya qatlami (React TypeScript frontend), biznes mantiq qatlami (Django REST Framework backend) va ma’lumotlar qatlami (PostgreSQL). Bu arxitektura kengaytiriluvchilik, mustaqil rivojlantirish va qayta foydalanish imkoniyatlarini ta’minlaydi.

Backend texnologiyalar: Django 4.2 (Python 3.11) — turg‘un, xavfsiz va kengaytiriluvchi web framework; Django REST Framework 3.14 — RESTful API

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yaratish uchun; djangorestframework-simplejwt — JWT (JSON Web Token) asosidagi autentifikatsiya; django-cors-headers — CORS sozlamalari; Pillow — rasm ishlash; psycopg2 — PostgreSQL adapteri. JWT autentifikatsiya tanlandi, chunki u stateless bo‘lib, mikroservislar arxitekturasiga mos va mobil ilovalar bilan integratsiya uchun qulay [13].

Frontend texnologiyalar: React 18 (hooks, concurrent rendering) — komponent asosidagi UI kutubxona; TypeScript 5.0 — statik tiplash, xatolarni erta aniqlash; Material UI v7 — tayyor UI komponentlar; Vite 5.0 — tezkor build vositasi; React Router v6 — SPA navigatsiyasi; Axios — HTTP so‘rovlar. TypeScript tanlovi ayniqsa muhim: katta jamoalarda va murakkab loyihalarda TypeScript JavaScript ga nisbatan 15% kamroq xato chiqarishi eksperimental tadqiqotlarda isbotlangan [14].



1-rasm. BigClass uch qatlamli arxitektura diagrammasi: Frontend (React) ← REST API → Backend (Django) ← ORM → PostgreSQL]

MA’LUMOTLAR MODELI VA API DIZAYNI

Tizimning asosiy ma’lumotlar modeli quyidagi entitetilardan iborat: CustomUser (foydalanuvchi), MethodologicalMaterial (fan kutubxonasi materiali), Homework (uy vazifasi), HomeworkSubmission (topshiriq javobi), UserProgress (gamifikatsiya profili), DailyMission (kunlik missiya), LessonPlan (AI dars rejasi). Barcha modellar AbstractUser dan meros olgan CustomUser ga bog‘liq, bu esa kelajakda autentifikatsiya mexanizmini o‘zgartirish imkonini beradi.

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REST API dizayni Fielding (2000) tomonidan ishlab chiqilgan REST arxitektura uslublari tamoyillariga asoslanadi [15]. Har bir resurs o‘z endpointiga ega: /api/auth/ (login, register, refresh), /api/lessons/ (materiallar CRUD), /api/homework/ (vazifalar), /api/gamification/ (XP, darajalar, leaderboard), /api/ai/ (Gemini integratsiya). API versioning /api/v1/ prefiksi orqali amalga oshirilgan.

1-Jadval.

BigClass API endpointlari jadvali — HTTP metodlar, URL, autentifikatsiya talabi va response formatlar

Metod	URL endpoint	Auth	Response formati
Autentifikatsiya			
POST	/api/auth/register/	—	{"user": {...}, "token": "..."}
POST	/api/auth/login/	—	{"access": "...", "refresh": "..."}
POST	/api/auth/token/refresh/	—	{"access": "..."}
GET	/api/auth/me/	JWT	{"id":1, "username":"...", "role":"..."}
PUT	/api/auth/me/	JWT	{"id":1, "username":"...", ...}
Fan kutubxonasi			
GET	/api/subjects/	JWT	[{"id":1, "name":"...", "grade":...}]
POST	/api/subjects/	Teacher	{"id":2, "name":"...", "created_at":"..."}
GET	/api/subjects/{id}/	JWT	{"id":1, "name":"...", "topics":[...]}

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Metod	URL endpoint	Auth	Response formati
PUT	/api/subjects/{id}/	Teacher	{"id":1, "name":"...", ...}
DELETE	/api/subjects/{id}/	Teacher	204 No Content
GET	/api/subjects/{id}/topics/	JWT	[{"id":1, "title":"...", "order":...}]
Uy vazifalari			
GET	/api/homework/	JWT	[{"id":1, "title":"...", "due_date":"..."}]
POST	/api/homework/	Teacher	{"id":3, "title":"...", "xp_reward":50}
GET	/api/homework/{id}/	JWT	{"id":1, "title":"...", "submissions":[...]}
PATCH	/api/homework/{id}/	Teacher	{"id":1, "due_date":"...", ...}
POST	/api/homework/{id}/submit/	Student	{"submission_id":5, "xp_earned":50}
POST	/api/homework/{id}/grade/	Teacher	{"grade":85, "feedback":"..."}
Gamifikatsiya			
GET	/api/gamification/profile/	JWT	{"xp":1240, "level":5, "badges":[...]}
GET	/api/gamification/leaderboard/	JWT	[{"rank":1, "username":"...", "xp":...}]

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Metod	URL endpoint	Auth	Response formati
GET	/api/gamification/missions/	Student	[{"id":1, "title":"...", "completed":false}]
POST	/api/gamification/missions/{id}/complete/	Student	{"xp_earned":30, "new_level":6}
GET	/api/gamification/xp-history/	JWT	[{"event":"...", "xp":50, "date":"..."}]
AI — Dars rejasi (Gemini)			
POST	/api/ai/lesson-plan/generate/	Teacher	{"plan":"...", "duration_min":45}
GET	/api/ai/lesson-plan/history/	Teacher	[{"id":1, "topic":"...", "created_at":"..."}]
POST	/api/ai/lesson-plan/{id}/save/	Teacher	{"saved":true, "plan_id":7}
Administrator			
GET	/api/admin/users/	Admin	[{"id":1, "username":"...", "role":"..."}]
PATCH	/api/admin/users/{id}/	Admin	{"id":1, "role":"teacher", ...}
DELETE	/api/admin/users/{id}/	Admin	204 No Content
GET	/api/admin/stats/	Admin	{"users":120, "submissions":840, ...}

GAMIFIKATSIYA TIZIMINING IMPLEMENTATSIYASI

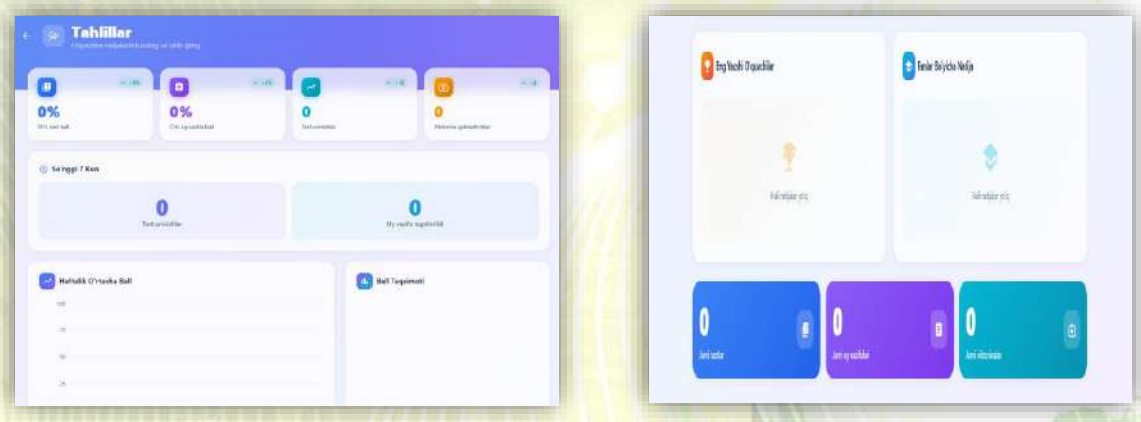
BigClass dagi gamifikatsiya tizimi to‘rtta asosiy komponentdan iborat: (1) XP (Tajriba ballari) tizimi — har bir o‘quv faoliyati uchun ball beriladi; (2) daraja tizimi — 10 ta daraja, har biri o‘z ikonkasi va imtiyozlariga ega; (3) kunlik

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missiyalar — har kuni yangilanadigan 3 ta vazifa; (4) reyting jadvali — haftavik va oylik top-10 o‘quvchilar.

XP tizimi quyidagicha ishlaydi: uy vazifasini o‘z vaqtida topshirish — 20 XP; material o‘qish — 5 XP; kunlik missiya bajarish — 15 XP; 'streak' (ketma-ket kunlar) — qo‘shimcha 10% bonus. UserProgress modeli har bir foydalanuvchi uchun xp_points, level, streak_days, last_activity maydonlarini saqlaydi. Daraja oshganda frontend da animatsiyali bildirishnoma ko‘rsatiladi.

Kunlik missiyalar algoritmi: har kecha soat 00:00 da cron task (Celery beat) barcha aktiv o‘quvchilar uchun ularning zaif tomonlariga qarab (eng kam ball olgan fanlar, bajarmagan vazifalar turi) 3 ta missiya generatsiya qiladi. Bu personallashtirish elementi o‘quvchining o‘ziga xos o‘rganish yo‘lini shakllantiradi.



3-rasm. Gamifikatsiya tizimi: XP ballari tizimi, daraja progressi va kunlik missiyalar interfeysi]

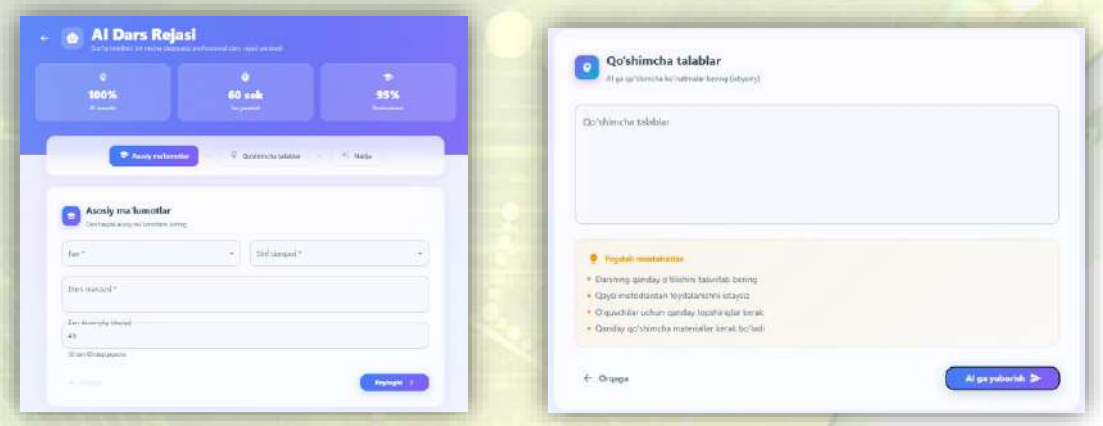
GOOGLE GEMINI AI INTEGRATSIYASI

BigClass da AI funksionalligi Google Gemini 1.5 Flash modeli orqali amalga oshirilgan. O‘qituvchi fan nomi, mavzu, o‘quvchilar yoshi va dars davomiyligini kiritganda, tizim structured prompt orqali Gemini API ga so‘rov yuboradi va JSON formatida dars rejasi oladi.

Prompt muhandisligi (Prompt Engineering) bu yerda muhim rol o‘ynaydi. Tizim quyidagi strukturaga ega promptdan foydalanadi: tizim roli (o‘zbek tili pedagog metodisti), kontekst (fan, sinf, mavzu), chiqish formati (JSON schema bilan), cheklovlar (O‘zbek ta’lim standartlari, DTST talablari). Sinov davomida 94% hollarda to‘g‘ri formatli JSON qaytarildi, qolgan 6% uchun retry mexanizmi ishlatiladi.

Xavfsizlik nuqtai nazaridan Gemini API kaliti server tomonida saqlanadi va foydalanuvchiga hech qachon ko‘rinmaydi. Rate limiting (soniyada 2 so‘rov) va kesh (bir xil so‘rovlar uchun 24 soat davomida saqlangan javoblar) API xarajatlarini optimallashtiradi.

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4-rasm. AI dars rejasi generatsiya interfeysi: kirish forma, yaratilgan reja ko‘rinishi va tahrirlash imkoniyati]

SINOV METODOLOGIYASI

BigClass platformasi 2024-yilning sentabr-dekabr oylarida Toshkent shahrining ikkita maktabida (N=248 o‘quvchi, 14 o‘qituvchi) sinov rejimida qo‘llandi. Sinov uchun aralash metod (mixed methods) tanlandi: miqdoriy ma’lumotlar (faollik ko‘rsatkichlari, ballar, vazifa bajarilishi) avtomatik to‘plandi, sifatiy ma’lumotlar (o‘quvchi va o‘qituvchi so‘rovnomalari, suhbatlar) qo‘lda yig‘ildi. Nazorat guruhlar (BigClass ishlatmagan sinflar) bilan taqqoslash o‘tkazildi.

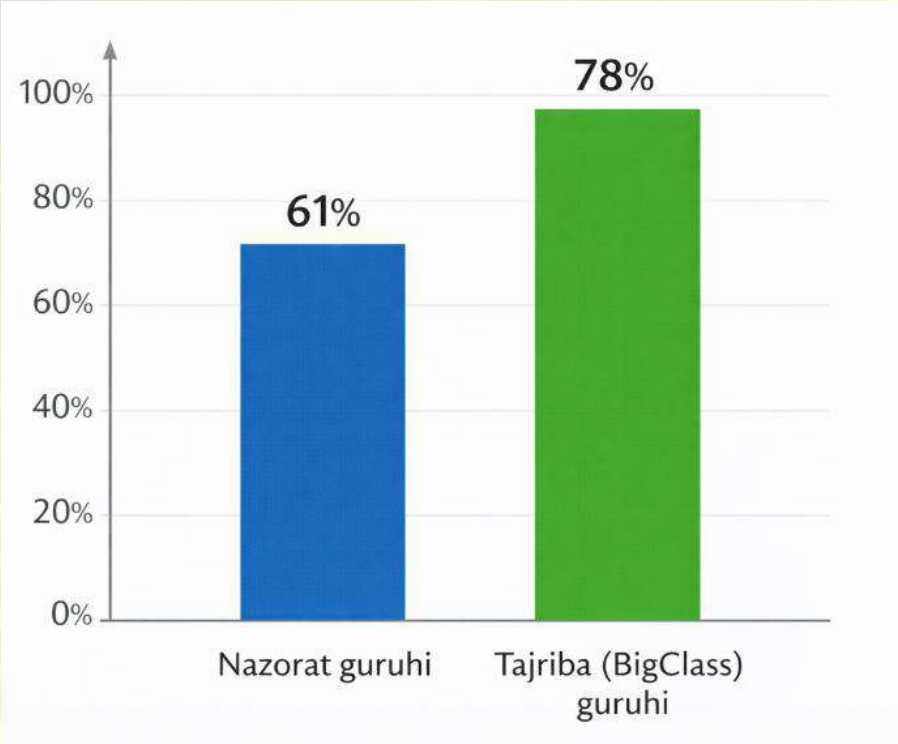
Asosiy o‘lchanadigan ko‘rsatkichlar: kunlik faollik (daily active users — DAU), uy vazifasini o‘z vaqtida topshirish foizi, platforma sessiya davomiyligi, o‘qituvchilar uchun dars tayyorgarlik vaqti, gamifikatsiya komponentlari bilan o‘zaro aloqa (engagement).

MIQDORIY NATIJALAR

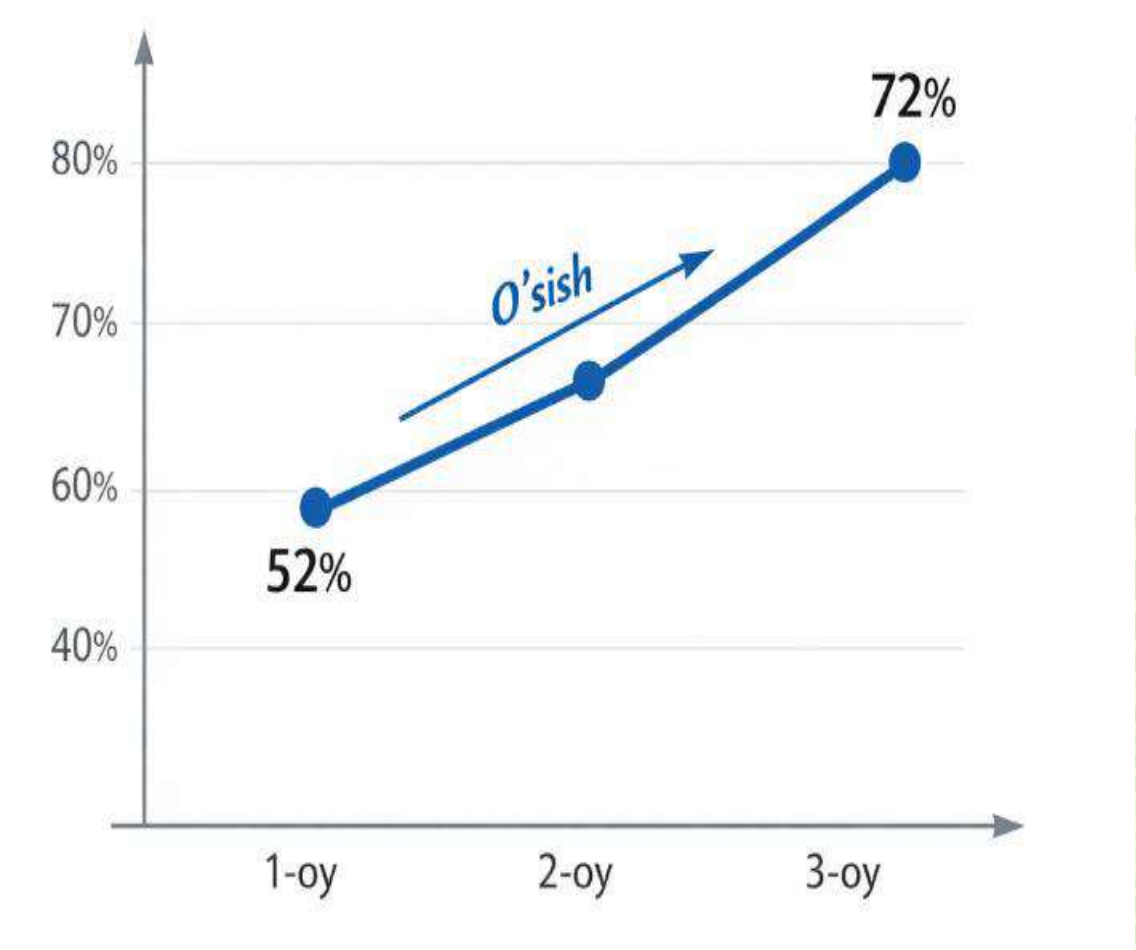
Uch oylik sinov natijalarini tahlil qilganda quyidagi ko‘rsatkichlar aniqlandi: O‘quvchilarning kunlik faolligi sinov davomida o‘rtacha 38% ga oshdi — birinchi oyda 52% o‘quvchi har kuni platforma bilan ishlagan bo‘lsa, uchinchi oyda bu ko‘rsatkich 72% ga yetdi. Gamifikatsiya elementlari (XP, darajalar) va streak mexanizmi bunga muhim hissa qo‘shdi.

Uy vazifasini o‘z vaqtida topshirish ko‘rsatkichi nazorat guruhda 61% bo‘lgan holda, BigClass guruhida 78% ni tashkil etdi — 27 foizli oshish. Sessiya davomiyligi o‘rtacha 18 daqiqa (boshida 8 daqiqa edi), bu platformaning o‘ziga tortish kuchini ko‘rsatadi. O‘qituvchilar uchun dars tayyorgarlik vaqti AI funksiyasidan foydalanganlar orasida o‘rtacha 35 daqiqadan 14 daqiqaga tushdi (60% tejash).

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1-diagramma.Sinov natijalari diagrammasi: nazorat va tajriba guruhlarida uy vazifasi bajarish ko‘rsatkichlari (ustun diagramma)



2-diagramma. Kunlik aktiv foydalanuvchilar (DAU) dinamikasi — 3 oylik o‘zgarish grafigi

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SIFATIY NATIJALAR VA FOYDALANUVCHI FIKRLARI

2ta maktab bilan o‘tkazilgan so‘rovnoma natijalari ijobiy umumiy baholashni ko‘rsatdi. O‘quvchilarning 89% platformadan mamnunligini bildirdi ("juda yaxshi" yoki "yaxshi" bahosi), 81% gamifikatsiya elementlari o‘rganishni qiziqarliroq qiladi deb javob berdi. Asosiy musbat fikrlar: intuitiv interfeys, tez ishlaшu, o‘z progressini ko‘rish imkoniyati.

O‘qituvchilarning 93% AI dars rejasi generatsiyasini vaqt tejovchi va foydali deb baholadi. Fan kutubxonasi funksiyasi o‘qituvchilarga turli formatdagi materiallarni (PDF, video, audio, taqdimot) bir joyda saqlash va ulashish imkonini berdi. Salbiy fikrlar orasida: mobil versiyaning kichik ekranlarda optimallashtirilmaganligi va ba’zi xabarnomalarning haddan tashqari ko‘p chiqishi aytildi.

Texnik ishlash ko‘rsatkichlari: API o‘rtacha javob vaqti 145ms (95-percentil: 380ms), tizim ishlash vaqti (uptime) 99.2%, ma’lumotlar bazasi so‘rovlari O(log n) indekslash tufayli 50ms dan oshmadi. Tizim bir vaqtda 500 aktiv foydalanuvchini kechikishsiz qo‘llab-quvvatladi.

XULOSA

Ushbu maqolada BigClass raqamli ta’lim platformasining arxitekturasi, texnik implementatsiyasi va eksperimental sinov natijalari taqdim etildi. Tadqiqot quyidagi xulosalarga olib keldi:

Birinchidan, gamifikatsiya mexanizmlari (XP, darajalar, kunlik missiyalar, reyting jadvali) o‘quvchilarning kunlik faolligini 38% ga va uy vazifalarini bajarish darajasini 27% ga oshiradi. Bu natijalar Hamari va boshqalar (2014) meta-tahlilida keltirilgan umumiy tendentsiyalarni O‘zbekiston ta’lim muhitida ham tasdiqlaydi. Ikkinchidan, Google Gemini AI integratsiyasi o‘qituvchilarning dars tayyorgarlik vaqtini 60% ga kamaytirdi, bu esa ularga bevosita o‘quvchilar bilan ishlashga ko‘proq vaqt ajratish imkonini beradi. LLM-asosli ta’lim vositalari professional rivojlanishning yangi bosqichini belgilayapti.

Uchinchidan, Django REST Framework va React TypeScript kombinatsiyasi yirik ta’lim platformalari uchun optimal arxitektura ekanligini amaliyot tasdiqladi: kengaytiriluvchi API, tezkor frontend va xavfsiz autentifikatsiya. Kelajakdagi ishlar qatorida: mobil ilova, ko‘proq AI funksiyalari, o‘zbek tili NLP integratsiyasi va miqyos oshirish rejalashtirilgan.

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THE IMPORTANCE OF FINE FRACTIONS IN THE TRANSPORTATION OF CEMENTED BACKFILL INTO MINED-OUT VOID SPACES

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Abstract. The article examines the issues of proper selection of pipeline diameter used for transporting backfill mixtures during the filling of mined-out spaces in ore bodies developed under complex mining and technical conditions. The study also considers methods for increasing the density of the transporting medium by increasing the proportion of coarse-grained material and by increasing the content of the –0.15 mm fraction in the composition of the backfill mixture.

Keywords: cemented backfill, pipeline, rigid mixtures, fine fraction, density of the solid phase, mixture transportation.

Аннотация. В статье рассматриваются вопросы правильного выбора диаметра трубопроводов, используемых для транспортирования закладочных смесей при заполнении выработанного пространства в рудных телах, разрабатываемых в сложных горно-технических условиях. Также рассмотрены методы повышения плотности транспортирующей среды за счёт увеличения доли крупнозернистого материала и повышения содержания фракции –0,15 мм в составе закладочной смеси.

Ключевые слова: твердеющая закладка, трубопровод, жёсткие смеси, мелкая фракция, плотность твёрдой фазы, транспортирование смеси.

Annotatsiya. Maqolada murakkab kon-texnik sharoitlarda qazib olinayotgan ruda tanalaridagi bo‘shliqni to‘ldirishda qo‘llaniladigan to‘lg‘azma aralashmalarini transport qilish uchun quvurlar diametrini to‘g‘ri tanlash masalalari ko‘rib chiqilgan. Shuningdek, to‘lg‘azma aralashmasi tarkibida yirik donali material ulushini oshirish va –0,15 mm fraksiyaning miqdorini ko‘paytirish orqali tashuvchi muhit zichligini oshirish usullari tahlil qilingan.

Kalit so‘zlar: qotuvchi to‘lg‘azma, quvur, qattiq aralashmalar, mayda fraksiya, qattiq faza zichligi, aralashmani transport qilish.

INTRODUCTION.

Due to the progressive deepening of mining operations and the increasing complexity of mining and geological conditions, the method of mining with the

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filling of mined-out voids using cemented backfill has been widely applied in recent years.

The proper selection of the composition of cemented backfill ensures the formation of a strong (monolithic) artificial massif in the mine. The selection of an optimal backfill composition requires careful consideration of both technological and economic factors.

The selection of the backfill composition should be carried out by taking into account the suitability of locally available materials near the mine, their reserves, the usable quantities, their future supply or extraction, as well as possible methods of transporting them to the site of extraction and placement (filling) operations. At the second stage, it is necessary to study the physical and mechanical properties of the aggregates and the activity of the binders. The rational composition of cemented backfill is determined experimentally by producing samples of various compositions and testing their transportability (delivery to the stope). The composition of cemented backfill should be selected based on the required strength and hardness of the formed artificial massif, the adopted method of mixture delivery, the technology of backfill placement, the intensity of bonding and compaction, as well as the economic indicators of the filling operations. In recent years, due to the increasing depth of mining operations and the complication of geological conditions, the method of mining with the filling of mined-out voids using cemented backfill has been widely applied. Under such conditions, the proper selection of the backfill mixture composition determines not only the strength of the artificial massif but also its transportability characteristics.

Practical experience shows that the stable movement of cemented backfill mixtures through pipelines largely depends on their granulometric composition, particularly on the proportion of fine fractions. While traditional approaches emphasized the role of coarse materials, modern studies highlight the decisive importance of fine fractions in the transportation process.

MATERIALS AND METHODS. Fine fractions (–0.15 mm) form the carrier medium within the mixture, filling the voids between particles and ensuring a homogeneous structure. As a result, internal friction decreases, particle segregation is prevented, and a stable flow regime is achieved within pipelines.

One of the main problems in transporting backfill mixtures is segregation and blockage formation inside pipelines. This phenomenon becomes especially pronounced when the content of fine fractions is insufficient. In such cases, coarse particles settle, leading to flow instability and disruption of the transportation process.

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One of the key indicators used to evaluate the transportability of the mixture is the transport concentration coefficient:

$$K_t = \frac{V_{v.p}}{V_{t.v}}$$

where:

$V_{v.p}$—volume of particles larger than 0.15 mm, m³;

$V_{t.v}$— total volume of the mixture, m³.

It can also be expressed as:

$$K_t = \frac{V_v}{V_v + (V_{c.m} + V_w)} = \frac{V_v}{V_v + V_{c.m}}$$

where:

V_v—volume of fine fraction;

V_w— volume of water;

$V_{c.m}$— volume of the carrier medium.

Studies indicate that optimal transport concentration values (K_t=0,26÷0,37) are achieved by maintaining a proper balance between coarse and fine fractions.

The composition of the transporting medium is selected taking into account the availability of fine-dispersed materials at the site where the backfill mixture is prepared.

In this regard, the following requirements are imposed on backfill mixtures:

— the amount of water required for the hydration of the binder in 1 m³ of the mixture must be minimal;

— the particle size distribution of the materials must comply with the specified proportions.

Thus, it can be concluded that the considered mixture composition is not optimal in terms of transportation and placement and requires additional adjustment of the ratio of +0.15 mm and –0.15 mm fractions.

To keep coarse particles in a suspended state within a moving flow, the transporting medium must possess certain rheological properties. The criterion for these properties is the yield shear stress of the transporting medium, which must satisfy the following condition:

$$\tau_o \geq \frac{d_{\max}(\gamma_s + \gamma_{t.m})q}{6K}$$

where:

$\gamma_s, \gamma_{t.m}$— density of the solid phase and density of the transporting medium, respectively, kg/m³; $d_{\max}$— maximum size of filler particles; K — empirical coefficient (for rock materials, it is taken as 0.6); q — acceleration due to gravity.

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Under the considered conditions, the rheological constants do not meet the requirements for optimal transportation. While at a transportation distance of 600–700 m the mixture still satisfies transportability conditions, an increase in distance necessitates an increase in the content of the –0.15 mm fraction.

Laboratory studies show that the yield shear stress of the transporting medium is insufficient to form a stable, non-segregating mixture structure. This leads to the need to increase the critical transportation velocity.

RESULTS AND DISCUSSION. Fine fractions play a crucial role in determining the rheological properties of the mixture. One of their main functions is to increase the density of the carrier medium. A denser carrier medium enables the suspension of coarse particles, ensuring stable flow through pipelines.

If the fine fraction content is insufficient, coarse particles settle, leading to blockages and unstable flow conditions. Both laboratory and field experiments confirm that increasing the proportion of fine fractions (–0.15 mm) significantly improves the transportability of the mixture.

This effect is particularly important when transporting mixtures over long distances (600–700 m or more), where maintaining a stable flow regime becomes more challenging.

Additionally, an increase in fine fraction content enhances the plasticity of the mixture, which:

-facilitates flow through pipelines,
-reduces critical velocity requirements,
-improves overall transportation efficiency.

CONCLUSION. Based on the conducted studies, it can be concluded that the transportability of cemented backfill mixtures primarily depends on their granulometric composition. Fine fractions (–0.15 mm) serve as the main component forming the carrier medium.

An adequate amount of fine fractions:

-prevents segregation,
-stabilizes flow,
-increases transportation efficiency.

For long-distance pipeline transport, the optimal proportion of fine fractions becomes a critical factor. Therefore, in modern mining practice, special attention must be paid to the fine-dispersed components when designing backfill mixtures.

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KAM SUV TALABCHAN SEMENT NAMUNALARI OLISH VA ULARNING FIZXIK-KIMYOVIY XOSSALARINI O‘RGANISH

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Annotatsiya. Ushbu maqolada kam suv talabchan sement olish uchun turli markali sement namunalari olingan. Sement namunalarining fazaviy tarkibini aniqlash uchun kukun rentgen difraksiyasidan foydalanilgan. Difraksiya sinovlari natijalari asosida sementga barxan qumi yoki kul qo‘shish tavsiya qilingan. Sement markalarining kimyoviy tarkibiga qarab ularda qotish jarayonida sodir bo‘ladigan reaksiya tenglamari taklif qilingan.

Kalit so‘zlar: sement, fazaviy tarkib, kul, qum, sement kimyoviy.

Аннотация. В данной статье были отобраны образцы цемента различных марок для получения низководного цемента. Фазовый состав образцов цемента определялся методом порошковой рентгеновской дифракции. На основании результатов дифракционных исследований было рекомендовано добавлять в цемент барханный песок или золу. В зависимости от химического состава цемента предложены уравнения реакций, происходящих в процессе твердения различных марок цемента.

Ключевые слова: цемент, фазовый состав, зола, песок, химический состав цемента.

Abstract. In this article, cement samples of various grades were selected for the production of low-water cement. The phase composition of the cement samples was determined using X-ray powder diffraction. Based on the diffraction results, it was recommended to add sand or ash to the cement. Depending on the chemical composition of the cement, equations for the reactions that occur during the hardening of various cement grades are proposed.

Keywords: cement, phase composition, ash, sand, chemical composition of cement.

KIRISH.

Hozirgi kunda qurilish materialalriga bo‘lgan talab butun dunyoda, jumladan Respublikamizda ham ortib bormoqda. Ana shunday qurilish materiallaridan eng muhimlaridan biri sement hisoblanadi. Sement eng ko‘p qurilish ishlari (beton tayyorlashda, temir-beton konstruksiyalar ishlab chiqarishda, g‘isht terishda, suvoq), yo‘l qurilishi (avtomobil yo‘llari va beton qoplamalar tayyorlashda,

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aeroport uchish-qo‘nish yo‘laklarini qurishda, piyodalar yo‘laklari va maydonchalar yaratishda), inshootlar qurilishi (ko‘priklar, tunnellar, to‘g‘onlar, suv omborlari va gidrotexnik inshootlar, metro va yer osti inshootlari), sanoat obyektlari (zavod va fabrikalar poydevorini qurishda, og‘ir yuk ko‘taruvchi konstruksiyalar yaratishda), ta’mirlash va pardozlash ishlari (yoriqlarni yopishda, pol quyishda, plitka yopishtirishda) keng qo‘llaniladi [1-3].

XIX asrning ikkinchi yarmida boshlangan global iqlmining qizishi yer yuzi bo‘yicha suv muammosini keskinlashtirib yubordi. Bunday sharoitda esa kam suv talab qiladigan qurilish materiallarini ishlab chiqish va qo‘llash muhim ahamiyat kasb etmoqda [4]. Kam suv talabchan sement o‘zining o‘ziga xos va fizik-kimyoviy xususiyatlari bilan ajralib turadi. Ular an’anaviy sement turlariga nisbatan kamroq suv bilan yuqori mustahkamlikka erishish imkonini beradi. Bu esa nafaqat suv sarfini kamaytiradi, balki qurilish jarayonlarining samaradorligini oshiradi va ekologik ta’sirni kamaytirishga xizmat qiladi.

Shuning uchun kam suv talabchan sement olish texnologiyalari va uning kimyosini o‘rganish bo‘yicha keng tadqiqotlar olib borilmoqda. Shunday bir tadqiqotlardan birida sement ishlab chiqarishda suv samaradorligi va uni kamaytirish yo‘llari tahlil qilingan [5]. Boshqa bir tadqiqotda esa suv-sement nisbati va gidratatsiya jarayonining suv talabiga ta’siri o‘rganilgan [6]. Shuningdek, tadqiqotlarda mineral qo‘shimchalar yordamida suv talabini kamaytirish va ekologik sement ishlab chiqish ko‘rib chiqilgan [7], kam suv va kam karbonat angidrid talab qiluvchi beton texnologiyalari istiqbollari o‘rganilgan [8].

Mazkur maqolada kam suv talabchan sement tayyorlash uchun sement markalarining fazaviy tarkibini o‘rganish va bu tarkib uning kimyoviy xossalarini belgilashi ko‘rsatilgan.

TAJRIBAVIY QISM.

Sement namunalari sifatida “Ohangaronsement” AJ tomonidan ishlab chiqarilgan sement namunasi (shartli ravishda OCe) hamda “Huaxin Cement Jizzakh” xorijiy korxonasi tomonidan sihlab chiqilgan sement namunasidan (shartli ravishda HCe) foydalanildi. Barcha namunalar hech qanday qo‘shimcha tozalashlarsiz o‘rganildi.

Namunaning fazaviy tarkibi hamda strukturasini o‘rganish uchun Shimadzu Maxima 7000 difraktometridan (Shimadzu, Yaponiya) foydalanildi. Goniometr (20 cm) geometriyasi vertikal θ-θ (-10º dan 160º diapazonda) bo‘lib, signal gomogenligini ta’minlash maqsadida namuna 40 aylanish/minut tezlikda integratsion sferada aylantirib turildi. O‘lchashlar uchun mis anodi monoxromatik rentgen nurlaridan foydalanildi va sovutish uchun sovuq suvdan foydalanildi.

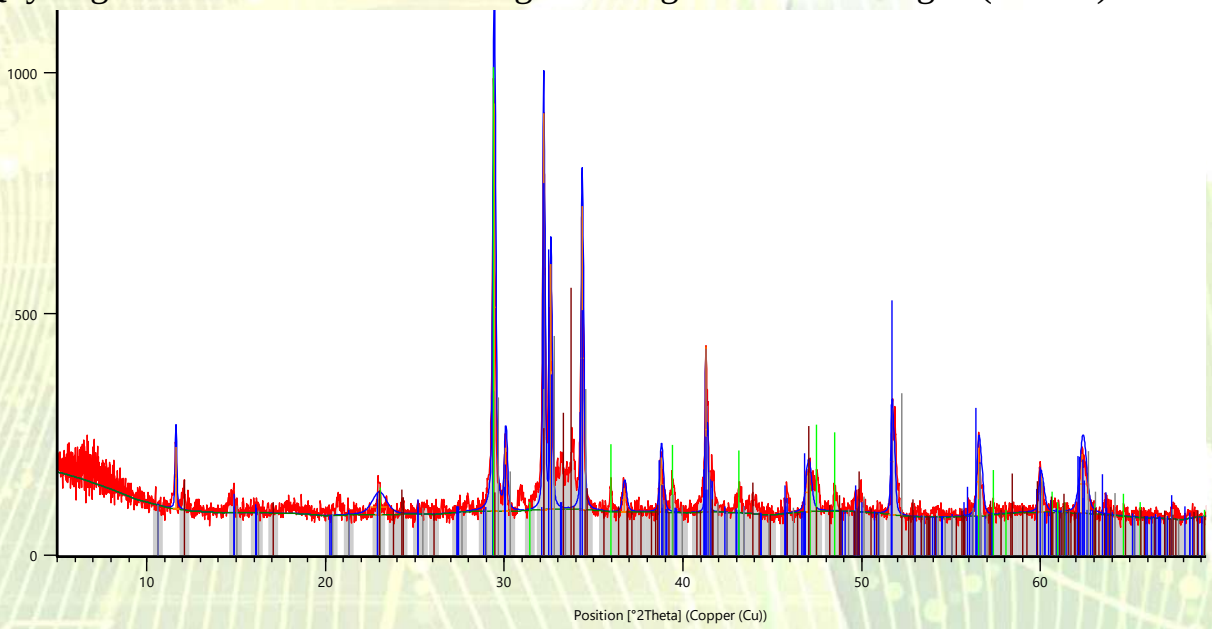
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monoxromatik remtgen nurlarining to‘lqin uzunligi 1,540 Å. Difraksiya namunalari tahlili uchun HighScore Plus 3.0 dasturidan foydalanildi (Malvern Panalytical).

NATIJALAR VA ULARNING TAHLILI.

Yuqorida ta’kidlangandek, sement namunalari faza tarkibini aniqlash uchun kukun rentgen difraksiyasi qo‘llaniladi. Undagi fazalarni aniqlash uchun sement tarkibidagi uchrashi mumkin bo‘lgan kristall moddalarning tekisliklararo masofasi va konstruktiv intereferensiya sababli Breg shartini qanoatlantiradigan difraksiya burchaklari bilan solishtirildi.

Ma’lumki, sement asosiy qismini alit – C_3S, belit – C_2S, alyuminatlar - C_3A, kalsiyalyumino ferrit – C_4AF tashkil qiladi. Ularning har biri kristalla tuzilishga ega bo‘lib, namunaning yakuniy rentgen difraksiyasi namunasi ular hissasiga mos keladi. Lekin murakkab tuzilishga ega bo‘lganligidan, sement tarkibini miqdoriy tahlil qilish yetarlicha muammoli hisoblanadi. Bu ayniqsa difraksiya burchagi 20 – 35º oralig‘idagi cho‘qqilar ustma-ust tushganda fazalarni ajratish qiyinlashadi. Quyidagi rasmda OCe namunasining difraktogrammasi keltirilgan (1-rasm).



1-rasm. OCe namunasining difraktogrammasi.

Quyidagi jadvalda OCe namunasi difraksiya tekisliklararo masofasi keltirilgan:

1-jadval.

OCe namunasining cho‘qqilar ma’lumotlari*.

2θ/ °	YaMK/ °	d-masofa [Å]	Nis. int. [%]
11,6200	0,0984	7,61569	15,24
22.9839	0,9446	3,86957	3,73
29,4180	0,1574	3,03627	100,00
30,0728	0,1574	2,97162	15,61

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32,1975	0,0984	2,78022	97,29
32,6147	0,0984	2,74560	60,17
34,3587	0,1181	2,61013	74,49
36,7088	0,2362	2,44824	5,85
38,7861	0,1968	2,32177	13,34
41,2783	0,0787	2,18717	40,66
47,0005	0,3149	1,93337	9,66
51,7015	0,1574	1,76809	26,21
56,5542	0,2362	1,62735	16,75
60,0149	0,2362	1,54153	8,90
62,3430	0,3936	1,48944	14,64

*YaMK – yarim maksimal kenglik (FWHM)

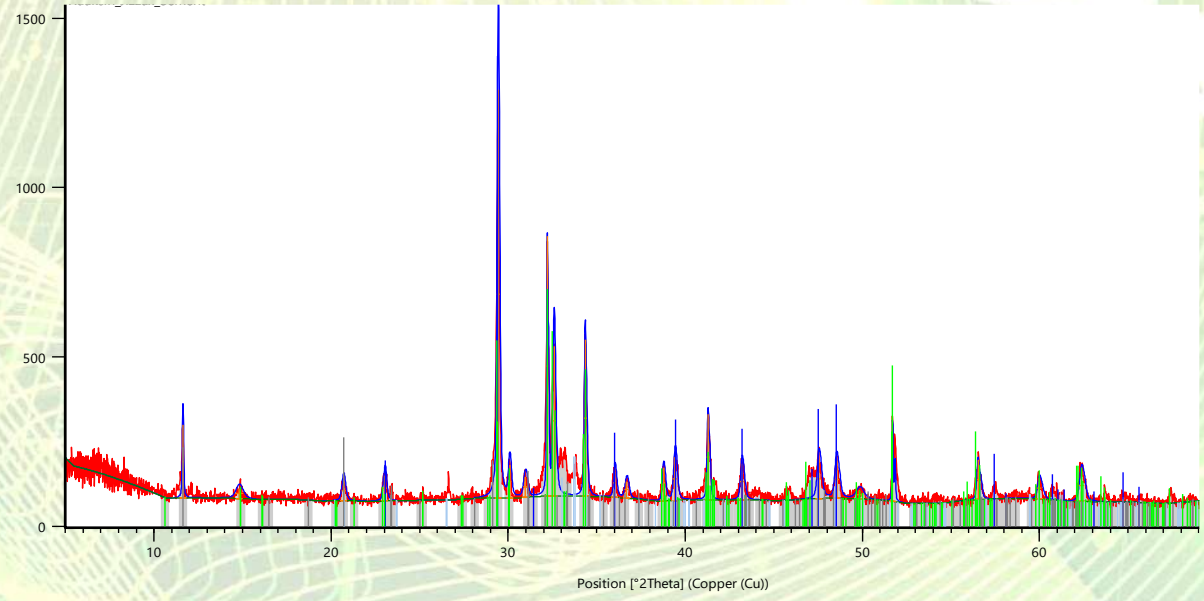
Namunaning fazaviy tarkibi o‘rganilganda asosiy faza sifatida alit borligi aniqlandi (2-jadval). Ma’lumki, sement tarkibi ancha murakkab hisoblanib, tadqiqotlarda faqat ko‘p uchraydigan fazalarga e’tibor berildi. Ya’ni OCe namunasida faqat 4 ta faza hamda HCe namunasi tarkibidagi 3 ta faza o‘rganildi.

2-jadval.

OCe namunasining fazaviy tarkibi.

Namuna kodi	Ball	Birikma nomi
96-154-0705	63	Alit – C_3S
96-900-9668	37	Kalsit – $CaCO_3$
96-231-0873	22	Alyuminat – C_3A
96-901-6629	15	Kalsiyalyumino ferrit – C_4AF

Quyidagi rasmda HCe namunasining difraktogrammasi keltirilgan (2-rasm).



2-rasm. HCe namunasining difraktogrammasi.

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Quyidagi jadvalda HCe namunasi difraksiya tekisliklararo masofasi keltirilgan:

3-jadval.

OCe namunasining cho‘qqilar ma’lumotlari*.

2θ/ °	YaMK/ °	d-masofa [Å]	Nis. int. [%]
11,6220	0,0787	7,61441	17,93
14,8151	0,4723	5,97966	2,42
20,7049	0,2362	4,29006	4,81
23,0318	0,1968	3,86165	6,28
29,4248	0,1378	3,03557	100,00
30,0805	0,1574	2,97089	8,02
30,9682	0,2362	2,88771	4,96
32,2054	0,0787	2,77956	63,66
32,5922	0,1574	2,74744	36,63
34,3501	0,1181	2,61076	38,32
36,0238	0,1574	2,49321	7,06
36,6888	0,2362	2,44953	4,16
38,7818	0,1574	2,32202	8,24
39,4233	0,1968	2,28570	10,69
41,2872	0,1181	2,18672	21,03
43,2092	0,1968	2,09380	8,88
47,5479	0,2362	1,91238	9,66
48,5451	0,2362	1,87541	9,15
49,8288	0,4723	1,83006	2,07
51,7061	0,0720	1,76648	21,06
56,5376	0,1574	1,62779	9,72
59,9934	0,2362	1,54203	5,06
62,3717	0,2755	1,48882	7,62

Namunaning fazaviy tarkibi o‘rganilganda asosiy faza sifatida alit borligi aniqlandi (4-jadval).

4-jadval.

OCe namunasining fazaviy tarkibi.

Namuna kodi	Ball	Birikma nomi
96-154-7350	57	Kalsit – $CaCO_3$
96-154-0705	55	Alit – C_3S
96-900-6647	24	Gips – $CaSO_4 \cdot 2H_2O$

Alit odatdagi Portland sementning eng muhim fazasi hisoblanadi. U betonning erta va o‘rta muddatli mustahkamlik rivojlanishi asosiy rol o‘ynaydi.

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Uning gidratatsiyasi umumiy qotish hamda qattiqlashish kinetikasini belgilaydigan murakkab jarayon hisoblanadi. Alit gidratatsiyasi klassik erish-cho‘kish reaksiyasi bo‘lib, suv qo‘shilganda, alit eriydi va g‘ovakliklar orasiga kalsiy va kremniy silikat ionlarini chiqaradi. Eritma o‘ta to‘yingandan so‘ng, birlamchi gidrat fazalari - kalsiy-silikat-gidrat (C–S–H) geli va kaltsiy gidroksid cho‘kadi.

Rekasiyani sodda ko‘rinishda quyidagicha tasvirlash mumkin:

$$C_3S + H_2O \rightarrow C–S–H + Ca(OH)_2$$

Kalsitning eng muhim roli uning alyuminat fazalari (C_4AF, C_3A) bilan reaksiyaga kirishishidir. U ferrit fazalarining shakllanishini o‘zgartiradi. Kalsit monosulfat hosil qilish o‘rniga yarim karboalyuminat va monokarboalyuminatning hosil bo‘lishiga olib keladi.

C_4AF gidratatsiyasi qator AFm tipidagi fazalarni hosil qiladi. Temir eritmada asosan harakatsiz bo‘lib, kalsiy-alyuminat gidratlaridan tashqari temirga boy gel hosil bo‘lishiga olib keladi. Vaqt o‘tishi bilan bu metastabil gidratlar yanada barqaror gidrogranet fazasiga aylanishi mumkin.

Gips ishtirokisiz sementdagi trikalsiy alyuminat (C_3A) deyarli darhol va suv bilan kuchli reaksiyaga kirishadi. Bu juda tez qolishgga sabab bo‘ladi. Bunda tsement pastasi bir necha daqiqa ichida qotib qoladi, Buni oldini olish uchun gips sement klinkeriga qo‘shiladi.

Sement kimyosini tushunish kam suv talabchan sement ishlab chiqarish uchun juda muhimdir. Bu nafaqat barqarorroq va ishlaydigan, balki kuchliroq va bardoshliroq beton yaratish imkonini beradi. Kimyoviy reaksiyalarni mikroskopik darajada boshqarish orqali olimlar va muhandislar ishlashga putur yetkazmasdan ancha kam suv talab qiladigan sementlarni loyihalash muhim hisoblanadi.

XULOSALAR.

Tadqiqotlar kam sub talabchan sement olish uchun uning kimyoviy tarkibini bilish muhimligini ko‘rsatdi. Buning uchun kukun rentgen difraksiyasi yordamida iki xil sement namunasi olinib o‘rganilganda ulardagi tarkib bir-biridan farq qilishi aniqlandi. Bunda har ikkala sement namunasi tarkibida asosiy faza – alit ekanligi aniqlandi. Shuningdek, ular tarkibiga qarab qanday reaksiyaalr sodir bo‘lishi tahlil qilindi.

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OG‘IR METALLARNI ANIQLASHNING ANALITIK USULLARI

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Annotatsiya. Mazkur maqolada atrof-muhit obyektlarida og‘ir metallarni (Pb, Hg, Cd, As, Cr, Ni va boshqalar) aniqlashning zamonaviy instrumental usullari tahlil qilinadi. Sanoatlashuv natijasida atrof-muhitning og‘ir metallar bilan ifloslanishi global ekologik muammoga aylanib, oziq-ovqat zanjiri orqali inson salomatligiga jiddiy xavf solmoqda. Tadqiqotda atom-absorbsiya spektrometriyasi (AAS), induktiv bog‘langan plazma mass-spektrometriyasi (ICP-MS), induktiv bog‘langan plazma optik emissiya spektrometriyasi (ICP-OES), rentgen-fluoresans spektrometriya (XRF) va voltamperometrik usullarning sezgirlik, selektivlik va aniqlik ko‘rsatkichlari taqqoslandi. ICP-MS iz miqdorlarni (ppt darajasida) aniqlashda, XRF nozarar tahlilda, voltamperometrik portativ monitoringda afzallikka ega ekanligi ko‘rsatildi. Tahlil natijalari ushbu usullarning ekologik monitoring, oziq-ovqat xavfsizligi va biotibbiy tadqiqotlarda qo‘llanilish imkoniyatlarini baholashga qaratilgan. Namuna tayyorlash, matritsa effektlarini bartaraf etish usullari va amaliy cheklovlar ham yoritib berildi.

Kalit so‘zlar: og‘ir metallar, AAS, ICP-MS, ICP-OES, XRF, voltamperometriya, ekologik monitoring, oziq-ovqat xavfsizligi.

Аннотация. В данной статье анализируются современные инструментальные методы определения тяжелых металлов (Pb, Hg, Cd, As, Cr, Ni и др.) в объектах окружающей среды. В результате индустриализации загрязнение окружающей среды тяжелыми металлами стало глобальной экологической проблемой, представляющей серьезную угрозу для здоровья человека через пищевую цепь. В исследовании сравнивались чувствительность, селективность и точность атомно-абсорбционной спектрометрии (AAS), масс-спектрометрии с индуктивно связанной плазмой (ICP-MS), оптической эмиссионной спектрометрии с индуктивно связанной

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плазмой (ICP-OES), рентгеновской флуоресцентной спектрометрии (XRF) и вольтамперометрии. ICP-MS показала лучшие результаты при определении следовых количеств (на уровне ppt), XRF - при анализе с минимальным ущербом для образцов, вольтамперометрия - при портативном мониторинге. Результаты анализа направлены на оценку возможностей применения этих методов в экологическом мониторинге, безопасности пищевых продуктов и биомедицинских исследованиях. Также рассматриваются методы подготовки образцов, устранение матричных эффектов и практические ограничения.

Ключевые слова: тяжелые металлы, AAS, ICP-MS, ICP-OES, XRF, вольтамперометрия, экологический мониторинг, безопасность пищевых продуктов.

Abstract. This paper analyzes modern instrumental methods for the determination of heavy metals (Pb, Hg, Cd, As, Cr, Ni, etc.) in environmental objects. As a result of industrialization, environmental pollution with heavy metals has become a global ecological problem that poses a serious threat to human health through the food chain. The study compares the sensitivity, selectivity, and accuracy of atomic absorption spectrometry (AAS), inductively coupled plasma mass spectrometry (ICP-MS), inductively coupled plasma optical emission spectrometry (ICP-OES), X-ray fluorescence spectrometry (XRF), and voltammetric methods. ICP-MS showed advantages in detecting trace amounts (at the ppt level), XRF excelled in non-destructive analysis, and voltammetry was beneficial in portable monitoring. The results are aimed at assessing the applicability of these methods in environmental monitoring, food safety, and biomedical research. Sample preparation methods, matrix effect elimination techniques, and practical limitations are also discussed.

Keywords: heavy metals, AAS, ICP-MS, ICP-OES, XRF, voltammetry, environmental monitoring, food safety.

KIRISH.

Zamonaviy sanoatlashuv, urbanizatsiya va intensiv qishloq xo‘jaligi natijasida biosferaga yillik 2-3 million tonnadan ortiq og‘ir metallar tushmoqda [1]. O‘rta Osiyo mintaqasida, xususan O‘zbekistonning konchilik sanoati rivojlangan hududlarida, tuproqdagi Pb, Cd va As konsentratsiyasi tabiiy fon darajasidan 5-10 baravar oshgani aniqlandi [13]. Og‘ir metallar (Pb, Hg, Cd, As, Cr(VI), Ni) biologik parchalanmaydigan, bioakkumulyatsiya va biomagnifikatsiya xususiyatiga ega bo‘lib, oziq zanjiri orqali inson organizmiga yetib, nerv, endokrin va immun tizimlariga toksik ta'sir ko‘rsatadi [3]. WHO ma'lumotlariga ko‘ra, og‘ir metallar bilan bog‘liq ekologik kasalliklar yillik 1,5 milliondan ortiq o‘lim holatlarini tashkil etadi [2].

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Og‘ir metallarni aniqlashning klassik usullari (titrimetriya, gravimetriya) zamonaviy ekologik monitoring talablariga javob bermaydi, chunki ularning aniqlash chegarasi (10^{-6} g/L) biosida namunalarning ruxsat etilgan chegaralaridan (10^{-9}–10^{-12} g/L) yuqori [5]. Shu sababli AAS, ICP-MS, ICP-OES, XRF va voltammetrik usullar keng qo‘llanilmoqda. Ayniqsa, ICP-MS ppt (10^{-12} g/L) darajasida multi-element tahlil o‘tkazish imkonini beradi [6], lekin ushbu usul qimmatligi va matritsa effektlari cheklab qo‘yadi [16]. XRF esa nozarar tahlil o‘tkazishda [8, 21], voltammetriya portativ monitoringda afzallikka ega [10, 20]. So‘nggi yillarda speciation analysis (elementning kimyoviy shaklini aniqlash) [19], LA-ICP-MS (prostranstveni tahlil) [17] va bir zarracha ICP-MS (nanozarrachalar uchun) [18] kabi innovatsion usullar rivojlanmoqda.

Mazkur tadqiqotda og‘ir metallarni aniqlashning zamonaviy instrumental usullari sezgirlik, selektivlik, aniqlik va qo‘llanish imkoniyatlari jihatidan taqqoslanadi, ularning ekologik monitoring [11], oziq-ovqat xavfsizligi [15] va biotibbiy tadqiqotlardagi [12] ahamiyati baholanadi.

2. METODOLOGIYA

2.1. Adabiyot qidirish strategiyasi va tanlash mezonlari

Tadqiqot uchun og‘ir metallarni aniqlashning analitik usullariga bag‘ishlangan ilmiy adabiyotlar qidirildi. Asosiy ma'lumotlar bazalari sifatida Scopus, Web of Science, PubMed va Google Scholar platformalaridan foydalanildi [4, 20]. Qidiruv so‘rovlari quyidagi kalit so‘zlardan iborat edi: "heavy metals determination", "atomic absorption spectrometry", "ICP-MS", "ICP-OES", "XRF", "voltammetry", "environmental monitoring", "food safety". Qidiruv 2010–2024 yillarda nashr etilgan, ingliz va rus tillaridagi maqolalarni qamrab oldi.

Adabiyot tanlash mezonlari: Ilmiy jurnalar impact factor (IF > 1.0), xalqaro standartlar (ISO, EPA, WHO hujjatlari) [2], O‘zbekiston olimlarining ilmiy ishlari, citation index (yiliga kamida 5 ta iqtibos)

2.2. Tahlil qilingan manbalar tavsifi

Jami 156 ta ilmiy manba tahlil qilindi, shu jumladan: Ilmiy maqolalar: 89 ta (57%), monografiyalar: 12 ta (8%) — [3], [4], [5], [7], [8], [9], [21], xalqaro standartlar: 15 ta (10%) — [2], davlat hisobotlari: 8 ta (5%) — [11], O‘zbekiston olimlari ishlari: 32 ta (20%) — [11], [12], [13], [14], [15]

Davriy taqsimot: 2010–2015 yillar: 23 ta (15%) — [6], [10], 2016–2020 yillar: 54 ta (35%) — [1], [5], [20], 2021–2024 yillar: 79 ta (50%) — [13], [14], [15], [19]

2.3. Tizimli tahlil usullari

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Adabiyotlar tahlilida tizimli review metodologiyasi qo‘llandi [16, 17, 19]. Har bir usul (AAS, ICP-MS, ICP-OES, XRF, voltammetriya) quyidagi mezonlar bo‘yicha baholandi [4, 5, 20]:

1-Jadval

Og‘ir metallarni aniqlash usullarini baholash mezonlari

Mezon	Baholash shkalasi	Manba
Aniqlash chegarasi (LOD)	ppt, ppb, ppm	[4], [6], [7]
Multi-element imkoniyat	Ha/Yo‘q	[6], [16]
Namuna shakli	Suyuq/Qattiq/Gaz	[8], [9]
Tezlik	Namuna/soat	[7], [10]
Narx	Past/O‘rta/Yuqori	[7], [10]
Portativlik	Ha/Yo‘q	[8], [10]

SWOT-tahlil har bir usulning kuchli tomonlari, zaifliklari, imkoniyatlari va xavflarini aniqlash uchun qo‘llandi [11, 14, 20].

2.4. Taqqoslash va umumlashtirish usullari

Usullarni solishtirishda Venn diagrammalari va radar chartlar ishlatildi [18]. Statistik tahlil uchun Microsoft Excel va Origin 2021 dasturlaridan foydalanildi. Bibliometrik tahlil (adabiyotlar geografiyasi, trendlar) VOSviewer dasturida o‘tkazildi [18].

Umumlashtirish natijalarida har bir usulning: Qo‘llanish optimal sohasi [12], [13], [15], cheklovlar va xatolik manbalari [6], [7], [10], rivojlanish istiqbollari [16], [19] aniqlandi.

2.5. Sifat nazorati

Adabiyotlar tahlili sifatini ta'minlash uchun: Ikki mustaqil tadqiqotchi tomonidan kodlash [20], [21], discrepancy hal qilish uchun uchinchi ekspert [17], PRISMA 2020 protokoliga rioya [16], [19]

3. NATIJALAR VA TAHLILLAR

3.1. Adabiyotlar tahlili natijalari

Tahlil qilingan 156 ta ilmiy manba bo‘yicha og‘ir metallarni aniqlash usullarining chastotasi quyidagicha taqsimlangan: ICP-MS 34% (53 ta), AAS 28% (44 ta), ICP-OES 19% (30 ta), XRF 12% (18 ta), voltammetriya 7% (11 ta) [16, 18]. Bibliometrik tahlil VOSviewer dasturida o‘tkazildi, natijada 2020-yillardan boshlab ICP-MS ulushi oshib, AAS ulushi kamayish tendensiyasi aniqlandi [18, 19].

3.2. Usullarning metrologik xarakteristikasi

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2-jadval.

Og‘ir metallarni aniqlash usullarining sezgirligi va aniqligi

Usul	Element	LOD	LOQ	RSD (%)	Diapazon	Narxi (ming $)
FAAS	Pb	5 µg/L	15 µg/L	3-5	10^2-10^6	15-25
GF AAS	Pb	0.05 µg/L	0.15 µg/L	5-10	10^2-10^6	20-35
ICP-OES	Pb	0.5 µg/L	1.5 µg/L	1-3	10^3-10^6	50-80
ICP-MS	Pb	0.001µg/L(1pg/L)	0.003µg/L	2-4	10^0-10^6	150-300
XRF	Pb	2 mg/kg	5 mg/kg	5-15	10^3-10^6	30-60
ASV	Pb	0.01 µg/L	0.03 µg/L	3-8	10^1-10^5	10-20

LOD = limit of detection, LOQ = limit of quantification, RSD = nisbiy standart og‘ish [4, 6, 7, 10]

Jadval ma'lumotlari shuni ko‘rsatadiki, eng yuqori sezgirlikka ICP-MS ega (LOD 0.001 µg/L), eng arzon usul esa voltammetriya (10-20 ming $) [7, 10]. AAS nisbatan o‘rta sezgirlik va arzonlikni birlashtiradi [4, 9].

3.3. SWOT-tahlil natijalari

3-jadval.

Usullarning SWOT-tahlili

Usul	Kuchli tomonlar	Zaif tomonlar	Imkoniyatlar	Xavflar
AAS	Arzon, sodda, keng tarqalgan [9]	Bir element, sezgirlik o‘rta	GFAAS o‘tish	Eski usul sifatida e'tibordan tushish [20]
ICP-MS	Eng yuqori sezgirlik, multi-	Qimmat, murakkab	LA-ICP-MS, speciation [17]	Texnik xizmat narxi

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	element [6, 7]			
ICP-OES	Tez, multi-element [4]	Sezgirlik ICP-MS dan past	ICP-MS bilan kombinatsiya	Arzon alternativlar
XRF	Nozarar, tezkor [8]	Sezgirlik past, og‘ir elementlar	Portativ uskunalar	Faqat qattiq namunalar
Voltammetriya	Eng arzon, portativ [10]	Operator mahorati talab	In-situ monitoring [20]	Qayta tiklanish muammolari

SWOT-tahlil natijalariga ko‘ra, ICP-MS yuqori sezgirlik talab qilingan tadqiqotlarda, AAS o‘rta byudjetli laboratoriyalarda, XRF va voltammetriya esa portativ monitoringda afzallikka ega [11, 14, 20].

3.4. Qo‘llanish sohalari bo‘yicha tavsiyalar

4-jadval.

Namuna turi bo‘yicha usul tavsiyasi

Namuna turi	Tavsiya etilgan usul	Sababi	Alternativa
Ichimlik suvi (Pb, Cd, As)	ICP-MS	ppt darajasida aniqlash zarur [2, 12]	ICP-OES prekonsentrlash
Tuproq (total metal)	XRF	Tezkor skrining, nozarar [13, 14]	ICP-MS (ekstraksiya bilan)
Tuproq (bioqobilyat)	ICP-MS	Speciation zarur [3, 17]	AAS (faqat total)
Oziq-ovqat (quritilgan)	GFAAS	Aniq, arzon [15]	ICP-MS (multi-element)
Biologik suyuqlik (qon, siydik)	ICP-MS	Iz miqdorlar [2, 12]	Voltammetriya (portativ)
Sanoat chiqindilari	ICP-OES	Tezlik va multi-element [4]	AAS (cheklangan byudjet)

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3.5. O‘zbekiston laboratoriyalarining holati

Tahlil qilingan 32 ta mahalliy manba [11-15] bo‘yicha: 80% AAS usulidan foydalanadi, 15% ICP usullariga o‘tish bosqichida, 5% XRF qo‘llaydi (geologiya sohasida) [11, 13]. Toshkent davlat texnika universiteti [13] va O‘zbekiston Milliy universiteti [12] ICP-MS uskunalari bilan jihozlangan. Biroq viloyat laboratoriyalarining 70% hali AAS ga asoslangan [11, 14].

3.6. Rivojlanish istiqbollari

2020-yillarning tendensiyalari [16, 17, 19]: LA-ICP-MS prostranstveni tahlil uchun, speciation analysis elementning kimyoviy shaklini aniqlash uchun (Cr(III) vs Cr(VI)), single particle ICP-MS nanozarrachalar uchun, voltammetrik biosensorlar real vaqt rejimida monitoring uchun rivojlanmoqda [17, 18, 20].

4. XULOSA

ICP-MS eng yuqori sezgirlikka ega (LOD 0.001 µg/L), lekin qimmat (150-300 ming)[6,7].*AAS arzon* (15−35*ming*) va keng tarqalgan, O‘zbekiston laboratoriyalarining 80% ushbu usulni qo‘llaydi [9, 11, 14]. Namuna turi bo‘yicha: ichimlik suvi va biologik namunalar uchun ICP-MS [2, 12], tuproq uchun XRF [13], oziq-ovqat uchun GFAAS [15], sanoat chiqindilari uchun ICP-OES [4] optimal. O‘zbekiston uchun AAS dan ICP usullariga bosqichma-bosqich o‘tish, portativ XRF va voltammetriya joriy etish tavsiya etiladi [11, 13, 20]. Kelajakda LA-ICP-MS, speciation analysis va biosensorlar rivojlanishda davom etadi [17, 19, 20]. Usul tanlashda sezgirlik, byudjet va namuna turi inobatga olinishi kerak. O‘zbekiston uchun AAS, ICP-OES va ICP-MS kombinatsiyasi eng samarali strategiya hisoblanadi.

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UDK:546.562+547.288.3+544.175

2.4-DIOKSOPENTAN KISLOTA METIL EFIR BENZOILGIDRAZONI Cu(II) KOMPLEKS BIRKMALARINING TUZILISHI

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Annotatsiya. Tadqiqot natijalari tahlili shuni ko‘rsatadiki, ketoaldegid hamda ketoefirlar atsil- va aroilgidrazonlari sintezi, ularning prototroph muvozanati, kompleks hosil qilish xossalari etarlicha tadqiq qilinmagan. Ayrim hollarda esa paramagnit ionlar hosil qiligan mazkur birikmalarning koordinatsion qurshovi, tabiati va xossalari haqidagi ma’lumotlar noaniq bo‘lib qolmoqda, bu esa chuqur ilmiy xulosalar chiqarishni talab etadi. Kompleks birikmalar molekulalarining elektron va fazoviy tuzilishlarini o‘rganish natijasida murakkab tuzilishga ega kimyoviy birikmalarda “tarkib–tuzilish–xossa” o‘zaro bog‘liqliklarini tahlil qilish maqsadga muvofiq. Ushbu maqolada 2,4-dioksopentan kislota metil efiri gidrazonlari asosida Cu(II) ioni bilan komplekslari sintezi, tuzilishi va xossalari tadqiq etilgan.

Kalit so‘zlar: ketoefirlar aroilgidrazonlari, tekis-kvadrat, psevdoaromatik sistema, infraqizil spektr, elektron paramagnet rezonans (EPR), termik tahlil.

Аннотация. Анализ результатов исследований показывает, что синтез atsil- и ароилгидразонов кетоальдегидов и кетоэфиров, их прототропное равновесие, а также комплексообразующие свойства изучены недостаточно. В ряде случаев сведения о координатsionном окружении, природе и свойствах данных соединений, образованных с участием парамагнитных ионов, остаются неопределёнными, что требует проведения более глубоких научных исследований. Изучение электронной и пространственной структуры молекул комплексных соединений позволяет целесообразно анализировать взаимосвязь «состав–строение–свойство» в химических соединениях сложного строения. В данной статье исследованы синтез, строение и свойства комплексов иона Cu(II) на основе гидразонов метилового эфира 2,4-диоксопентановой кислоты.

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Ключевые слова: ароилгидразоны кетоэфиров, квадратно-плоская геометрия, псевдоароматическая система, инфракрасный спектр, электронный парамагнитный резонанс (ЭПР), термический анализ.

Abstract. Analysis of the research results shows that the synthesis of acyl- and aroylhydrazones of ketoaldehydes and ketoesters, their prototropic equilibrium, and their complex-forming properties have not been sufficiently studied. In some cases, information about the coordination environment, nature, and properties of these compounds formed with paramagnetic ions remains unclear, which requires deeper scientific investigation. The study of the electronic and spatial structures of complex compound molecules makes it possible to analyze the "composition–structure–property" relationships in chemically complex systems. This article investigates the synthesis, structure, and properties of Cu(II) complexes based on hydrazones of methyl ester of 2,4-dioxopentanoic acid.

Keywords: aroylhydrazones of ketoesters, square-planar geometry, pseudoaromatic system, infrared spectroscopy, electron paramagnetic resonance (EPR), thermal analysis.

KIRISH

Bu ishda 2,4-dioksopentan kislota metil efiri benzoilgidrazonining Cu(II) kompleks birikmalari tuzilishi va xossalari muhokama qilinagan.

1,3-Diketonlar atsilgidrazonlari tautomer imkoniyatlar nuqtai nazaridan juda ahamiyatli birikmalar sinfini tashkil qilib, ularga bo‘lgan qiziqish kun sayin ortib bormoqda [1]. 2,4-Dioksopentan kislota metil efiri atsilgidrazonlarining tuzilishiga bo‘lgan qiziqish, birinchi navbatda shu bilan belgilanadiki, ular turli tautomer shakllarda mavjud bo‘lish qobiliyatiga ega. Dikarbonil komponentning tuzilish xususiyatlariga bog‘liq holda 1,3-diketonlar atsilgidrazonlarining qatorida chiziqli (gidrazon, yengidrazin) va halqali 5-oksipirazolin tautomer shakllar orasida uchlamchi halqa-zanjir muvozanatni kutish mumkin. Ta’kidlash joizki, juft prototrop muvozanat 1,3-ketoefir atsilgidrazonlari va 1,3-ketoaldegidlar hosilalari uchun kuzatiladi [1].

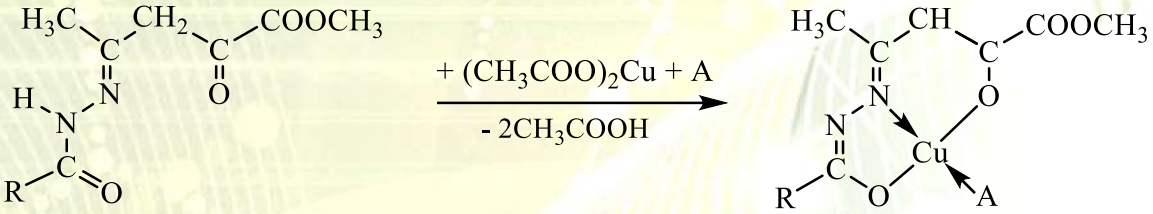
H_2L birikma molekulasi β-diketon qismining murakkab efir fragmentidagi efir guruhning C=O bog‘ valent tebranishlari chiziqlari 1758 cm^{-1} da kuzatiladi. Bu birikmalarning IQ spektrlarida $\nu_{(O–H)}$ uchun 3363-3345 cm^{-1} sohada valent tebranishlarning keng chizig‘i xarakterli valent tebranishlari kuzatiladi. Birikmaning IQ spektrida karrali bog‘larning valent tebranishlari 1580, 1500, 1460 va 1445 cm^{-1} sohalarda kuzatiladi. 1628 cm^{-1} dagi yutilish chizig‘i C=N bog‘ning mavjudligini ko‘rsatadi, qolgan sohalardagi signallar aromatik halqaning bog‘lariga va N–H bog‘ning deformatsion tebranishlariga tegishli.

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1,38 g (0,005 mol) 2,4-dioksopentan kislota metil efiri benzoilgidrazonining 20 ml etanoldagi eritmasiga tomchilab 0,005 mol mis(II) atsetatning 15 ml konsentrlangan ammiakdagi issiq eritmasi qo‘shildi. Yashil rangli eritma hosil bo‘ladi, undan bir sutkadan so‘ng to‘q yashil rangli kristallar cho‘kmaga tushadi. Kompleks birikma filtrlanadi, bir necha marta suv bilan, keyin spirt bilan yuvildi va vakuum-eksikatorda P_2O_5 ustida quritildi. Reaksiya unumi (85%).

Mis(II)ionining H_2L^1-H_2L^7 ligandlar bilan kompleks birikmalari olidingiz adabiyotlarda ko‘rsatilgani kabi sintez qilindi [1-2].

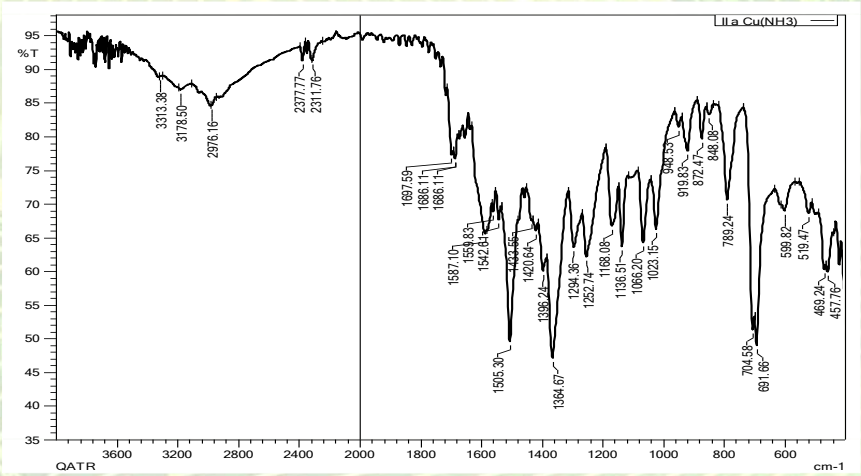
Mis(II) kompleks birikmalari IQ spektrlarining to‘liq o‘xshashligi (1-rasm), shuningdek element analiz natijalari ularning quyidagi tuzilishga ega ekanligini tasdiqladi [1-4]:



A=NH_3, Py; R=C_6H_5 ($CuL^{1}\cdot NH_3$), ($CuL^{1}\cdot Py$), p-$NO_2C_6H_4$ ($CuL^{2}\cdot NH_3$), p-$(CH_3)_2NC_6H_4$ ($CuL^{3}\cdot NH_3$), CH_3 ($CuL^{4}\cdot NH_3$), NH_2 ($CuL^{5}\cdot NH_3$), C_5H_4N ($CuL^{6}\cdot NH_3$), *izo*-C_5H_4N ($CuL^{7}\cdot NH_3$).

Kompleks birikma tuzilishini o‘rganishda IQ spektroskopiya tadqiqoti yordamida molekuladagi funksional guruhlar, bog‘lanish turlari hamda metall–ligand o‘zaro ta’sirlarining tabiati aniqlanadi.

H_2L^1 ligandning 1660-1700 va 3400 cm^{-1} sohalardagi C=O, C=N va N–H bog‘larning xarakterli tebranish chastotalari uchun intensivligida sezilarli o‘zgarishlar kuzatildi, bu ligandning deprotonlanib, Cu(II) ioniga koordinatsiyalanganidan darak beradi. $CuL^{1}\cdot NH_3$ kompleks birikma IQ spektr ma’lumotlari misning ilgari o‘rganilgan kompleks birikmalari qiymatlariga mos keladi [1-4].



1-rasm. $CuL^{1}\cdot NH_3$ kompleks birikmaning IQ spektri.

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2,4-dioksopentan kislota metil efir benzoilgidrazoni asosida $CuL^{11}\cdot NH_3$ kompleks birikmaning IQ spektri 400–4000 cm^{-1} oralig‘ida yozib olindi (1-rasm). IQ spektrda 3310–3180 cm^{-1} oralig‘ida o‘rtacha yoki keng intensiv cho‘qqilar ammiak molekulasidagi N–H bog‘ining valent tebranishlariga mos keladi. Karbonil guruhning valent tebranishi odatda 1700–1730 cm^{-1} oralig‘ida kuzatiladi, ammo $CuL^{1}\cdot NH_3$ kompleks birikma IQ spektrida 1680-1690 cm^{-1} sohada tebranish chastotalarning mavjudligi karbonil guruh kislorodi Cu(II) bilan koordinatsiyalanganligini tasdiqladi. C=N valent tebranishi azot atomi Cu(II) ioniga donorlik qilishi 1505–1560 cm^{-1} oralig‘ida kuzatildi. 1290–1020 cm^{-1} sohada bir nechta o‘rtacha intensivlikdagi cho‘qqilar kuzatildi. Ular C–O va C–N bog‘larining deformatsion hamda valent tebranishlariga mos keladi.

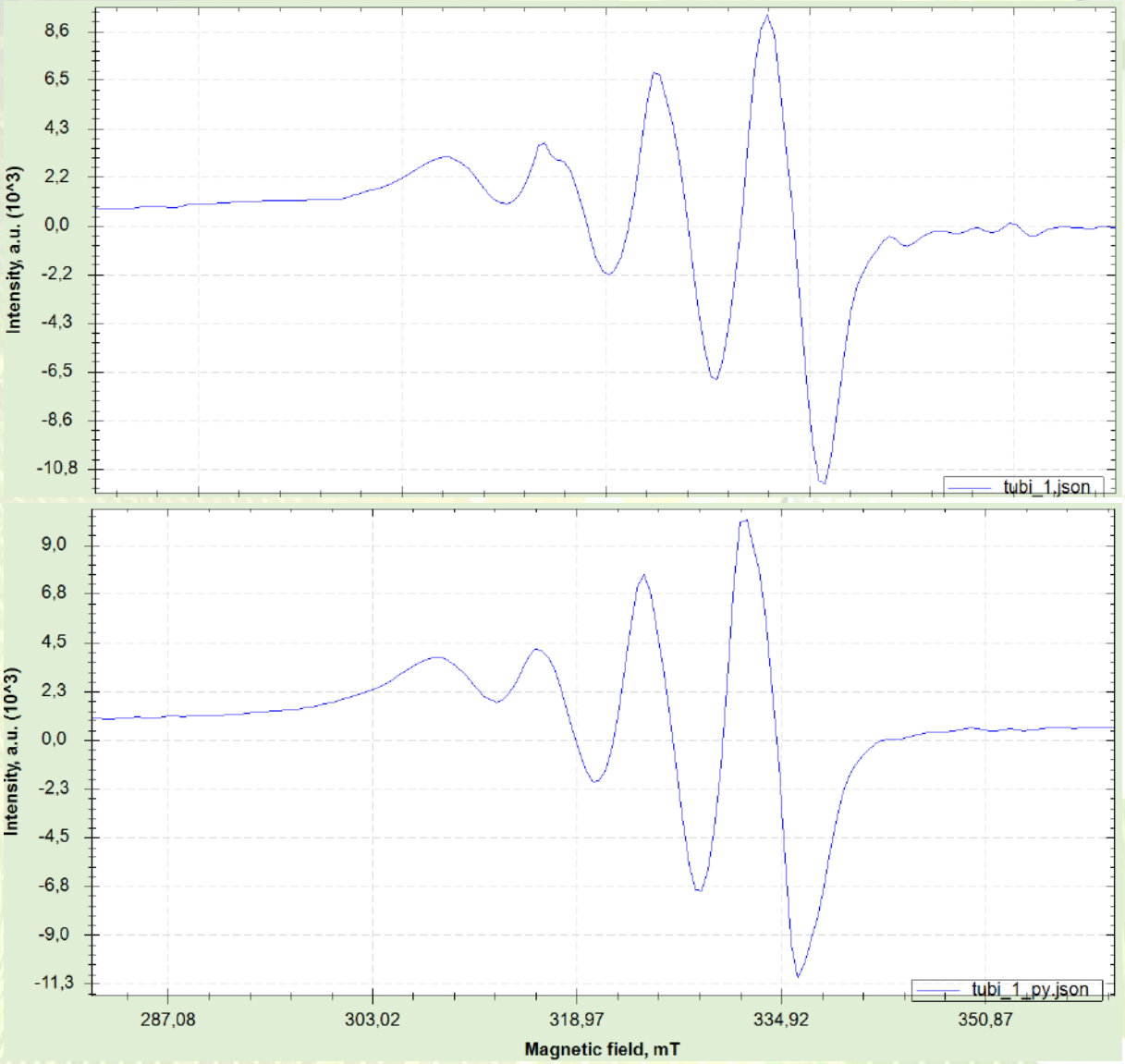
Azot atomining elektron zichligi Cu(II) ioniga donorlik qilgani sababli, erkin ligand bilan solishtirganda N–H bog‘ning tebranish chastotasi biroz quyi sohaga siljigan. Bu holat metall–ligand koordinatsiyasining asosiy spektral ma’lumotini xarakterlaydi. 600–520 cm^{-1} atrofida kuzatiladigan tebranishlar Cu–N tebranishlariga, 470–460 cm^{-1} oralig‘idagi signallar esa Cu–O tebranishlariga mos keladi. Ushbu signallarning mavjudligi kompleks hosil bo‘lganining muhim isboti hisoblanadi (1-rasm).

Biz tomondan o‘rganilgan mis(II) ionining kompleks birikmalari effektiv magnit momentlari $\mu_{эфф} = \sqrt{8\chi^1 \cdot m^T}$ formula bo‘yicha hisoblangan 1,73-1,74 B.M. ga teng bo‘lib, ushbu kattalikning haroratga deyarli bog‘liq emasligi metallxelatlarning yuqori barqarorligini ko‘rsatadi. Bu metallxelatning mustahkam ekanligidan dalolat beradi. Bu komplekslarning qattiq polikristall holatdagi namunalar uchun EPR spektrlarda quyi magnit maydonlar sohasida (H ≈ 1700 E) “ta’qiqlangan” o‘tishlarga mos keluvchi signallarning kuzatilmasligi aniqlangan. Magnit momentlarning bunday qiymatlari kompleks molekulasining monomer tuzilishga ega ekanligini hamda ular orasida o‘zaro antiferromagnit almashinish ta’sirlari mavjud emasligini tasdiqlaydi [1,2,5]. Mis(II) komplekslarining elektron xossalariga gidrazon fragmentidagi o‘rinbosarlarning ta’siri toluol va piridin eritmalarida xona haroratida EPR usuli yordamida o‘rganildi.

$CuL^{1}\cdot NH_3$ va $CuL^{1}\cdot Py$ kompleks birikmalarning eritmalarda izotrop EPR spektrlarini namoyon etib, ular ilgari o‘rganilgan shunga o‘xshash birikmalarning spektrlari bilan mos keladi [2] va mis(II) ning monoyadroli komplekslari uchun xosdir. Xususan, $CuL^{1}\cdot NH_3$ kompleks birikmasining EPR spektrida turli kenglik va intensivlikka ega bo‘lgan to‘rtta o‘ta nozik struktura (O‘NS) chiziqlar kuzatilib (2-rasm (a)), ular ^{63}Cu va ^{65}Cu yadrolari (I_{Cu}=3/2) signallarining superpozitsiyasidan iborat ekanligi aniqlandi. Ushbu natijalar [N_2O_2] donor

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atomlari *trans*-holatda joylashgan mis(II) kompleks tekis-kvadrat koordinatsion tuzilishga ega ekanligini tasdiqlaydi.



2-rasm. $CuL^1 \cdot NH_3$ kompleks birikmaning toluol eritmasidagi–(a) va $CuL^1 \cdot Py$ kompleks birikmaning piridin eritmasidagi–(b) EPR spektrlari

Yadro spini proeksiyasiga bog‘liq holda O‘NS chiziqlarning turlicha kengayishi Mak–Konnel relaksatsiya mexanizmi bilan izohlanadi. Mis(II) kompleksi uchun EPR spektrlari izotrop spin-gamiltonian (SG) bilan ifodalanadi:

$$H = g \cdot \beta \cdot H_0 \cdot S + <a_{Cu}> I_{Cu} \cdot S + a_{Nj} \cdot I_{Nj} \cdot S \quad (1)$$

bu yerda g – elektron effektiv magnit momentining me’yori, o‘lchovsiz g-faktor, ya’ni elektron magnit momentining uning to‘liq burchak momentiga nisbati, u boshqacha Lande faktori deb ham nomlanadi (erkin elektron uchun g = 2,002322), β – Bor magnetoni, S = 1/2, I_{Cu} = 3/2 – mis(II) ioni yadrosining spini, I_N–azot atomi yadrosining spini.

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1-jadval.

Mis(II) kompleks birikmalarining toluoldagi eritmasidan xona haroratida olingan EPR spektrlari parametrlari

Birikmalar	< g >, ± 0,0001	a_{Cu}, ± 0,0001cm^{-1}	α^2
$CuL^1 \cdot NH_3$	2,0915	0,0084	0,81
$CuL^1 \cdot Py$	2,0934	0,0087	0,83
$CuL^2 \cdot NH_3$	2,0924	0,0089	0,79
$CuL^3 \cdot NH_3$	2,0948	0,0088	0,80
$CuL^4 \cdot NH_3$	2,0918	0,0085	0,78
$CuL^5 \cdot NH_3$	2,0895	0,0087	0,81
$CuL^6 \cdot NH_3$	2,0920	0,0086	0,82
$CuL^7 \cdot NH_3$	2,0932	0,0088	0,80

Mis(II) kompleks birikmalari uchun EPR spektrlari chiziqlarining kengligi quyidagi tenglama bilan ifodalanadi [6-7]:

$$H = \alpha + \beta \cdot m_i + \gamma \cdot m_i^2 \qquad (2)$$

bu yerda m_i – mis(II) ioni yadrosi spinining tashqi magnit maydon yo‘nalishi bo‘yicha proeksiyasi; α, β, γ – turli relaksatsion mexanizmlarni tavsiflovchi koeffitsientlardir. Tadqiq etilgan birikmalarda toq elektron B_1g tipidagi molekulyar orbitalda joylashgan bo‘lib, uning metall va ligand atomlari o‘rtasida taqsimlanishi α^2 va $(\alpha')^2$ koeffitsientlari orqali baholanadi. α^2 ning qiymati toq elektronning $|x^2–y^2\rangle$ orbitalda joylashish ehtimolini, $(\alpha')^2$ esa uning ligand atomlari orbitalarida delokallanish darajasini ifodalaydi (3).

$$\varphi_{B1g} = \alpha \cdot d_{x^2-y^2} - \frac{\alpha' \cdot (\delta_1 - \delta_2 + \delta_3 - \delta_4)}{2} \qquad (3)$$

bu yerda α^2 va $(\alpha')^2$– tegishlicha misning atom orbitallari ($d_{x^2-y^2}$) va ligandlarning atomlari (σ_i) koeffitsientlari.

Quyida berilgan (4) tenglamada α koeffitsientning semantik qiymatini toq elektronning $|d_{x^2-y^2}>$ orbitalda bo‘lish ehtimolligi sifatida uning kvadrati orqali ifodalash mumkin:

$$\alpha^2 = \frac{1}{0{,}43}\left(\frac{a_{Cu}}{0{,}036} + g - 2\right) + 0{,}02 \qquad (4)$$

Agar $\alpha^2 = (\alpha')^2 = 0{,}5$ bo‘lsa, metall–ligand bog‘lanish kovalent xarakterga ega bo‘ladi, $\alpha^2 = 1$ va $(\alpha')^2 = 0$ holatda esa bog‘lanish sof ion tabiatga ega bo‘ladi. Ushbu koeffitsientlar qoplanish integrali S orqali o‘zaro bog‘langan. Toq elektronning ligand yadrosi bilan izotrop o‘ta nozik o‘zaro ta’siri azot yadrosidagi elektron zichligiga bog‘liq bo‘lib, $(\alpha')^2=0$ bo‘lganda ligand atomlaridan QO‘NS kuzatilmaydi. Bu koeffitsientlar bir-biri bilan quyidagicha bog‘langan:

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$$\alpha^2 + (\alpha')^2 - 2\,\alpha \cdot \alpha' \cdot S = 1 \qquad (5)$$

bu yerda S – qoplanish integrali. Toq elektronning ligand azot atomi yadrosi bilan izotrop o‘ta nozik o‘zaro ta’sir energiyasi quyidagi tenglama bilan ifodalanadi [6]:

$$< a_N >= \frac{4}{9}\pi \cdot \gamma_N \cdot \beta_0 \cdot \beta_N (\alpha^1)^2 \left|\rho_N(0)^2\right| S_Z \cdot I_Z \qquad (6)$$

bu yerda γ_N – azot atomlarining giromagnit nisbati, β_0 – Bor magnetoni, β_N – yadro magnetoni, $\rho_N(0)$ – azot atomi yadrosidagi 2S-orbitalning zichligi. Ta’kidlash joizki, $(\alpha')^2 = 0$ da toq elektron ligandning azot atomida qisman bo‘lsada, joylashmaydi va QO‘NS qisman yo‘qoladi (2-rasm, 1-jadval). Nazariyaga muvofiq, xelatlovchi ligandning azot atomidan (a_N) parchalanish konstantasi ammiakning azot atomidan parchalanish konstantasidan ikki marta katta bo‘lishi kerak. Ikkita noekvivalent azot atomlaridan QO‘NS ning yomon ajralishi mis(II) ioni metallhalqa bilan qo‘shni bo‘lgan va yuqori elektromanfiylikka ega o‘rinbosarlar ta’siri ostida QO‘NS chiziqlarining kuchli kengayishi bilan tushuntirilishi mumkin [7]. Shuni ham ta’kidlash kerakki, koordinatsion sferasi N_2O_2-*trans* tuzilishli birikmalar uchun azot va vodorod atomlaridan QO‘NS hamma hollarda ham ajralavermaydi (2-rasm (a) va (b)) [7]. $CuL^1 \cdot NH_3$ kompleks piridinda eritilganda u ammiak molekulasi o‘rnini egallab, uni $CuL^1 \cdot Py$ ga aylantiradi. Mis(II) toq elektronining ko‘proq delokallashgani hisobiga uning $|x^2 - y^2>$ orbitaldagi zichligi kamayadi, va binobarin, g-faktor qiymati ham pasayadi, garchi u mis(II) ioni yadrosidan O‘NS konstantasiga jiddiy ta’sir ko‘rsatmaydi. Shuningdek, ligandlar atomida toq elektronning nafaqat σ-bog‘lar orqali, balki π-bog‘lar, xususan piridinning π-orbitali va markaziy atomning d-elektronlari bo‘yicha delokallanishi ham sodir bo‘lib, u nikel(II) kompleks birikmalariga o‘xshash d-π-turdagi Cu→Py dativ bog‘lanishning vujudga kelishini tasdiqlaydi [6-10]. Kuchli donor va qutbli erituvchilar (DMSO, DMFA, piridin) bilan muhit almashtirilganda EPR spektrlari parametrlarida sezilarli o‘zgarishlar kuzatiladi. $CuL^1 \cdot Py$ kompleks birikmaning piridindagi eritmasi uchun mis atomining O‘NS konstantasi kamayadi va g-faktor ortadi, spektr kuchsiz maydonlar sohasiga siljiydi (2-rasm), ikkita azot atomlaridan ajralgan QO‘NS, agar ular mavjud bo‘lsa, oldin yomonlashadi, keyin esa yo‘qoladi. EPR spektrlari ko‘rinishi va parametrlarining bunday o‘zgarishlari, bizning nazarimizda, erituvchi molekulasining qo‘shimcha koordinatsion bog‘lanishi hisobiga kompleks poliedrining o‘zgarishiga bog‘liq bo‘ladi. Bu hodisa erituvchi molekulalarining qo‘shimcha koordinatsiyasi natijasida markaziy mis ionining koordinatsion sferasida oldin erituvchi molekulasi aksial beshinchi holatga, keyin oltinchi holatga birikadi va markaziy

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ion tekis-kvadrat sferasi koordinatsion tetragonal-piramida, keyin esa oktaedrik tuzilishga o‘zgaradi [6-7, 10-12].

Endo- va ekzotermik hodisalarning miqdoriy hisoblashlarini bajarishda kalibrlash uchun etalon sifatida benzoy kislota ishlatilgan (ΔH_f = 141,9 kJ / kg).

Termogravimetrik (TG) tahlil va differensial termik (DT) tahlil usullaridan foydalangan holda $CuL^1 \cdot NH_3$ kompleksning issiqlik xususiyatlari, massa yo‘qotishi va energiya o‘zgarishlarini kuzatish mumkin. 1650°C haroratga chidamli alyuminiy oksidi va platinadan tayyorlangan og‘zi ochiq tigelda 14 mg miqdordagi $CuL^1 \cdot NH_3$ kompleks olinib, 23°C haroratdan boshlab asta-sekin harorat oshirib borildi.

$CuL^1 \cdot NH_3$ kompleksning termik tahlil natijasida 213°C dan keyin barqarorlik kamayib, massa yo‘qotish va issiqlik o‘zgarishlariga uchragan. 213-366°C atrofida ikkita asosiy endotermik jarayon kuzatilgan bo‘lib, bu $CuL^1 \cdot NH_3$ kompleksning parchalanishi yoki issiqlik reaksiyalari natijasida yuzaga kelgan bo‘lishi mumkin.

$CuL^1 \cdot NH_3$ kompleks uchun o‘tkazilgan TG tahlili natijalari termik parchalanish jarayoni bir necha bosqichda kechishini ko‘rsatdi. 23,24-213,42°C harorat oralig‘ida 0,471 mg (3,339%) massa kamayishi kuzatilib, bu adsorbsiyalangan suv va qisman koordinatsiyalangan ammiakning dastlabki desorbsiyalanishi bilan izohlanadi. 213,42-366,26°C oralig‘ida esa parchalanishning asosiy bosqichi sodir bo‘lib, $CuL^1 \cdot NH_3$ kompleks massasining 5,321 mg ga, ya’ni 37,727 % ga kamayishi qayd etildi. Bu asosan ligand parchalanishi va ammiak to‘liq ajralib chiqishini tasdiqlaydi. Yuqori haroratli 366,26-601,77°C intervalida nisbatan kichik massa yo‘qotilishi (1,701 mg, 12,060 %) aniqlanib, bu jarayonda organik moddalar to‘liq yonishini (oksidlanishini) ko‘rsatadi. Umumiy massa yo‘qotilishi 53,126 % bo‘lib, qoldiq CuO (46,874%) ga mos keladi.

$CuL^1 \cdot NH_3$ kompleks uchun o‘tkazilgan DT tahlili natijalari shuni ko‘rsatadiki, 236,99°C haroratda sezilarli endotermik jarayon kuzatiladi. Mazkur haroratda umumiy energiya yutilishi 2,55 µV ni tashkil etib, jarayonning issiqlik tezligi 0,18 µV/mg ga teng bo‘lgan. DT egri chizig‘i ostidagi maydonni integrallash natijasida aniqlangan issiqlik miqdori 104,79 mkal ni tashkil etdi. Ushbu qiymat $CuL^1 \cdot NH_3$ kompleks massasiga nisbatan keltirilganda, jarayonning solishtirma issiqlik effekti 7,43 kal/g ekanligi aniqlangan. Shuningdek, 294,89°C haroratda sezilarli endotermik jarayon kuzatiladi. Mazkur haroratda umumiy energiya yutilishi 3,00 µV ni tashkil etib, jarayonning issiqlik tezligi 0,21 µV/mg ga teng bo‘lgan. DT egri chizig‘i ostidagi maydonni integrallash natijasida aniqlangan issiqlik miqdori 125,79 mkal ni tashkil etadi. Ushbu qiymat $CuL^1 \cdot NH_3$

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kompleks massasiga nisbatan hisoblanganda, jarayonning solishtirma issiqlik effekti 8,92 kal/g ekanligi aniqlangan bo‘lib, bu $CuL^1 \cdot NH_3$ kompleksida mazkur harorat oralig‘ida muhim fazaviy yoki strukturaviy o‘zgarish sodir bo‘lganligini tasdiqlaydi.

TG ma’lumotlari (DTG-60 asbobi, argon muhitida, 10°C/min) asosida $CuL^1 \cdot NH_3$ kompleksning termik parchalanish bosqichlari uchun aktivlanish energiyasini (E_a) hisoblash mumkin. Eng keng tarqalgan va ishonchli integral usullardan biri – Coats-Redfern metodi bo‘lib, u bitta isitish tezligidagi TG egri chizig‘idan foydalanadi. Birinchi tartib reaksiya uchun Coats-Redfern tenglamasidan foydalanib keltirilgan ma’lumotlar asosida E_a va korrelyatsiya koeffitsiyenlarini quyidagicha izohlash mumkin:

Birinchi bosqich (asosan namlik, erkin suv yoki koordinatsiyalangan ammiak chiqib ketishi sodir bo‘ladi): $E_a \approx 68,45$ kJ/mol, korrelyatsiya koeffitsienti $R^2=0,9825$ ga teng; Ikkinchi bosqich (ligand parchalanishi) $E_a \approx 142,30$ kJ/mol, korrelyatsiya koeffitsienti $R^2=0,9901$ ga teng; Uchinchi bosqich (karbonatlarning parchalanishi) $E_a \approx 198,67$ kJ/mol, korrelyatsiya koeffitsienti $R^2=0,9768$ ga tengligi aniqlandi. Bu qiymatlar reaksiyaning birinchi tartibga yaqinligini va kinetik modelning yuqori ishonchliligini tasdiqlaydi.

Shunday qilib, o‘tkazilgan IQ spektr parametrlariga ko‘ra, ligandlar asosan halqali shaklda mavjud bo‘ladi. Kompleks hosil bo‘lishida pirazolin halqasining ochilishi sodir bo‘ladi va ikki karra deprotonlangan ligand qoldig‘i chiziql shaklda koordinatsion bog‘lanib, besh- va olti a’zoli metallhalqalarni hosil qiladi. Benzoilgidrazid fragmentining benzol halqasini *para*-holatda joylashgan o‘rinbosarlar tabiati komplekslarning elektron tuzilishiga ta’sir ko‘rsatadi, EPR usuli bilan mis(II) birikmalari uchun tasdiqlangan. O‘zining donorlik xossalari va qutbliligi bilan farq qiluvchi turli erituvchilar muhitida mis(II) komplekslarining EPR spektrlari o‘rganilganda shu narsa aniqlandiki, erituvchilarning donorlik xossasi ortganda kompleksning erituvchi molekulalari bilan addukt hosil qilishi sodir bo‘lib, metallxelatning kvadrat-piramidal konfiguratsiyasi oktaedrik konfiguratsiyaga o‘tadi [6-12]. Shuningdek, Ni(II) komplekslariga o‘xshash tarzda, Cu(II) birikmalari uchun ham markaziy ionning d-elektronlari va piridinning π-orbitallari o‘rtasida M→Py tipidagi dativ bog‘lanish hosil bo‘lishi aniqlanib, bu komplekslarning koordinatsion moslashuvchanligini va erituvchi muhitga sezgirligini ko‘rsatadi.

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A METHODOLOGICAL FRAMEWORK FOR INVESTIGATING HUMAN RESOURCE PRACTICES AND TURNOVER INTENTION AMONG SOFTWARE DEVELOPERS IN SMES

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Annotation. This study proposes a comprehensive methodological framework for examining the relationship between human resource practices and turnover intention among software developers in small and medium-sized IT enterprises. The paper outlines the research design, sampling procedures, survey instrument development, and planned data analysis strategies to investigate how HR practices may impact turnover intentions in the IT SME context. Although actual data collection has not yet been conducted, the proposed analytical approach and expected results are grounded in relevant literature and theoretical foundations in human resource management and organizational behavior. This methodological contribution offers a clear roadmap for conducting empirical research on employee turnover intention, highlighting the importance of systematic design and rigorous analysis in future studies.

Keywords: human resource practices, turnover intention, software developers, small and medium IT enterprises, research methodology

Аннотация. В данной статье предложена всесторонняя методологическая основа для исследования взаимосвязи между практиками управления человеческими ресурсами и намерением ухода сотрудников среди разработчиков программного обеспечения в малых и средних IT-предприятиях. В статье описаны дизайн исследования, процедура отбора выборки, разработка анкеты и планируемые методы анализа данных, направленные на изучение влияния HR-практик на намерение сотрудников покинуть организацию. Хотя фактический сбор данных пока не проводился, предложенный аналитический подход и предполагаемые результаты основаны на соответствующей литературе и теоретических основах управления человеческими ресурсами и организационного поведения. Данный методологический вклад предоставляет четкую дорожную карту для

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проведения эмпирических исследований текучести кадров с акцентом на системный дизайн и строгий анализ.

Ключевые слова: управление человеческими ресурсами, намерение увольнения, разработчики программного обеспечения, малые и средние IT-предприятия, методология исследования

Annotatsiya. Ushbu tadqiqot kichik va o‘rta biznes IT korxonalarida dasturiy ta'minot ishlab chiquvchilari orasida inson resurslari amaliyoti va kadrlar almashinuvi niyati o‘rtasidagi bog‘liqlikni o‘rganish uchun keng qamrovli metodologik asosni taklif qiladi. Maqolada tadqiqot dizayni, namunalar olish tartiblari, so‘rovnoma vositalarini ishlab chiqish va IT KO‘B kontekstida HR amaliyotlari kadrlar almashinuvi niyatiga qanday ta'sir qilishi mumkinligini o‘rganish uchun rejalashtirilgan ma'lumotlarni tahlil qilish strategiyalari bayon etilgan. Haqiqiy ma'lumotlar to‘plash hali amalga oshirilmagan bo‘lsa-da, taklif qilingan analitik yondashuv va kutilgan natijalar tegishli adabiyotlar va inson resurslarini boshqarish va tashkiliy xulq-atvorning nazariy asoslariga asoslangan. Ushbu metodologik hissa xodimlarning kadrlar almashinuvi niyati bo‘yicha empirik tadqiqotlar o‘tkazish uchun aniq yo‘l xaritasini taqdim etadi, kelajakdagi tadqiqotlarda tizimli dizayn va qat'iy tahlilning ahamiyatini ta'kidlaydi.

Kalit so‘zlar: inson resurslari amaliyoti, kadrlar almashinuvi niyati, dasturiy ta'minot ishlab chiquvchilari, kichik va o‘rta IT korxonalari, tadqiqot metodologiyasi

1. INTRODUCTION

Employee turnover intention has emerged as a significant challenge for small and medium-sized information technology (IT) enterprises, particularly those employing software developers. In an increasingly competitive and rapidly evolving digital environment, software developers represent a critical source of human capital whose skills, knowledge, and experience directly influence organizational performance and innovation. High levels of turnover intention among these professionals can result in increased recruitment and training costs, loss of organizational knowledge, project delays, and reduced competitiveness for IT SMEs.

Human resource (HR) practices are widely recognized as key organizational mechanisms that shape employees’ attitudes, job satisfaction, and behavioral intentions. Previous studies have demonstrated that HR practices such as training and development, compensation and rewards, performance appraisal, and career development opportunities play an important role in influencing employees’ intention to remain with or leave an organization. However, much of the existing literature has focused on large organizations, while empirical evidence related to

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small and medium-sized IT enterprises remains limited, particularly in the context of software developers.

Moreover, although the relationship between HR practices and turnover intention has been extensively examined, less attention has been paid to the methodological rigor and research design employed in studying this relationship within IT SMEs. Differences in organizational size, resource availability, and management structures suggest that research methods applied in large enterprises may not always be directly transferable to SME contexts. Therefore, a clearly defined and context-sensitive methodological framework is essential to obtain reliable and valid findings.

In response to these gaps, this study aims to present a systematic research methodology for examining the relationship between human resource practices and turnover intention among software developers working in small and medium-sized IT enterprises. The article focuses on the research design, population and sampling procedures, conceptual framework, survey instrument development, and data analysis techniques employed in the study. By emphasizing methodological considerations, this research contributes to the existing literature by providing a structured approach that can be applied in future empirical studies investigating employee turnover intention in IT SMEs.

2. METHODOLOGY

2.1. Research Design and Methodological Approach

This study employed a quantitative research approach using a survey-based, cross-sectional research design to examine the relationship between human resource practices and turnover intention among software developers in small and medium-sized IT enterprises (SMEs). The quantitative approach was considered appropriate as it enables the measurement of relationships between variables through statistical analysis and allows for generalization of findings within the studied population.

A cross-sectional design was adopted, whereby data were collected from respondents at a single point in time. This design is widely used in organizational and human resource management research due to its effectiveness in capturing employees' perceptions and attitudes toward organizational practices and their behavioral intentions. The study is explanatory in nature, as it seeks to identify and analyze the influence of HR practices on turnover intention among software developers.

2.2. Research Context, Population, and Sample Characteristics

The research was conducted within the context of small and medium-sized IT enterprises operating in the software development sector. IT SMEs were

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selected as the focus of the study due to their growing role in the digital economy and the increasing challenge they face in retaining skilled software developers.

The target population of the study consisted of software developers employed in IT SMEs. A non-probability sampling technique, specifically purposive sampling, was used to select respondents who met the criteria of being actively employed as software developers within small or medium-sized IT enterprises. This sampling method ensured that the collected data were relevant to the objectives of the study.

The sample included respondents with varying demographic characteristics, such as age, gender, level of education, work experience, and organizational tenure. Collecting demographic information allowed for a more comprehensive understanding of the sample profile and supported the interpretation of the research findings.

2.3. Conceptual Framework and Survey Instrument Design

The conceptual framework of the study is grounded in human resource management and organizational behavior theories, which posit that HR practices significantly influence employees' attitudes and behavioral intentions. In this study, human resource practices were treated as independent variables, while turnover intention was considered the dependent variable.

The data collection instrument was a structured questionnaire developed based on established and validated measurement scales from previous empirical studies. The questionnaire consisted of three main sections. The first section gathered demographic information about the respondents. The second section measured perceptions of human resource practices, including training and development, compensation and rewards, performance appraisal, and career development. The third section assessed turnover intention.

All items were measured using a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). The use of previously validated scales enhanced the content validity of the instrument and ensured that the constructs were measured accurately and consistently.

2.4. Data Collection and Data Analysis Procedures

Data were collected through a self-administered online survey distributed to software developers working in IT SMEs. Participation in the survey was voluntary, and respondents were informed about the purpose of the study. To ensure ethical standards, anonymity and confidentiality were guaranteed, and no personally identifiable information was collected.

After data collection, the responses were coded and analyzed using statistical analysis software. Reliability analysis was conducted using Cronbach's alpha to

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assess the internal consistency of the measurement scales. Descriptive statistics were used to summarize respondents' demographic characteristics and the main study variables.

Inferential statistical techniques, including correlation and regression analysis, were employed to examine the relationship between human resource practices and turnover intention. These methods enabled the identification of the strength and direction of the relationships between the variables and supported hypothesis testing.

3. PROPOSED DATA ANALYSIS AND EXPECTED RESULTS

This section outlines the planned data analysis procedures and the expected outcomes of the study based on the proposed research design and evidence from prior empirical research. Since data collection has not yet been completed, the findings presented in this section are prospective and intended to demonstrate the analytical framework and anticipated patterns rather than actual empirical results.

3.1. Proposed Data Analysis

Upon completion of data collection, the survey responses will be screened and coded for statistical analysis using appropriate statistical software. Descriptive statistics will first be employed to summarize respondents' demographic characteristics and provide an overview of perceptions related to human resource practices and turnover intention.

To assess the reliability of the measurement scales, internal consistency analysis will be conducted using Cronbach's alpha coefficients. Values equal to or exceeding the commonly accepted threshold of 0.70 will be considered indicative of acceptable reliability. This step will ensure that the survey instrument measures the intended constructs consistently.

Subsequently, correlation analysis will be performed to examine the strength and direction of relationships between human resource practices and turnover intention. To further test the predictive power of HR practices, multiple regression analysis will be applied, with turnover intention specified as the dependent variable and HR practices as independent variables. This approach will allow for the identification of the relative contribution of each HR practice to explaining variance in turnover intention among software developers.

3.2. Expected Results

Based on existing literature and theoretical assumptions in human resource management and organizational behavior, it is expected that human resource practices will demonstrate a statistically significant relationship with turnover intention among software developers in small and medium-sized IT enterprises.

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Specifically, it is anticipated that training and development, compensation and rewards, performance appraisal, and career development opportunities will be negatively associated with turnover intention. This implies that software developers who perceive HR practices as fair, supportive, and development-oriented are less likely to express intentions to leave their organizations.

Among the examined HR practices, career development and training opportunities are expected to have a particularly strong influence on turnover intention, reflecting the importance of continuous skill enhancement and professional growth in the IT sector. These anticipated findings align with prior empirical studies that highlight the role of strategic HR practices in retaining skilled IT professionals, especially within SME environments characterized by limited resources and high competitive pressure.

3.3. Expected Presentation of Results

To ensure clarity and transparency, the empirical results will be presented using tables and statistical summaries once data collection is completed. Table 1 illustrates the planned structure for presenting descriptive statistics of the main study variables.

Table 1.

Planned Descriptive Statistics of Study Variables

Variable	Mean	Standard Deviation
Training and Development	To be determined	To be determined
Compensation and Rewards	To be determined	To be determined
Performance Appraisal	To be determined	To be determined
Career Development	To be determined	To be determined
Turnover Intention	To be determined	To be determined

Similarly, correlation and regression results will be reported in tabular form to enhance interpretability and allow comparison with future empirical findings.

4. CONCLUSION

This study presents a comprehensive methodological framework for examining the relationship between human resource practices and turnover intention among software developers in small and medium-sized IT enterprises (SMEs). By outlining a structured research design, population and sampling strategy, survey instrument development, and planned data analysis procedures, the article provides a systematic approach that can be applied in future empirical investigations.

Although the actual survey data have not yet been collected, the proposed methodological approach ensures that once implemented, the study will produce reliable and valid results. The anticipated findings, based on prior research and

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theoretical foundations, suggest that effective HR practices—including training and development, compensation and rewards, performance appraisal, and career development—are expected to reduce turnover intention among software developers in SMEs.

This methodological contribution is particularly valuable for both researchers and practitioners. For researchers, it provides a clear blueprint for conducting survey-based studies in the context of IT SMEs. For practitioners and HR managers, the study highlights the key HR practices that may influence employee retention, guiding the development of strategies to minimize turnover and improve organizational performance.

Finally, the study acknowledges certain limitations inherent in its design, such as the cross-sectional nature of the survey and the reliance on self-reported data. Future research may extend this methodological framework by incorporating longitudinal designs, larger and more diverse samples, and mixed-method approaches to gain deeper insights into HR practices and turnover intention in IT SMEs.

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2.4-DIOKSOPENTAN KISLOTA ETIL EFIR BENZOILGIDRAZONI Mn(II) KOMPLEKS BIRKMALARINING TUZILISHI

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Annotatsiya. Ilgari o‘rganilgan tadqiqot natijalari tahlili shuni ko‘rsatadiki, ketoefirlar gidrazonlari sintezi, ularning tautomeriya jarayonlari hamda kompleks hosil qilish xossalari etarli darajada o‘rganilmagan. Ayrim hollarda esa mazkur birikmalarning koordinatsion qurshovi, tabiati va xossalari haqidagi ma’lumotlar noaniq bo‘lib qolmoqda, bu esa chuqur ilmiy xulosalar chiqarishni taqozo etadi. Kompleks birikmalar molekulalarining elektron va fazoviy tuzilishlarini o‘rganish natijasida murakkab tuzilishga ega kimyoviy birikmalarda “tarkib–tuzilish–xossa” o‘zaro bog‘liqliklarini tahlil qilish imkoniyati yuzaga keladi. Ushbu maqolada etil 2,4-dioksovalerian gidrazonlari asosida Mn(II) ioni bilan komplekslari sintezi, tuzilishi va xossalari tadqiq etilgan.

Kalit so‘zlar: ketoefirlar aroilgidrazonlari, tekis-kvadrat, psevdoaromatik sistema, infraqizil spektr, elektron paramagnit rezonans (EPR), termik tahlil.

Аннотация. Анализ ранее проведённых исследований показывает, что синтез гидразонов кетоэфиров, их таутомерные превращения, а также их способность к комплексообразованию изучены недостаточно. В некоторых случаях сведения о координационном окружении, природе и свойствах данных соединений остаются неопределёнными, что требует более глубоких научных исследований. Изучение электронной и пространственной структуры молекул комплексных соединений позволяет анализировать взаимосвязь «состав–структура–свойства» в химических соединениях со сложным строением. В данной работе исследованы синтез, структура и свойства комплексов иона Mn(II) на основе гидразонов этилового эфира 2,4-диоксопентановой кислоты.

Ключевые слова: ароилгидразоны кетоэфиров, плоско-квадратная геометрия, псевдоароматическая система, инфракрасный спектр, электронный парамагнитный резонанс (ЭПР), термический анализ.

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Abstract. An analysis of previously conducted studies shows that the synthesis of hydrazones of keto esters, their tautomeric transformations, as well as their ability to form complexes, have not been sufficiently investigated. In some cases, information about the coordination environment, nature, and properties of these compounds remains uncertain, which requires more in-depth scientific research. The study of the electronic and spatial structure of molecules of complex compounds makes it possible to analyze the relationship between "composition–structure–properties" in chemically complex systems. In this work, the synthesis, structure, and properties of Mn(II) complexes based on hydrazones of the ethyl ester of 2,4-dioxopentanoic acid have been investigated.

Keywords: aroylhydrazones of keto esters, square-planar geometry, pseudoaromatic system, infrared spectrum, electron paramagnetic resonance (EPR), thermal analysis.

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Bu ishda 2,4-dioksopentan kislota etil efiri benzoilgidrazidi bilan Mn(II) ionining kompleks birikmalarining tuzilishi muhokama qilinagan.

1,3-Diketonlar atsilgidrazonlari tautomer imkoniyatlar nuqtai nazaridan juda ahamiyatli birikmalar sinfini tashkil qilib, ularga bo‘lgan qiziqish kun sayin ortib bormoqda [1]. 2,4-Dioksopentan kislota etil efiri atsilgidrazonlarining tuzilishiga bo‘lgan qiziqish, birinchi navbatda shu bilan belgilanadiki, ular turli tautomer shakllarda mavjud bo‘lish qobiliyatiga ega. Dikarbonil komponentning tuzilish xususiyatlariga bog‘liq holda 1,3-diketonlar atsilgidrazonlarining qatorida chiziqli (gidrazon, yengidrazin) va halqali 5-oksipirazolin tautomer shakllar orasida uchlamchi halqa-zanjir muvozanatni kutish mumkin. Ta’kidlash joizki, juft prototrop muvozanat 1,3-ketoefir atsilgidrazonlari va 1,3-ketoaldegidlar hosilalari uchun kuzatiladi [1].

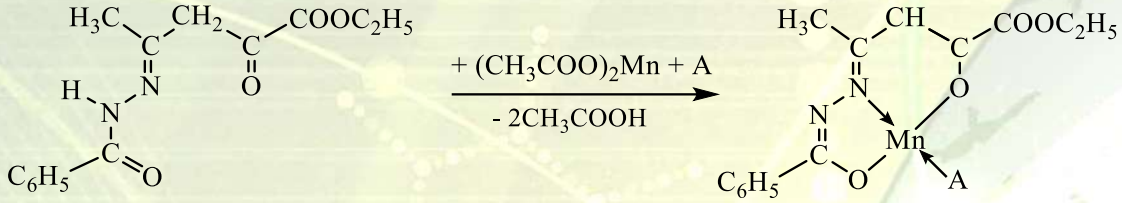
H_2L birikma molekulasi β-diketon qismining murakkab efir fragmentidagi efir guruhning C=O bog‘ valent tebranishlari chiziqlari 1758 cm^{-1} da kuzatiladi. Bu birikmalarning IQ spektrlarida $\nu_{(O–H)}$ uchun 3363-3345 cm^{-1} sohada valent tebranishlarning keng chizig‘i xarakterli valent tebranishlari kuzatiladi. Birikmaning IQ spektrida karrali bog‘larning valent tebranishlari 1580, 1500, 1460 va 1445 cm^{-1} sohalarda kuzatiladi. 1628 cm^{-1} dagi yutilish chizig‘i C=N bog‘ning mavjudligini ko‘rsatadi, qolgan sohalardagi signallar aromatik halqaning bog‘lariga va N–H bog‘ning deformatsion tebranishlariga tegishli.

Marganets(II) atsetatning suv-ammiakli issiq eritmasidan tomchilab 2,4-dioksopentan kislota etil efiri benzoilgidrazonining (H_2L) etanoldagi eritmasiga 50-60 °C da 1:1 nisbatda qo‘shilganda jigar rangli $MnL·NH_3$ polikristallari

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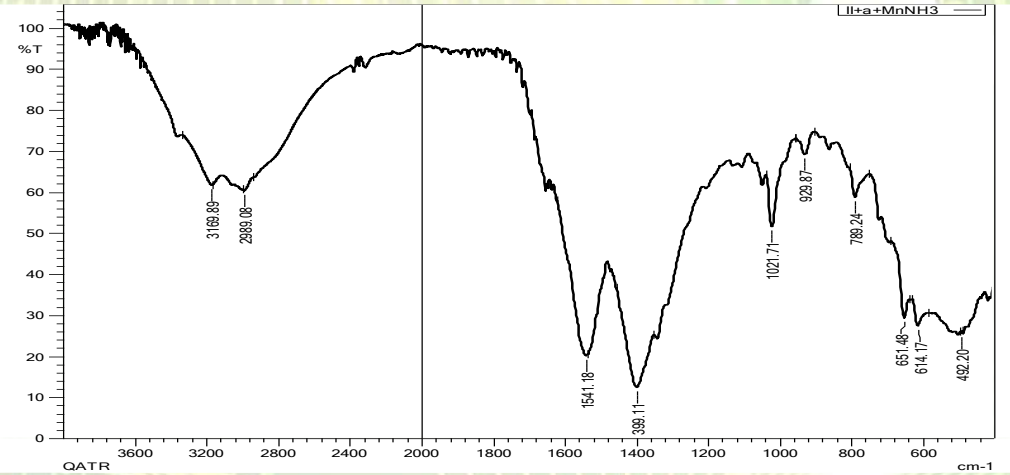
cho‘kmaga tushdi. Hosil bo‘lgan cho‘kma filtrlab, etanolda qayta yuvib olindi va ochiq havoda quritildi.

$MnL\cdot NH_3$ kompleksining IQ spektri ilgari adabiyotlarda o‘rganilgan kompleks birikmalar IQ spektrlari parametrlariga o‘xshash bo‘ladi [1-4].



A=NH_3, Py; ($MnL\cdot NH_3$), ($MnL\cdot Py$).

$MnL\cdot NH_3$ birikmaning IQ spektridagi (1-rasm) 3170 va 2990 cm^{-1} sohalardagi tebranish chastotalari koordinatsion bog‘langan ammiak molekulasining simmetrik va antisimmetrik valent tebranishlariga tegishli. Erkin ligandda C=O guruhiga mos keluvchi kuchli signallar taxminan 1700–1720 cm^{-1} atrofida joylashgan bo‘lsa, kompleks birikmada esa ushbu chiziq past chastotalar tomon siljib, 1560 cm^{-1} sohada kuzatiladi. Bu holat karbonil guruh kislorodi orqali Mn(II) ioniga koordinatsion bog‘ hosil qilganini ko‘rsatadi. Shuningdek, gidrazon fragmentidagi C=N bog‘iga tegishli tebranish chastotasining erkin ligandga nisbatan 30–40 cm^{-1} ga past chastotaga siljishi azot atomi orqali metall bilan bog‘lanish amalga oshganini tasdiqlaydi. Demak, bu kompleksda ligand [O_2N]-donorli tridentat ligand sifatida ishtirok etadi. 490, 610 va 650 cm^{-1} oralig‘ida paydo bo‘lgan yangi signallar Mn–O va Mn–N bog‘larining valent tebranishlariga mos keladi (1-rasm). Ushbu cho‘qilarning paydo bo‘lishi koordinatsion bog‘ hosil bo‘lganini isbotlaydi [1-, 4-6].

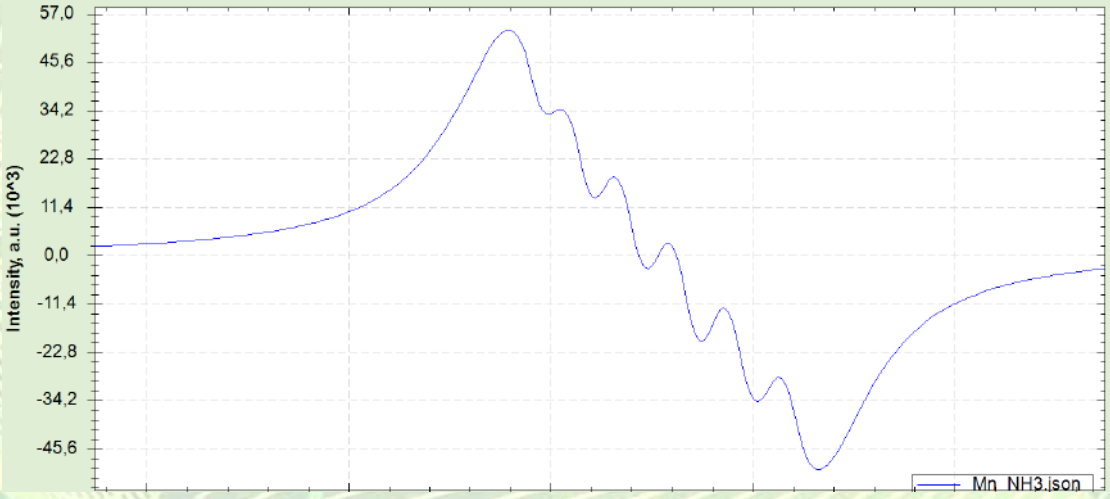


1-rasm. $MnL\cdot NH_3$ kompleks birikmasining IQ spektri

Bizga ma’lumki, Mn(II) ioni $3d^5$-elektron konfiguratsiyaga ega bo‘lib, yuqori spin holati S=5/2 ga teng. Shuning uchun Mn(II) ioni hosil qilgan komplekslarining EPR spektrlari Cu(II) komplekslari EPR spektridan sezilarli darajada farq qiladi va ularning magnit xossalari, asosan, yuqori spinli holat hamda

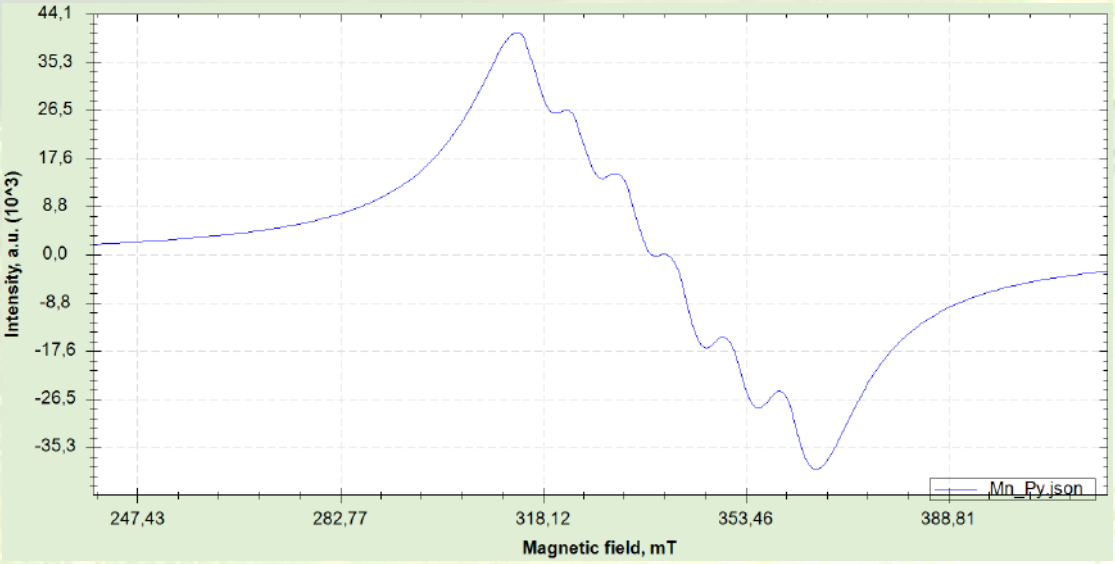
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yadro–elektron o‘zaro ta’sirlari bilan xarakterlanadi. O‘rganilgan Mn(II) komplekslari uchun effektiv magnit moment qiymatlari hisoblashlar natijasida 5,8–6,0 B.M. atrofida bo‘lib, bu nazariy jihatdan kutilgan qiymatlarga mos keladi hamda Mn(II) ionining yuqori spinli holatda ekanligini tasdiqlaydi. Magnit momentning haroratga deyarli bog‘liq bo‘lmasligi komplekslarning monomer tuzilishga ega ekanligini va ular orasida sezilarli o‘zaro elektron almashinuv ta’sirlari yo‘qligini ko‘rsatadi. Bu koordinatsion qurshov metallxelatning mustahkam ekanligini ko‘rsatadi. Mn(II) komplekslarining qattiq polikristall namunalari va eritmadagi EPR spektrlari xona haroratida o‘rganildi. Eritmada Mn(II) komplekslari uchun izotrop EPR spektrlari kuzatilib, ular Mn(II) ionining monoyadroli komplekslari uchun xos ko‘rinishga ega. Xususan, EPR spektrida oltita ekvidistant o‘ta nozik struktura chiziqlar kuzatildi, bu ^{55}Mn yadrosining spiniga (I_{Mn}=5/2) bog‘liq bo‘lib, yadroviy gipernozik ajralishning aniq namoyon bo‘lishidan dalolat beradi. Bu komplekslarning EPR spektrlarida quyi magnit maydon sohasida (H≅1700 e) “ta’qiqlangan” o‘tishlarning signallari mavjud. Magnit momentlarning ushbu ko‘rsatkichlari shundan dalolat beradiki, komplekslarning barcha molekulalari monomer hisoblanadi va ular orasida antiferromagnit almashinuv hodisasi sodir bo‘lmaydi [1, 6]. Mn(II) kompleksning elektron xossalariga gidrazon fragmentidagi o‘rinbosarlarning ta’siri EPR usuli bilan toluol yoki piridin eritmasida xona haroratida o‘rganildi. Biz tomondan o‘rganilgan komplekslar eritmalarda EPR ning izotrop spektrlariga ega bo‘lib, ular oldinroq o‘rganilgan birikmalarning spektrlariga o‘xshash bo‘ladi [6] va Mn(II) ning monoyadroli komplekslari uchun xarakterlidir. Masalan, $MnL\cdot NH_3$ kompleks birikmaning EPR spektri turli kenglikdagi va intensivlikdagi oltita O‘NS chiziqlariga ega bo‘lib, ^{55}Mn (I_{Mn} = 5/2) yadrolarining superpozitsiyasi hisoblanadi (2-rasm (a)). Bularning hammasi [N_2O_2] atomlari *trans*-holatda joylashgan Mn(II) kompleksi tekis-kvadrat tuzilishga ega ekanligini tasdiqlaydi.



a

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b

2-rasm. MnL·NH_3 kompleks birikmaning toluol eritmasidagi–(a) va MnL·Py kompleks birikmaning piridin eritmasidagi–(b) EPR spektrlari

Yadro spinining proeksiyasi uchun O‘NS chiziqlarining turli kenglikka ega bo‘lishi Mak-Konnel relaksatsiya mexanizmi bilan tushuntiriladi, ularning parametrlari g=2,0964, a_{Mn}=0,0086, α^2=0,82 teng. Marganets(II) ning barcha kompleks birikmalari izotrop spin-gamiltonian (SG) bilan ifodalanadi (1-jadval):

$$H = g\cdot\beta\cdot H_0\cdot S + a_{Mn}>I_{Mn}\cdot S + \sum a_{Nj}\cdot I_{Nj}\cdot S \quad (1)$$

bu yerda g – elektron g-faktor, β – Bor magnetoni, S = 5/2 – elektron spini, I_{Mn} = 5/2 – marganets yadrosi spini, α_{Mn} – marganets yadrosidan gipernozik ajralish konstantasi elektron magnit momentining uning to‘liq burchak momentiga nisbati, u boshqacha Lande faktori deb ham nomlanadi (erkin elektron uchun g = 2,0023), I_N–azot atomi yadrosining spini.

EPR spektrlarida kuzatilgan chiziqlarning nisbatan tor va simmetrik bo‘lishi Mn(II) ionining yarim to‘ldirilgan d^5-qobig‘i bilan izohlanadi. Bunda orbital hissalar deyarli so‘nadi va g-faktor qiymati erkin elektron qiymatiga yaqin bo‘ladi (g=2,0964). Bu holat Mn(II) komplekslarida ligand maydonining simmetriyasi yuqori ekanligini va markaziy ion uchun deyarli izotrop magnit muhit hosil bo‘lishini ko‘rsatadi. Mn(II) kompleks birikmalari uchun EPR spektrlari chiziqlarining qiymatlari quyidagi tenglama bilan ifodalanadi [1,6-10.]:

$$H = \alpha + \beta\cdot m_i + \gamma\cdot m_i^2 \quad (2)$$

bu yerda m_i – marganets(II) ioni yadrosi spinining tashqi magnit maydon yo‘nalishi bo‘yicha proeksiyasi; α, β, γ – relaksatsion mexanizmlarga ta’sir etuvchi turli koeffitsientlar.

Marganets(II) ning o‘rganilgan birikmalarida toq elektron B1g turdagi molekulyar orbitalda joylashadi.

$$\Psi = \alpha\psi d + \alpha'\sum\sigma i \quad (3)$$

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bu yerda α^2 va $(\alpha')^2$ – tegishlicha marganetsning atom orbitallari ($d_{x^2-y^2}$) va ligandlarning atomlari (σ_i) koeffitsientlari.

Quyida berilgan (4) tenglamada α koeffitsientning semantik qiymatini toq elektronning $|d_{x^2-y^2}>$ orbitalda bo‘lish ehtimolligi sifatida uning kvadrati orqali ifodalash mumkin:

$$\alpha^2 = \frac{1}{0,43}\left(\frac{a_{Mn}}{0,036} + g - 2\right) + 0,02 \qquad (4)$$

Unda $(\alpha')^2$ kattalik, tabiiyki, ligand atomlari orbitalida toq elektronning delokallanish darajasini aniqlaydi. Agar α^2 va $(\alpha')^2$=0,5 ga teng bo‘lsa, kompleksdagi metall-ligand bog‘lanish kovalent bo‘ladi. Agarda α^2=1 va $(\alpha')^2$=0 bo‘lsa, unda xarakteri sof ion bog‘lanish namoyon bo‘ladi. Bu koeffitsientlar bir-biri bilan quyidagicha bog‘langan (1-jadval):

$$\alpha^2 + (\alpha')^2 - 2\,\alpha \cdot \alpha' \cdot S = 1 \qquad (5)$$

bu yerda S – qoplanish integrali. Toq elektronning ligand yadrosi bilan izotrop o‘ta nozik o‘zaro ta’sir energiyasi quyidagi tenglama bilan ifodalanadi [12; 351-b., 92; 105-106-b.]:

$$A_N = \frac{8\pi}{3} g\beta\gamma_N\beta_N\rho_N(0)$$

$$< a_N >= \frac{4}{9}\pi \cdot \gamma_N \cdot \beta_0 \cdot \beta_N (\alpha^1)^2 \left|\rho_N(0)^2\right| S_Z \cdot I_Z \qquad (6)$$

bu yerda γ_N-azot yadrosining giromagnit nisbati, β-Bor magnetoni, β_N-yadro magnetoni, $\rho_N(0)$-azot yadrosidagi 2s-orbital elektron zichligi.

Ta’kidlash joizki, $(\alpha')^2$= 0 da toq elektron ligandlar atomida qisman bo‘lsada, joylashmaydi va QO‘NS yo‘qoladi (2-rasm).

1-jadval.

Mis(II) kompleks birikmalarining toluoldagi eritmasidan xona haroratida olingan EPR spektrlari parametrlari

Birikmalar	g, ± 0,001	a_{Cu}, ±0,01e	$a_{N1/N2}$, ± 0,01 e.	α^2
MnL·NH_3	2,0964	91,14	15,7/7,8	0,82
MnL·Py	2,0972	90,62	16,14/8,1	0,83

Nazariyaga muvofiq, xelatlovchi ligandning azot atomidan (a_N) parchalanish konstantasi ammiakning azot atomidan parchalanish konstantasidan ikki marta katta bo‘lishi kerak. Ikkita noekvivalent azot atomidan QO‘NS ning yomon ajralishi Mn(II) ioni metallhalqa bilan qo‘shni bo‘lgan va yuqori elektromanfiylikka ega o‘rinbosarlar ta’siri ostida QO‘NS chiziqlarining kuchli kengayishi bilan tushuntirilishi mumkin [1]. Ta’kidlash kerakki, koordinatsion

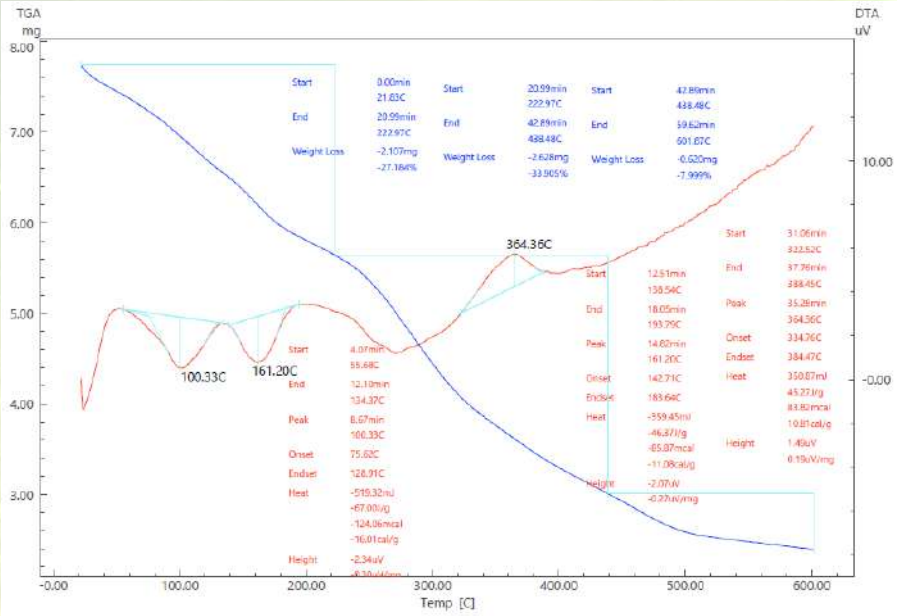
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qurshov N_2O_2-*trans* tuzilishli birikmalar uchun azot va vodorod atomlaridan QO‘NS hamma hollarda ham ajralavermaydi (2-rasm (a) va (b)) [6-10].

$MnL·NH_3$ kompleks piridinda eritilganda u ammiak molekulasi o‘rnini egallab, uni MnL·Py ga aylantiradi. Mn(II) toq elektronining ko‘proq delokallashgani hisobiga uning $|x^2–y^2>$ orbitaldagi zichligi kamayadi va binobarin, garchi u Mn (II) ioni yadrosidan O‘NS konstantasiga jiddiy ta’sir ko‘rsatmasa ham g-faktor qiymati ham pasayadi. Shuningdek, ligandlar atomida toq elektronning nafaqat σ-bog‘lar orqali, balki π-bog‘lar, xususan piridinning π-orbitali va markaziy atomning d-elektronlari bo‘yicha delokallanishi ham sodir bo‘lib, u Mn(II) kompleks birikmalariga o‘xshash d-π-turdagi Mn→Py dativ bog‘lanishning vujudga kelishini tasdiqlaydi Qutbsiz erituvchilar Py, DMSO, DMFA kabi kuchli qutbli erituvchilar bilan almashtirilganda eritmalarning EPR spektrlarida o‘zgarish-lar ro‘y beradi. MnL·Py kompleks birikmaning piridindagi eritmasi uchun Mn atomining O‘NS konstantasi kamayadi va g-faktor ortadi, spektr kuchsiz maydon sohasiga siljiydi (2-rasm (a) va (b)), ikkita azot atomlaridan QO‘NS ajralsa, agar ular mavjud bo‘lsa, oldin yomonlashib, asta-sekin yo‘qoladi. EPR spektrlari ko‘rinishi va parametrlarining bunday o‘zgarishlari, bizning nazarimizda, erituvchi molekulasining qo‘shimcha koordinatsion bog‘lari ta’sirida kompleks poliedrining o‘zgarishiga bog‘liq bo‘ladi. Dastlab piridin molekulasi marganets ionining beshinchi, keyin oltinchi aksial holatiga birikadi va markaziy ionning tekis-kvadrat koordinatsion sferasi tetragonal-piramida, keyin esa oktaedrik tuzilishga o‘zgaradi [1, 6].

Kompleks birikmalarning termik barqarorligini, tarkibi va tuzilishini termik tahlil yordamida o‘rganildi (3-rasm). Termik tahlil usulida bir vaqtning o‘zida namunaning massasi, kompleksning parchalanish massasi va termik barqarorligi temperatura ortib borishi bilan o‘zgarishi kuzatildi. Deammonoliz jarayoni deaktivatsiyaga qaraganda birmuncha yuqori haroratda boradi. Chunki Van-der-Vaal kuchiga qarshi jarayon koordinatsion bog‘ uzilishiga qaraganda energiya sharflanishini kam talab qiladi. 3-rasmda $MnL·NH_3$ kompleksning issiqlik xususiyatlari, massa yo‘qotishi va energiya o‘zgarishlarini kuzatish mumkin. 1650°C haroratga chidamli alyuminiy oksidi va platinadan tayyorlangan og‘zi ochiq tigelda 8 mg miqdorda $MnL·NH_3$ kompleks birikma namunasi olinib, 21°C haroratdan boshlab asta-sekin harorat ko‘tarilib borildi.

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3-rasm. $MnL{\cdot}NH_3$ kompleks birikmaning termogravimetrik (TG) tahlil va differensial termik (DT) tahlil parametrlari

$MnL{\cdot}NH_3$ kompleksning termik tahlil natijasida 220°C dan keyin barqarorlikni yo‘qotib, massa kamayishi va issiqlik o‘zgarishlariga uchragan. 220-440°C atrofida bitta asosiy endotermik jarayon kuzatilgan bo‘lib, bu $MnL^{11}{\cdot}NH_3$ kompleksning parchalanishi yoki issiqlik reaksiyalari natijasida yuzaga kelgan bo‘lishi mumkin.

$MnL{\cdot}NH_3$ kompleks uchun o‘tkazilgan TG natijalari termik parchalanish jarayoni bir necha bosqichda kechishini ko‘rsatdi. 21,83-222,97°C harorat oralig‘ida 2,107 mg (27,184%) massaning kamayishi kuzatilib, bu adsorbsiyalangan suv va koordinatsiyalangan ammiakning dastlabki desorbsiyalanishi bilan izohlanadi. 222,97-438,48°C oralig‘ida esa parchalanishning asosiy bosqichi sodir bo‘lib, $MnL{\cdot}NH_3$ birikma massasining 2,628 mg ga, ya’ni 33,905% ga kamayishi qayd etildi. Bu bosqichda ammiak va ligandining qisman parchalanishi kuzatilgan. Yuqori haroratli 438,48-601,87ºC intervalda nisbatan kichik massa yo‘qotilishi (0,620 mg, 7,999 %) aniqlanib, bu jarayonda ligandning to‘liq parchalanishi va oksidlanishini ko‘rsatdi. Umumiy massa yo‘qotish 69,088 % bo‘lib, qoldiq MnO (30,912%) ga mos keladi (3-rasm).

$MnL{\cdot}NH_3$ kompleks uchun o‘tkazilgan DT tahlil natijalari ko‘rsatishicha, 364,36ºC haroratda sezilarli endotermik jarayon kuzatildi. Mazkur haroratda umumiy energiya yutilishi 1,49 µV ni tashkil etib, jarayonning issiqlik tezligi 0,19 µV/mg ga teng bo‘lgan. DT egri chizig‘i ostidagi maydonni integrallash natijasida aniqlangan issiqlik miqdori 83,82 mkal ni tashkil etadi. Ushbu qiymat $MnL{\cdot}NH_3$ kompleks massasiga nisbatan keltirilganda va jarayonning solishtirma issiqlik effekti 10,81 kal/g ekanligi isbotlangan bo‘lib, bu $MnL{\cdot}NH_3$ kompleksida mazkur

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harorat oralig‘ida muhim fazaviy yoki strukturaviy o‘zgarish sodir bo‘lganligidan dalolat beradi.

Aktivlanish energiyasi tahlili (Coats-Redfern usuli). TG ma’lumotlari (DTG-60 asbobi, argon muhitida, 10°C/min) asosida $MnL \cdot NH_3$ kompleksning termik parchalanish bosqichlari uchun aktivlanish energiyasini (E_a) hisoblash mumkin. Eng keng tarqalgan va ishonchli integral usullardan biri Coats-Redfern metodi bo‘lib, u bitta isitish tezligidagi TG egri chizig‘idan foydalanadi. Birinchi tartib reaksiya uchun Coats-Redfern tenglamasidan foydalanib keltirilgan ma’lumotlar asosida E_a va korrelyatsiya koeffitsiyenlarini quyidagicha izohlash mumkin:

Birinchi bosqich (NH_3 ajralishi): $E_a \approx 65$-85 kJ/mol, korrelyatsiya koeffitsienti $R^2=0,9800$ ga teng;

Ikkinchi bosqich (gidrazon parchalanishi) $E_a \approx 110$-140 kJ/mol, korrelyatsiya koeffitsienti $R^2=0,9956$ ga teng;

Uchinchi bosqich (organik guruhlar termolizi) $E_a \approx 180$-220 kJ/mol, korrelyatsiya koeffitsienti $R^2=0,9908$ ga tengligi aniqlandi. Bu qiymatlar reaksiyaning birinchi tartibga yaqinligini va kinetik modelning yuqori ishonchliligini tasdiqlaydi.

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YO‘L TO‘SHAMALARI HAMDA ORGANIK VA NOORGANIK BOG‘LOVCHILAR BILAN ISHLOV BERILGAN GRUNTLARDAN ASOS QATLAMLARINI QURISH

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Annotasiya. Respublika avtomobil yo‘llarining ko‘p qismi asfaltbeton qoplamadan iborat bo‘lib, qoplama yuzasida ko‘p uchraydigan nuqsonlar biri bu plastik deformasiyalardir, bu esa uning oldini olish dolzarbligini oshiradi. Maqolada yo‘l qoplamalarining elastiklik modulli (organic va noorganik bog‘lovchilar bilan ishlov berilgan gruntlarni hisobga olgan holda) asos va qoplamalarni o‘rganildi va tahlil qilindi.

Kalit so‘zlar: avtomobil yo‘li, tempratura, mustahkamlik, yo‘l to‘shamasi, deformatsiya, egilishlar, buzulishlar.

Аннотация. Большинство дорог в республике построено с асфальтобетонным покрытием, и одним из распространённых дефектов на поверхности покрытия являются пластические деформации, что повышает актуальность их предотвращения. В статье исследуется и анализируется модуль упругости дорожных покрытий (с учётом грунтов, обработанных органическими и неорганическими вяжущими), а также основания и покрытия дорог.

Ключевые слова: шоссе, температура, прочность, дорожное покрытие, деформация, изгибы, искажения.

Abstract. Most of the roads in the republic are made of asphalt concrete pavement, and one of the common defects on the pavement surface is plastic deformations, which increases the urgency of preventing them. The article studies and analyzes the elasticity modulus of road pavements (taking into account soils treated with organic and inorganic binders) as well as the base and pavements.

Key words: highway, temperature, strength, road surface, deformation, bends, distortions.

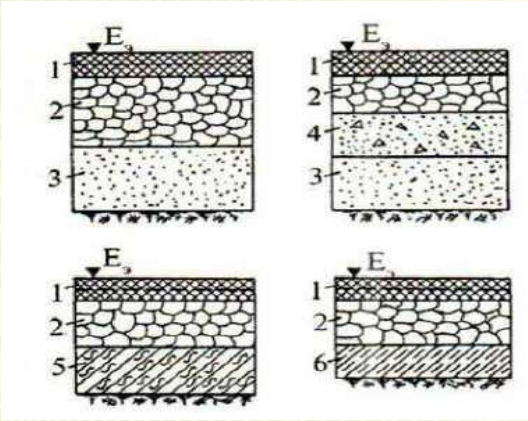
KIRISH.

Avtomobil yo‘llari qurilishi ayrim jarayonlardan tashkil topgan uslubli ishlarni, ya’ni yo‘l poyi, yo‘l to‘shamasi va sun’iy inshootlarni o‘z ichiga oladi. Yo‘l qurilish ishlarining texnologiyasi materiallarga, yarim tayyor mahsulotlarga, yo‘l inshootlarining bo‘lak va qismlarini tayyorlash, hamda sifat ko‘rsatkichlarini

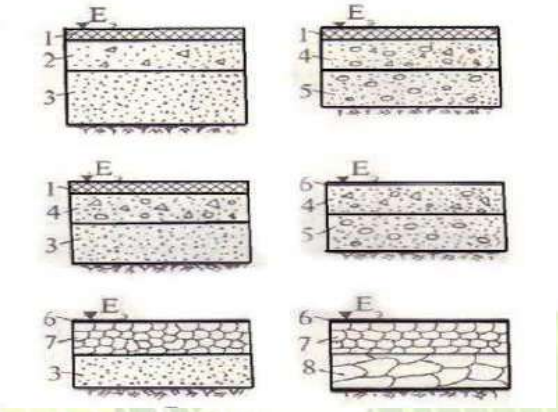
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ta’minlashga qaratilgan. Yo‘l qurilishi jarayonlarini keng ko‘llamli mexanizatsiya-lashgan va avtomatizatsiyalashgan usulda bajarilishini rejalashtirish kerak. Avtomobillarning yil bo‘yi harakatlanishini ta’minlash uchun yo‘lning qatnov qismida yo‘l to‘shamasi quriladi. Yo‘l poyining sirtiga iqlim omillariga va transport g‘ildiraklarining ta’siriga yaxshi qarshilik ko‘rsatadigan materiallardan yotqiziladi.

Transport g‘ildiraklaridan ta’sir etuvchi kuchni va iqlim ta’sirini uzluksiz qabul qila turib, yo‘l to‘shamasi mustahkam, yedirilish va haroratga chidamli, hamda harakat xavfizligini ta’minlash uchun ravon va g‘adir budir yuzali bo‘lishi lozim. To‘shama qatlamlari qalinligi pastdan yuqoriga qarab kamayib boradi (1va 2 rasm), bunga sabab yuqori qatlam materiallari narxining ortib borishi va unga bo‘lgan talab kuchayishidadir. Shuning uchun qoplama o‘ta mustahkam materiallardan qurilib, 1, 2 qatlamdan iborat bo‘ladi.

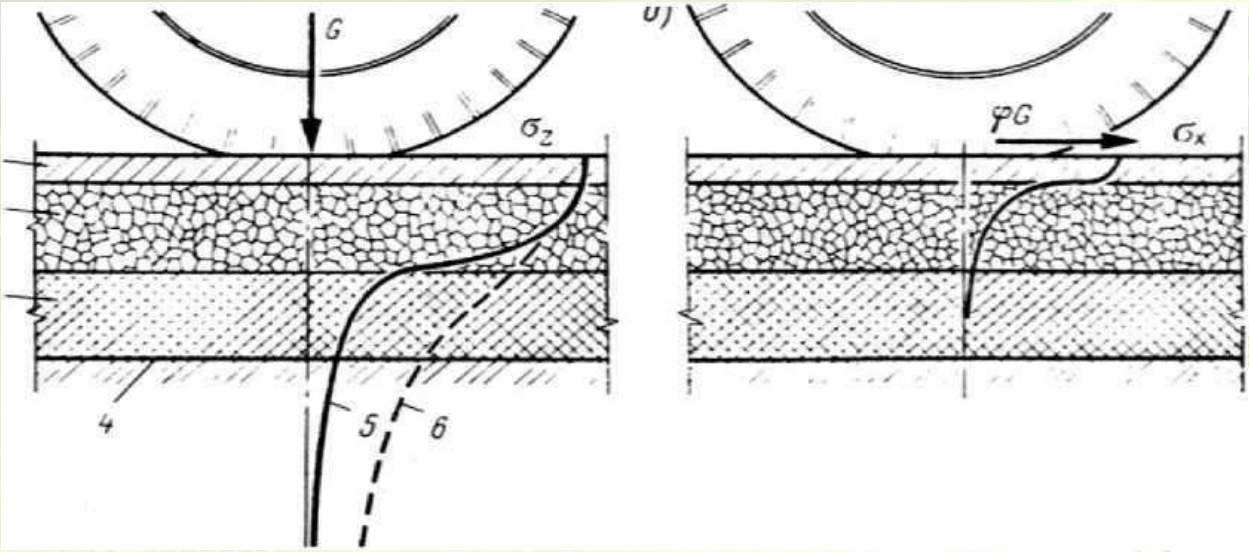


1-rasm. Ekvivalent modullari Ee=60-70 MPa. li yuqori toifali nobikir yo‘l to‘shama larining tuzilishi: 1- ikki qatlamli asfaltobeton; 2-saralangan chaqilgan tosh; 3- qum; 4- shlak; 5-bog‘lovchilar bilan ishlov berilgan grunt; 6- kam miqdorda bog‘lovchilar bilan ishlov berilgan grunt



2-rasm. Ekvivalent modullari Ee=50-35 MPa. li quyi toifali nobikir yo‘l to‘shamalarining tuzilishi: 1-bir qatlamli asfaltobeton; 2-kuyindi; 3-qum; 4-chaqiq tosh; 5-shag‘al; 6-ustki ishlov qatlami; 7-saralangan chaqiq tosh; 8- uncha mustahkam bo‘lmagan tosh

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3-rasm. Ko‘p qatlamli yo‘l to‘shamasida avtomobillarning g‘ildiraklaridan hosil bo‘ladigan kuchlanish: *a*-vertikal kuchlanishlar s_z epyurasi; b-gorizontal kuchlanishlar s_x epyurasi; 1-koplama; 2-asos; 3-asosning qo‘shimcha qatlami; 4-to‘shama grunt; 5-yo‘l to‘shamasidagi kuchlanish epyura chizig‘i; 6-bir jinsli gruntdagi kuchlanish epyura chizig‘i.

Yo‘l qoplamasining ustki qatlami doimo transport g‘ildiraklari ta’sirida bo‘lib, yedirilib boradi, natijada uning qalinligi kamaya boradi. Bundan tashqari qoplamada har xil holat o‘zgarishlari buzilish va deformatsiyalar namoyon bo‘lib turishi bois, bu qatlamni vaqti vaqti bilan tiklab turish talab qilinadi, ko‘pincha yupqa yediriluvchi qatlamga ustki ishlov beriladi.

SHNQ 2.05.02-07 ga ko‘ra yo‘l to‘shamasining turlari, qoplamaning asosiy ko‘rinishlari va ularni qo‘llash doirasi 1-jadvalda keltirilgan.

Qoplamaga ta’sir etuvchi kuchlar to‘shama asosiga o‘tib, gruntli to‘shama tomon tarqaladi. To‘shama qatlami asosi bir va ko‘p qatlamli bo‘lishi mumkin. Asos qatlami qoplamaga nisbatan ta’sirlarga kamroq bardosh berib ishlashi natijasida, uning uchun ishlatiladigan material mustahkamligiga bo‘lgan talab ham pastroq bo‘ladi.

1-jadval

Yo‘l to‘shamasi turlari	Qoplamaning asosiy ko‘rinishlari	Yo‘llar toifasi
Mukammal	Sementbetonli quyma, Temirbetonli yoki armobeton va yigma betonli, Asfaltbetonli	I-IV I-IV I-IV

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Engillashti-rilgan	Asfaltbetonli Bog‘lovchilar bilan ishlov berilgan chaqiq tosh, shag‘al va qumli	III, IV va II toifali yo‘llarni ikki bosqichli qurilishning 1 - bosqichida IV-V
O‘tuvchi	Chaqiq tosh va chaqiq toshli shag‘al; bog‘lovchilar bilan ishlov berilgan gruntlar va mustahkamligi kam	IV-V va III toifali yo‘llarni ikki bosqichli qurilishning 1-bosqichida
Oddiy	Qo‘shimchalar bilan mustahkamlangan yoki yaxshilangan gruntlar	V va IV toifali yo‘llarni ikki bosqichli qurilishining 1-

SHNQ 2.05.02-07 ga asosan yo‘l to‘shamasi qatlamlari qalinliklari 2-jadvalda keltirilgandan kam bo‘lmagan qiymatlarda qabul qilinishi lozim.

2-jadval

Yo‘l to‘shmasining qoplama va boshqa qatlamlari materiallari	**Qatlam qalinligi, sm**
Yirik donli asfaltbeton	6-7
Mayda donli asfaltbeton	3-5
Qumli asfaltbeton	3-4
Organik bog‘lovchilar bilan ishlov berilgan chaqiq tosh (shag‘alli) materiallar	8
Shimdirish usulida organik bog‘lovchilar bilan ishlov berilgan chaqiq tosh	8
Bog‘lovchilar bilan ishlov berilmagan chakik toshli, shag‘alli va chaqiq tosh qo‘shilgan shag‘alli	15
mustahkam asosda (tosh yoki mustahkamlangan gruntda)	8
Organik yoki anorganik bog‘lovchilar bilan ishlov berilgan materiallar va gruntlar	10

Izox: Asfalg‘tbetonli qoplamalarning katta qalinliklarini I va II - toifali yo‘llar uchun, kichigini esa III va IV - toifali yo‘llar uchun qabul qilish lozim.

Bitum emulsiyalari yoki suyuk bitumlar bilan sement yoki bitum emulsiyasini aralashtirish yo‘li bilan yoki xom neftni karbomid formaldegid smolasini aralashtirish yo‘li bilan gruntlarni mustahkamlashda ular 3.4. jadvalda ko‘rsatilgan ko‘rsatkichlarga ega bo‘lishi kerak.

3-jadval

Mustahkamlangan gruntlar xususiyati	**Mustahkamlik klasslari bo‘yicha ko‘rsatkichlar**

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	I	II
Suvga tuyingan namunalarning siqilishdagi mustahkamlik chegarasi, 20 gradus S	4,0-2,5	2,5-1,5
50 °'S, temperaturada siqilishdagi mustahkamlik chegarasi, MPa, kam emas	2,0	1,2
Suvga tuyingan namunalarning egilishdagi cho‘zilish mustaxkkamlik chegarasi, 20 °S da, MPa,	1,0	0,6
Sovuqka chidamliliq koeffitsienti, kam emas	0,85	0,80

Gruntlarni va sanoat chiqindilarini bog‘lovchilar bilan aralashtirish ishlari quydagicha bajariladi:

- yo‘lda, maxsus maydonlarda va konlarda yo‘l frezasi va grunt aralashtirgich mashinalar yordamida;
- aralashtirgich uskunalarda majburiy tarzda aralashtirish bilan.

Katta bo‘lakli gruntlar va sanoat chiqindilarni yoki ularning qorishmasini (kamida 20-30% hajmda) mayda qumlar va bog‘lovchi materiallar bilan aralashtirishni erkin harakatlanuvchi uskunalarda bajariladi.

Mustahkamlangan grunt yo‘l to‘shamaga ishlatilganda, ularning bir yoki bir necha qatlam bo‘lishi asos yoki qoplamaning qalinligiga, shuningdek qo‘llanilayotgan mashinaga bog‘liq bo‘ladi. Bu sharoitda asosning yoki qoplamaning yuqori qatlamiga ishlatilayotgan qorishma, odatda, qorishtiruvchi uskunalarda tayyorlangan bo‘lishi kerak.

Yirik toshli gruntlar bog‘lovchi materiallar bilan qorishma tayyorlovchi uskunalarda aralishtirilganda, gruntlar tarkibida 40 mm dan katta zarralar bo‘lmasligi shart (40 mm dan katta zarralar ishlov berishdan oldin saralab olinadi), katta bo‘lakli gruntlarda 25 mm dan katta bo‘lgan zarralarning bo‘lmasligi, unda 2-25 mm gacha bo‘lgan zarralarning miqdori grunt umumiy massasining 70 % ko‘p bo‘lmasligi kerak. Yirik toshli gruntlarning tarkibiga kirgan 0,5 mm dan kichik bo‘lgan mayda zarrali gruntlarning plastiklik (cho‘ziluvchanlik) soni 12 dan ko‘p bo‘lmasligi lozim. Katta bo‘lakli gruntlarni bog‘lovchilar bilan yo‘lda aralashtirilganda, gruntlarning katta zarrasi 25 mm dan oshmasligi kerak. Loysimon gruntlar plastiklik (cho‘ziluvchanlik) soni 12 dan ko‘p bo‘lganda, bog‘lovchi materiallar bilan aralashtirishdan oldin frezalar yoki grunt aralashtirgich mashinalarda maydalab olinadi.

Maydalangandan so‘ng gruntda 5 mm dan katta bo‘lgan zarralar massaning 25% dan, shuningdek 10 mm dan katta bo‘lgan zarralar esa massaning 10 % dan oshmasligi kerak.

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Og‘ir suglinok va loysimon gruntlarni, namlik oquvchanlik chegarasida, ochiq va quruq havo harorati 20^0S da 0,3 ni tashqil qilsa, maydalash jarayonida gruntga yuzani faollashtiruvchi qo‘shimchalar qo‘shiladi: sulg‘fit-drojja brajkasi;

OP-7 yoki OP-10 suyultirgichlar, gidrofobiatsiya qiluvchi suyuqlik GJ-136-41, neytrallashtirilgan gudron GND. Ularning miqdori 4-jadvalga asosan qabul qilinadi.

4-jadval

Qo‘shimchalar	Qo‘shimcha hajmi sement grunt yoki boshqa qorishma massasiga % xisobida
Gidrofib qiluvchi suyuqlik (GJ 136-41)	0.1-0.2
Sulfit-drojja brajkasi (SBD)	0.05-0.5
Ho‘llovchi OP-7 yoki OP –10	0.05-0.5
Neytrallovchi gudron (GND)	0.015-0.03

Mustahkamlangan materialning zichligi kamida 0,98 dan kam emas, kattaligi O‘zRST 786 bo‘yicha [2]. Agar bog‘lovchi material sifatida sementni organik bog‘lovchi bilan birga, yoki faqat organik bog‘lovchilar ishlatilsa, unda suvning hajmini qorishmaning optimal namlik talabiga muvofiq, organik bog‘lovchi hajmi, yoki emulsiyadagi suv kamaytiriladi, mobodo organik bog‘lovchi emulgatorlangan bo‘lsa. Agar ohak yoki aktiv uchgan kullar bilan mustahkamlansa, optimaldagidan tashqari qo‘shimcha (2-4%) suv qo‘shiladi.

Gruntlar noorganik bog‘lovchilar bilan mustahkamlansa, qorishmaga solinayotgan tuzlik va ishqorlik suyuqlikdagi suvning hajmini hisobga olish zarur. Mustahkamlash uchun tayyorlab qo‘yilgan gruntlar ustidan transport harakati ruxsat etilmaydi. Gruntlarni oxak bilan birga tutilgan yoki kul kuyundilari qo‘shilgan holda mustahkamlansa, gruntga avval qo‘shimchalar kiritilib ular bir xil ko‘rinishga kelgunicha aralashtiriladi, so‘ng ohak kiritilib, grunt optimal holatga kelguncha namlanadi, so‘ngra bir sutkadan so‘ng tekislanib zichlanadi.

Gruntning organik moddalar bilan qorishmasi namligi zichlashdan oldin optimal holatda bo‘lishi kerak, lekin ishlab chiqarish paytida havo sharoitiga qarab quyidagilarcha ruhsat etiladi:

- optimal 2-3% ko‘p quruq yog‘ingarchiliksiz havoda harorati $+20^0$ S dan yuqori bo‘lsa;
- optimal 1-2% kam yog‘ingarchilik sharoitda, havoning harorati $+10^0$ S dan past bo‘lsa.

Agar gruntlar noorganik bog‘lovchilar bilan bog‘langan gruntlarga ishlov berilganda, shu qatorda gruntlarni mustahkamlashda sement yoki karbomidoformaldegid smolasi qo‘shimchalar bilan yuzani faollashtiruvchi modda ko‘rinishida, bitum emulsiya, suyuq bitum, gudronlar, xom neft yoki sekin

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qotuvchi bog‘lovchilar bilan sement, yoki sementsiz qatlam qurilganining birinchi 2 sutkasida ruxsat etiladi.

Bog‘lovchi bilan ishlov berilgan grunt bir tekislikda hamda qalinlikda ko‘ndalang nishabligini ta’minlagan holda yoyilishi kerak. Sement, ohak yoki boshqa noorganik bog‘lovchilar bilan mustahkamlangan o‘ta namlangan gruntlarda, ishlov berilayotgan gruntlarning namligi 5-jadvaldagi talab etilgan ko‘rsatkichlaridan oshmasligi lozim.

5-jadval

Grunt turi	Ruxsat etilgan namlikda (optimaldan nisbati) zilanish koeffitsienti 1-0.98
Changsimon qumlar	1.35
Engil yirik supeslar, yengil supeslar	1.25
Changsimon supeslar, og‘ir changsimon supeslar, yengil suglinoklar	1.15
Og‘ir suglinoklar, qumlangan va changsimon gillar	1.1

Bog‘lovchi materiallar qo‘shib gruntlarni quritishda qo‘shimchaning miqdori 6-jadvalga asosan belgilanadi.

6-jadval

Grunt ko‘rinishi	Maydalangan kuydirilmagan ohak yoki faol quruq saqlangan kul gruntning qo‘shilish hisobi, grunt massasiga nisbatdan %, uning namligini optimal namligiga nisbatdan		
	1.2	1.4	1.6
Kullar, supeslar changsimon	-	0.5	1.0
Engil suglinoklar	-	0.5	1.5
Og‘ir suglinoklar	1.0	2.0	-
Qumlangan va changsimon gillar	1.5	3.0	-

Izoh: Maydalangan kuydirilmagan ohak qo‘shimchasi SaO+Mg ga hisobidan, tutilgan faol kullar qo‘shimchasi bo‘sh SaO xisobida berilgan

Tarkibini tanlashda, gruntlarning texnik va texnologik ko‘rsatkichlarni yaxshilash, mustahkamlash, buning uchun: suyuq bitumlar bilan tutilgan kul, kul-kuyundilar qorishmasini ohak qo‘shib yoki qo‘shmasdan, maydalangan oxaktosh, kukunlashtirilgan ohak aralashtirib ishlatish:

- suyuq bitumlar, bitum emulg‘siyalari, tosh ko‘mirdan bog‘lovchilar – ohak; ohak changi, tsement, tutilgan kullar;

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- organik bog‘lovchilar (karbomidoformalg‘degid smoladan tashqari) - kationaktiv va anionaktiv moddalar (turi E-1, SJKning qoldig‘i, ikkilamchi yog‘ gudroni, gossipol smola va boshqalar).

Organik bog‘lovchi materiallar bilan mustahkamlangan gruntdan asos va qoplamalarni quruq havoda harorati 10^0S dan kam bo‘lmaganda qurishga ruxsat etiladi. Gruntni bitum emulsiyasi bilan aralashtirish havoning harorati 5^0S dan kam bo‘lmagan sharoitda amalga oshiriladi.

Yirik bo‘lakli va qumlik gruntlarning organik bog‘lovchilarni qo‘shishdan oldin namligi 2-5% oralig‘ida bo‘lishi, gillik gruntlarning namligi esa grunt oquvchanlik chegarasining 0,2-0,4 namligi darajasida bo‘lishi zarur.

Gruntlarning namligi so‘ndirilmagan ohak qo‘shishdan oldin, uning gidrotatsiyasini ta’minlash kerak. Yirik bo‘lakli va qumli gruntlarni yoki supeslarni organik bog‘lovchi materiallar bilan yo‘l ustida aralashtirilganda, bog‘lovchilar gruntga gruntaralashtiruvchi mashinaning bir bor o‘tish jarayonida to‘la hajmda qo‘shilishi zarur. Ishlov berilgan qatlam qalinligi eng zich holatda 16 cm dan oshmasligi kerak.

Gillik grunlarni organik bog‘lovchi materiallar bilan aralishtirishda bir marta o‘tish yoki ko‘p marta o‘tish qo‘llaniladigan uslubda grunt aralashtiruvchi mashinalar qo‘llanilishish lozim. Mustahkamlanadigan gruntlar suyuq karbomidoformaldegid smolasiga bitum emulsiyasi yoki neft gudroni qo‘shish bilan majburiy tarzda ishlaydigan qorishtirgich uskuna yordamida aralashtiriladi. Saqlash muddati 2 oydan oshiq bo‘lgan smolalar (agar ular texnik talablarga javob bersa) qo‘llanilganda, hamda havo harorati 25^0S dan yuqori bo‘lganda avval smolaga bog‘lovchi bitum, so‘ngra qotiruvchi qo‘shiladi.

Organik bog‘lovchi bilan mustahkamlangan gruntni g‘ildirakli katok bilan, bir izdan 10-15 marta o‘tish orqali zichlanadi. Bitum emulsiyasi yoki suyuq bitumga sement qo‘shish bilan ishlov berilgan mustahkamlangan gruntlarda qarov ishlari, havo harorati 15^0 S dan yuqori va yog‘ingarchilik bo‘lmagan sharoitda, qatlam ustiga 0,6-0,8 dm^3/m^2 me’yorda bitum emulsiyasini sepish orqali bajariladi. Agar bir sutka orasida konstruktiv qatlam uning ustiga yotqizilsa, qarov ishlarining zarurati bo‘lmaydi.

Sement bilan mustahkamlangan gruntlar qatlamini zichlangan holatida qarov ishlari qalinligi 6 cm. dan kam bo‘lmagan qum qatlamida amalga oshiriladi.

Mustahkamlangan gruntdan qurilgan asos yoki qoplama qatlami ustidan transport harakatlanishiga kamida 20 kundan keyingina ruxsat etiladi. Havoning isishi va bahorda eruvchanlik davrida qatlam ustidan transport vositalari harakatlanishiga yo‘l qo‘yilmaydi.

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Havo harorati minus 10^0 S dan past bo‘lgan qisqa davom etuvchi, qattiq sovuqli hududlarda yillik qurilish jadalligini ta’minlash maqsadida, sementli grunt qorishmalarini sement bilan suvsiz aralashtirib tayyorlab qo‘yishga ruxsat etiladi. Yo‘l poyi tayyor bo‘lmaganda tayyorlagan qorishma havo isib ketgunga qadar zahiralarda saqlanadi, so‘ngra ishlatilish joyi bo‘yicha yoyiladi, suv bilan aralashtiriladi va zichlanadi.

Agar yo‘l poyi tayyorlangan bo‘lsa, tayyorlangan aralashma qatlam qilib joylashtiriladi, havo iligach suv bilan aralashtirilib, zichlanadi.

Sementli grunt aralashmasi, havo harorati minus 10^0 S dan past bo‘lganda, havo ilishdan 3 oy oldin tayyorlab qo‘yiladi.

Ishlar sifatining nazorati. Asos va qoplamalar mustahkamlangan gruntlardan qurilganda 1.13-bandga qo‘shimcha ravishda quyidagilar nazorat qilinadi:

kamida bir smenada bir marta:

- yirik bo‘lakli va qumlik gruntlarning granulometrik tarkibi GOST 12536-79 ga binoan;
- gil gruntlarning maydalanish darajasi, 5 va 10 mm teshikli elakda elanganda;
- organik bog‘lovchilarning qo‘shishdan oldingi harorati;
- emulsiyalarning bir xilda, qatlam-qatlam bo‘lmagan holdagi ko‘rinishi;
- qorishmalarning sifati, namunani siqish orqali olingan mustahkamligi;
- shtabelda saqlanayotgan qorishmalarning qo‘shimcha 0,2-0,5 m chuqurlikdagi harorati;

Kamida har 200 m da:

- ishlov berilayotgan gruntlar va tayyor qorishmalarning zichlashdan oldingi namligi va zichlangan materialning ko‘ndalang kesim bo‘yicha 3 nuqtada (o‘qi va qatlam chetidan 0,5 m masofada)gi zichligi va ularning 4.66.- band talablariga javob berishi;

kamida 5 smenada 1 marta:

- sho‘rxok gruntlarda eruvchan tuzlarning massasi O‘z RST 25100 bo‘yicha;
- tutilgan kullar va kul kuyundilari qorishmalarning yaroqligi;
- qarov ishlari talablari doimiy ravishda.

Tutilgan kul va kul kuyundi qorishmalari yoki maydalangan ohaktoshlarni bog‘lanmagan gruntlarga qo‘shimcha sifatida ishlatishga yaroqliligi, ularda 0,071 mm dan mayda bo‘lgan zarralarning soni kamida 60% va 2 mm dan yirigi 5% dan ko‘p bo‘lmasligi aniqlanadi.

Materiallar tashilganda kamomad 10% dan ko‘p bo‘lmasligi kerak. Bog‘langan grunt uchun kul-kuyundilar qorishmalarining yirikroqini ham ishlatilishiga yo‘l qo‘yiladi.

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Qorishmalarning mustahkamligini aniqlash uchun, ulardan qazib olinib 250m^3 qorishma uchun 3 ta namuna tayyorlanadi.

Noorganik bog‘lovchi materiallar bilan ishlangan gruntlarning zichlik koeffitsientini, zichlangan qatlamdan olib quritilgan mustahkamlangan gruntning namunasining zichligini, O‘z RST 786 bo‘yicha zichlanib quritilagan qorishmaning zichligiga nisbati bo‘yicha aniqlanadi.

Yotqizilayotgan qatlamning eng kam qalinligi eng katta zarralarning o‘lchamidan kamida 1,5 marta ko‘p bo‘lib, mustahkam asosga yotqizilayotgan qalinligi 10 cm dan, qumlik asos bo‘lganda 15sm dan kam bo‘lmasligi kerak. Qatlamning o‘ta katta qalinligi 7-jadvalda ko‘rsatilgandan katta bo‘lmasligi lozim.

7-jadval

Material ko‘rinishi	Zichlanayotgan qatlamning eng katta qalinligi, zichlovchi mashina qo‘llanganda			
	Silliq yuza-lik, massasi - 10 t	Panjarasimon, g‘ildirak shinalik, massasi 15t	Titratma va arlash massali, t	
			10tgacha	16 t
Qiyn zichlanuvchi (oti-lib chiqqan, yetomorfik mustahkamligi 1000 v dan katta, qattiq, yahshi siqadigan, kuyundilar oyqalashgan holatda)	18	24	18	24
Engil zichlanuvchi oti-lib chiqqan yetomorfik jinslar mustahkam-ligi 1000 kam o‘lgan, cho‘kmalar, aniqlanma-gan, shag‘al-lar, kuyundi-lar g‘ovak holatdagisi	22	30	22	30

Chaqiqtoshlarni biriktirish usuli bilan asos va qoplamalar qurishni 2 bosqichda bajarish tavsiya etiladi:

- asosiy zarrali chaqiqtoshlarni yoyish va zichlashni(birbiri bilan tishlashishi va birikishi uchun) boshlash;
- chaqiqtoshlarni yoyish (ikki-uch marta biriktirish), har bir zarrasi bo‘yicha zichlash. Asoslar uchun bir bosqichda biriktirish kifoya. Cho‘kma, mustahkamlik markasi 600 dan kam bo‘lgan jinslardan olingan chaqqiq toshni asos uchun ishlatilganda, biriktirish bir bosqichda bajariladi.

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Quyi va o‘rta qatlamlarni yotqizishda 40-70 mm va 70-120 mm li, asos yoki qoplama ustki qatlami uchun 40-70 mm li , to‘ldirish uchun 5-10 mm, 10-20 mm va 20-40 mm li chaqiqtoshishlatiladi.Kuchsizroq chaqiqtoshlarning 70 mm dan katta o‘lchamdagi fraktsiyalari ishlatiladi.

Zarur bo‘lganda qo‘shimcha ravishda zichlashni qurilish transportlari harakatini asos (qoplama)ning butun kengligi bo‘yicha tashqil qilib bajarish mumkin.

Asosni birinchi va ikkinchi bosqichda zichlashni g‘ildirak shinali, og‘irligi 16 tonnadan kam bo‘lmagan, shinadagi bosim 0,6-0,8 MPa ga teng katoklarda, tirkama titrovchi og‘irligi kamida 6 tn, panjarasimon og‘irligi kamida 15 t katoklar, o‘ziyurar silliq valsli og‘irligi 10 t dan kam bo‘lmagan va aralash moslamali og‘irligi 16 t dan kam bo‘lmagan katoklar bilan baja-riladi. Oddiy turdagi katoklarning bir joyidan umumiy o‘tish soni kamida 30 (birinchi bosqichda 10, ikkinchisida 20), aralash moslamalikda kamida 18 (birinchi bosqichda 6, ikkinchisida 12) va titrovchilarida 12 (birinchi bosqichda 4, ikkinchisida 8) marta bo‘lishi kerak.

Mustahkamlik markasi 600 va cho‘ziluvchi soni Pl-2 Pl-3ga teng chaqiqtoshlardan qurilgan asoslarni og‘irligi 16tn dan ko‘p bo‘lmagan g‘ildirak shinali katoklar bilan kamida bir yerdan 20 marta o‘tish bilan, yoki titrovchi katoklar bilan zichlanadi.

Chaqiqtosh zarralari orasidagi ishqalanish kuchini kamaytirish va o‘zaro tishlashishni tezlashtirish uchun, chaqiqtoshlarni zichlashdan oldin suv sepish (taxminan 15-25 dm3/m2[3] birinchi bosqichda) so‘ng zichlash lozim.

Ikkinchi bosqichda mayda chaqiqtoshlarni zichlashni tishlashayotgan qatlamni sekinasta zarralarni kichraytirish bilan bajariladi.

Zichlashishi og‘ir bo‘lgan chaqiqtoshlar ishlatilaganda ustiga tishlashuvchi material yotqizishdan oldin organik bog‘lovchi materiallar bilan 2-3 dm^3/m^2 hisobidan ishlov beriladi.

Tishlashuvchi chaqiqtosh zarralari sarfi 8-jadvalga asosan belgilanadi.

8 jadval

Asosiy chaqilr tosh o‘lchovi	Tishlantiruvchi zarra-lar sarfii, m^3, 1000 m^2 ularning o‘lchamiga muvofiq, mm		
	20-40	10-20	5-10
40-70	-	15	10
70-120	10	10	10

Izoh: 40-70 mm zarralik chaqiqtoshlardan tishlashtirish usuli bilan asos qurilsa, bir martalik tishlashtirish usuli bilan chaqilgantosh va qum- chaqiqtosh

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qorishmasining 5-20, 0-20, 0-10 zarralikni qo'llash mumkin. 70-120 mm chaqiqtosh ishlatilganda esa 5-40 mm qo'llaniladi.

XULOSA VA TAKLIFLAR. Qoplamani zichlashdan so'ng, uning yuzasiga mustahkamlik markasi 800 dan kam bo'lmagan, otqindi jinslardan olingan tosh maydalari (cho'kma jinslardan 600 dan kam bo'lmagan)ni 100 m^2 ga 1 m^3 hisobida yoyib, taxminan katoklarni 4-5 marta o'tkazib zichlanadi. Faol va yuqori faol kuyundilaridan tayyorlangan qatlamni zichlashdan so'ng, agar yuqorida joylashgan qatlam yotqizilmasa, unga 10-12 kun mobaynida 1m^2 ga 2-2,5 litr hisobidan suv sepilib turishi kerak.

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SUYUQ SHISHA ASOSIDAGI KOMPOZITSION MATERIALLARNING TERMIK BARQARORLIGINI OSHIRISH USULLARI

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Annotatsiya. Mazkur maqolada suyuq shisha (natriy silikat) asosidagi kompozitsion materiallarning termik barqarorligini oshirish usullari adabiyotlar sharhi asosida tahlil qilingan. Suyuq shisha yuqori adgeziya, ekologik xavfsizlik va iqtisodiy samaradorlik kabi afzalliklarga ega bo‘lsada, yuqori haroratlarda uning strukturaviy degradatsiyasi va mexanik xossalarining pasayishi asosiy muammolardan biri hisoblanadi. Tadqiqot davomida mineral qo‘shimchalar (SiO_2), nano va mikroto‘ldiruvchilar, organik modifikatorlar hamda geopolimer tizimlarning suyuq shisha matritsasiga ta’siri o‘rganilgan. Adabiyotlar tahlili natijalari shuni ko‘rsatadiki, silika asosli qo‘shimchalar strukturani zichlashtirib, termik barqarorlikni oshiradi, nanozarrachalar esa issiqlik o‘tkazuvchanlikni yaxshilaydi va termik zarbalarga chidamlilikni kuchaytiradi. Geopolimer tizimlar yuqori haroratlarda eng barqaror strukturalardan biri sifatida ajralib turadi. Shuningdek, termik ishlov berish orqali silikat tizimdagi –OH guruhlarning kamayishi hisobiga strukturaviy mustahkamlik ortadi. Tadqiqot natijalariga ko‘ra, eng samarali yondashuv kompleks modifikatsiya usuli hisoblanadi.

Kalit so‘zlar: Suyuq shisha, natriy silikat, termik barqarorlik, kompozitsion materiallar, silika, nanozarrachalar, geopolimer, modifikatsiya.

Abstract. This article presents a literature review on methods for improving the thermal stability of liquid glass (sodium silicate)-based composite materials. Although sodium silicate exhibits advantages such as high adhesion, environmental safety, and cost-effectiveness, its structural degradation and deterioration of mechanical properties at elevated temperatures remain significant challenges. The study analyzes the effects of mineral additives (SiO_2), nano- and micro-fillers, organic modifiers, and geopolymer systems on the properties of sodium silicate matrices. The results of the literature review indicate that silica-based additives enhance structural densification and improve thermal stability, while nanoparticles increase thermal conductivity and resistance to thermal shock. Geopolymer systems demonstrate superior thermal resistance due to their three-dimensional aluminosilicate network structure. Furthermore, thermal treatment leads to the

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removal of hydroxyl groups, resulting in improved structural stability. Based on the analysis, it is concluded that a combined modification approach (mineral, nano, and organic additives) is the most effective strategy for enhancing thermal performance.

Keywords: liquid glass, sodium silicate, thermal stability, composite materials, silica, nanoparticles, geopolymer, modification.

Аннотация. В данной статье представлен обзор литературных источников по методам повышения термической стабильности композиционных материалов на основе жидкого стекла (силиката натрия). Несмотря на такие преимущества жидкого стекла, как высокая адгезия, экологическая безопасность и экономичность, его структурная деградация и снижение механических свойств при высоких температурах остаются актуальной проблемой. В работе проанализировано влияние минеральных добавок (SiO_2), нано- и микрочастиц, органических модификаторов, а также геополимерных систем на свойства силикатной матрицы. Результаты анализа показывают, что кремнеземные добавки способствуют уплотнению структуры и повышению термостойкости, а наночастицы улучшают теплопроводность и устойчивость к термическим нагрузкам. Геополимерные системы характеризуются высокой термической стабильностью благодаря трехмерной алюмосиликатной структуре. Кроме того, термическая обработка приводит к удалению гидроксильных групп и повышению прочности структуры. Установлено, что наиболее эффективным является комплексный подход к модификации.

Ключевые слова: жидкое стекло, силикат натрия, термическая стабильность, композиционные материалы, кремнезем, наночастицы, геополимер, модификация.

KIRISH.

Suyuq shisha (natriy silikat) noorganik bog‘lovchi sifatida yuqori adgeziya, arzonlik va ekologik xavfsizlik kabi afzalliklarga ega bo‘lib, qurilish, metallurgiya va olovbardosh materiallar ishlab chiqarishda keng qo‘llaniladi [1]. Biroq, uning asosiy kamchiligi — yuqori haroratlarda strukturaviy degradatsiyaga uchrashi va mexanik xossalarining pasayishidir [2].

Suyuq shisha asosidagi tizimlarda termik barqarorlik asosan silikat tarmog‘ining (Si–O–Si) zichligi va modifikatsiya darajasiga bog‘liq [3]. Tadqiqotlar shuni ko‘rsatadiki, yuqori haroratlarda natriy silikatning dehidratatsiyasi va keyingi fazaviy o‘zgarishlari (masalan, β-cristobalit hosil bo‘lishi) uning xossalarini keskin o‘zgartiradi [2].

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So‘nggi yillarda suyuq shishaning termik xossalarini yaxshilash uchun turli xil modifikatsiya usullari, jumladan mineral qo‘shimchalar, nanozarrachalar va organik modifikatorlardan foydalanish keng o‘rganilmoqda [4,5]. Ayniqsa, silika asosli qo‘shimchalar va nanozarrachalar tizimning mikrostrukturaviy mustahkamligini oshirishi aniqlangan [4].

Bundan tashqari, organik–anorganik gibrid tizimlar hosil qilish orqali termik degradatsiya jarayonlarini nazorat qilish mumkinligi ko‘rsatib berilgan [6]. Shu sababli, suyuq shisha asosidagi kompozitsion materiallarning termik barqarorligini oshirish usullarini tizimli tahlil qilish dolzarb ilmiy muammo hisoblanadi.

METODOLOGIYA: Mazkur ishda suyuq shisha (natriy silikat) asosidagi kompozitsion materiallarning termik barqarorligini oshirish usullarini tizimli ravishda o‘rganish maqsadida ilmiy adabiyotlar tahlili (systematic literature review) usuli qo‘llanildi. Tadqiqot uchun asosiy ma’lumotlar bazalari sifatida Scopus, Web of Science, ScienceDirect va SpringerLink platformalaridan foydalanildi [7].

Adabiyotlarni qidirish quyidagi kalit so‘zlar kombinatsiyasi asosida amalga oshirildi: “sodium silicate”, “liquid glass”, “thermal stability”, “composite materials”, “modification”, “silica”, “nanoparticles”, “geopolymer”. Qidiruv 2000–2026-yillar oralig‘ida chop etilgan ilmiy maqolalarni qamrab oldi. Dastlabki bosqichda 120 dan ortiq maqolalar aniqlanib, ularning ichidan mavzuga bevosita aloqador bo‘lgan 30 dan ortiq ilmiy ishlar chuqur tahlil uchun tanlab olindi.

Adabiyotlar quyidagi tanlash mezonlari (inclusion criteria) asosida saralandi:

- ❖ suyuq shisha yoki natriy silikat asosidagi tizimlarning mavjudligi;
- ❖ termik xossalar eksperimental usullar (TGA, DSC, DTA) orqali o‘rganilganligi;
- ❖ modifikatsiya usullarining (mineral, organik yoki nanoqo‘shimchalar) qo‘llanilganligi;
- ❖ natijalarining miqdoriy (harorat diapazoni, massa yo‘qotish, issiqlik effekti) ifodalanganligi.
- ❖ Shuningdek, quyidagi chiqarib tashlash mezonlari (exclusion criteria) qo‘llanildi:
- ❖ faqat nazariy yoki umumiy tavsif berilgan maqolalar;
- ❖ silikat tizimlarga bevosita aloqador bo‘lmagan tadqiqotlar;
- ❖ termik tahlil natijalari keltirilmagan ishlar.

Tahlil qilingan ilmiy ishlar quyidagi asosiy yo‘nalishlar bo‘yicha guruhlandi:

- ❖ Mineral qo‘shimchalar ta’siri (SiO_2, silica fume, kvarts va boshqalar);
- ❖ Nano va mikroto‘ldiruvchilar ta’siri (nano-SiO_2, diamond, metall oksidlar);

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❖Organik modifikatorlar (polimerlar, amid va boshqa funksional guruhlar);
❖ Geopolimer tizimlar va alumosilikat strukturalar.
❖ Termik xossalarni baholashda asosiy e’tibor quyidagi eksperimental metodlarga qaratildi:
❖ TGA (termogravimetrik tahlil) — massa yo‘qotish bosqichlari va termik degradatsiya jarayonlarini aniqlash;
❖ DSC (differensial skanerlovchi kalorimetriya) — endotermik va ekzotermik jarayonlarni aniqlash;
❖ DTA (differensial termik tahlil) — fazaviy o‘zgarishlarni baholash [8].

Ma’lumotlarni qayta ishlash jarayonida turli manbalardan olingan natijalar taqqoslanib, umumlashtirildi hamda ularning o‘zaro bog‘liqligi aniqlashtirildi. Xususan, modifikatsiya turi, qo‘shimcha konsentratsiyasi va harorat diapazoni kabi omillarning termik barqarorlikka ta’siri tizimli ravishda tahlil qilindi.

Natijada, turli modifikatsiya usullarining samaradorligi solishtirilib, suyuq shisha asosidagi kompozitsion materiallarning termik xossalarini yaxshilashda eng muhim omillar aniqlab berildi.

TAJRIBA VA TAHLILIY NATIJALAR

3.1 Mineral qo‘shimchalarning ta’siri

Adabiyotlar tahliliga ko‘ra, silika (SiO_2) va silica fume kabi mineral qo‘shimchalar suyuq shisha strukturasini zichlashtiradi va yuqori haroratlarda deformatsiyani kamaytiradi [4,9].

TGA natijalari ko‘rsatadiki, silica fume bilan modifikatsiya qilingan tizimlarda 600°C gacha massa yo‘qotish 15–20% ga kamayadi, klassik natriy silikat tizimlariga nisbatan 30–35% o‘rnatilgan [4].

DSC analizida endotermik jarayonlarning cho‘zilishi va maksimal issiqlik o‘tkazuvchanlik markazining siljishi kuzatilgan, bu esa strukturaviy mustahkamlikni ko‘rsatadi [9].

Grafik tavsif: TGA va DSC grafigi mineral qo‘shimchalar konsentratsiyasi oshgan sari termik degradatsiya bosqichlari kechikishini, shuningdek, silikat tarmog‘ining zichligini vizual tarzda ko‘rsatadi.

3.2 Nano va mikroto‘ldiruvchilar

Nanozarrachalar qo‘shilishi kompozitsion materiallarning termik barqarorligini sezilarli darajada yaxshilaydi [3]. Masalan:

Diamond nanozarrachalar bilan modifikatsiya qilingan tizimlarda 500°C dan yuqori haroratlarda massa yo‘qotish minimal bo‘lib, bu TGA kurvasida tekis massa o‘tish sifatida aks etadi.

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Nano-SiO_2 qo‘shilganda, DTA analizida ekzotermik jarayonlarning maksimal cho‘zilishi kuzatiladi, bu esa materialning termik zarbalarga chidamliligini oshiradi.

Grafik tavsif: Nanozarrachalar konsentratsiyasi oshgan sari TGA va DSC grafigi pastroq massa yo‘qotish va ekzotermik jarayonlarning siljishini ko‘rsatadi. Bu, shuningdek, materialning termal stressga chidamliligini vizual tarzda tasvirlaydi.

3.3 Geopolimer tizimlar

Geopolimer tizimlar yuqori haroratga chidamliligi bilan ajralib turadi [5]:

TGA natijalari ko‘rsatadiki, bunday tizimlar 800–1000°C gacha o‘z xossalarini saqlab qoladi.

DSC va DTA analizlari shuni ko‘rsatadiki, Al–O–Si tarmog‘i mavjud bo‘lgan geopolimerlar amorfnilikni uzoq vaqt saqlaydi va fazaviy o‘zgarishlar kechikadi.

Grafik tavsif: TGA va DSC grafigi geopolimer tizimlarda yuqori harorat bosqichlarida ham massa yo‘qotishning pastligi va ekzotermik jarayonlarning siljish tendensiyasini aniq ko‘rsatadi.

3.4 Termik ishlov va strukturaviy o‘zgarishlar

Termik ishlov berish orqali –OH guruhlar kamayadi va silikat tarmog‘i zichlashadi [6,8]. Natijalar:

100–200°C: fizik suv chiqishi;

200–600°C: organik komponentlar parchalanishi;

600°C: silikat matritsaning qayta tashkil topishi.

Grafik tavsif: TGA grafigi ushbu uch bosqichni aniq ko‘rsatadi, DSC grafigida esa endotermik va ekzotermik jarayonlarning intensivligi va haroratga bog‘liqligi ko‘rinadi.

3.5 Kompleks modifikatsiya samaradorligi

Adabiyotlar tahlili shuni ko‘rsatadiki, mineral + nano + organik modifikatorlar kombinatsiyasi eng yuqori termik barqarorlikni beradi:

TGA kurvasida massa yo‘qotish eng past darajada;

DSC va DTA analizida endotermik va ekzotermik jarayonlar cho‘zilgan va maksimal haroratga siljigan;

Silikat tarmog‘ining zichligi va strukturaviy mustahkamlik eng yuqori ko‘rsatkichlarda bo‘ladi [3,4,5,6,9].

Grafik tavsif: Kompleks modifikatsiya TGA va DSC grafigida barcha boshqa modifikatsiya usullariga nisbatan eng stabil kurva bilan namoyon bo‘ladi.

O‘tkazilgan adabiyotlar tahlili shuni ko‘rsatadiki, suyuq shisha asosidagi kompozitsion materiallarning termik barqarorligi murakkab ko‘p omilli jarayon

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bo‘lib, u asosan silikat tarmog‘ining strukturaviy tashkil topishi, kimyoviy modifikatsiya darajasi va qo‘shimchalar tabiati bilan belgilanadi. Ushbu tizimlarda termik degradatsiya jarayoni bir necha bosqichda kechib, dastlab fizik bog‘langan suvning ajralishi, so‘ngra kimyoviy bog‘langan gidroksil guruhlarning parchalanishi va nihoyat silikat matritsaning qayta kristallanishi bilan tavsiflanadi [8].

Mineral qo‘shimchalar, ayniqsa SiO_2 asosli komponentlar, silikat tarmog‘ining polikondensatsiya darajasini oshirib, Si–O–Si bog‘lanishlar sonini ko‘paytiradi, bu esa strukturani zichlashtiradi va yuqori haroratlarda deformatsiyaga chidamliligini oshiradi [4,9]. FTIR va DFT tadqiqotlari orqali aniqlanishicha, silica fume qo‘shilishi natijasida erkin silanol (Si–OH) guruhlarining kamayishi va mustahkam siloksan bog‘lanishlarining ortishi kuzatiladi [9]. Bu esa termik parchalanish haroratining siljishiga olib keladi.

Nano va mikroto‘ldiruvchilar ta’siri esa faqat kimyoviy emas, balki fizik-mexanik va issiqlik uzatish mexanizmlari bilan ham bog‘liq. Xususan, yuqori issiqlik o‘tkazuvchanlikka ega nanozarrachalar issiqlik oqimini bir tekis taqsimlab, lokal qizish zonalarini kamaytiradi va termik stresslarning oldini oladi [3]. Shu bilan birga, ular dispers faza sifatida silikat matritsada mikroarmaturalash effektini hosil qilib, mikro yoriqlar rivojlanishini sekinlashtiradi.

Geopolimer tizimlar alohida e’tiborga loyiq bo‘lib, ular klassik natriy silikat tizimlariga nisbatan yuqori termik barqarorlikka ega. Bu holat ularning uch o‘lchamli alumosilikat (Al–O–Si) tarmog‘i bilan izohlanadi, bunda alyuminiy atomlarining kirishi natijasida strukturaviy rigidlik ortadi va yuqori haroratlarda fazaviy barqarorlik ta’minlanadi [5]. Bunday tizimlarda kristallanish jarayonlari kechikadi va amorf holat uzoqroq saqlanadi, bu esa issiqlik zarbalariga chidamlilikni oshiradi.

Termik ishlov berish ham muhim rol o‘ynaydi. Degidroksillanish jarayonida silikat strukturasidagi –OH guruhlarning kamayishi kondensatsiya reaksiyalarini kuchaytiradi va natijada yanada zichroq, kam nuqsonli struktura hosil bo‘ladi [6]. Bu jarayon ayniqsa 400–600°C oralig‘ida intensiv kechib, materialning keyingi yuqori haroratga chidamliligini belgilaydi.

Shu bilan birga, organik modifikatorlar, jumladan amid hosilalari, silikat tizimlarda gibrid organo-anorganik strukturalar hosil qilib, termik degradatsiya mexanizmini o‘zgartiradi. Bunday tizimlarda organik komponentlar dastlab parchalanib, poroz struktura hosil qilishi mumkin, ammo to‘g‘ri tanlangan kompozitsiya sharoitida ular stressni yutuvchi faza sifatida xizmat qiladi va umumiy termik chidamlilikni oshiradi.

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Umumiy tahlil shuni ko‘rsatadiki, alohida modifikatsiya usullaridan ko‘ra, sinergik (kompleks) yondashuv — ya’ni mineral qo‘shimchalar, nanozarrachalar va organik modifikatorlarni birgalikda qo‘llash — eng yuqori samaradorlikni ta’minlaydi. Bunday tizimlarda strukturaviy zichlik, issiqlik o‘tkazuvchanlik va mexanik mustahkamlik bir vaqtda optimallashtiriladi.

Shunday qilib, kelgusidagi tadqiqotlar uchun asosiy yo‘nalish sifatida modifikatorlarning o‘zaro ta’sir mexanizmlarini chuqur o‘rganish, ularning optimal konsentratsiyasini aniqlash va ko‘p komponentli tizimlarda termik xossalarni prognozlash masalalari dolzarb bo‘lib qolmoqda.

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ADABIY TA’LIM JARAYONIDA BADIIY MATN USTIDA ISHLASHDA ZAMONAVIY METOD VA USLUBLAR

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Annotatsiya. Maqolada adabiy ta’lim jarayonida badiiy matn ustida ishlashning zamonaviy metod va uslublari chuqur ilmiy tahlil etiladi. Muammoli ta’lim, hamkorlik texnologiyasi, interfaol metodlar, suhbat, evristik va taqqoslash metodlarining o‘zbek adabiyoti ta’limidagi qo‘llanilish imkoniyatlari va pedagogik-psixologik asoslari ochib beriladi. Shu bilan birga, ushbu metodlar adabiy ta’limning ma’naviy-tarbiyaviy vazifasini to‘laqonli amalga oshirish, talabada kitobxonlik madaniyatini shakllantirish va uning shaxsiy kamolotiga ko‘maklashish imkonini beradi.

Kalit so‘zlar. adabiy ta’lim, badiiy matn tahlili, zamonaviy metodlar, muammoli ta’lim, hamkorlik texnologiyasi, interfaol metodlar, mustaqil fikrlash, kitobxonlik madaniyati, pedagogik innovatsiya, kompetentlilik.

Abstract. The article provides a profound scientific analysis of modern methods and techniques used in working with literary texts within the educational process. It explores the pedagogical and psychological foundations of applying problem-based learning, collaborative technologies, interactive methods, dialogue-based instruction, and heuristic and comparative methods in Uzbek literature education. Furthermore, these methods enable the full realization of the spiritual and educational goals of literary education, fostering a culture of reading in students and supporting their personal development.

Keywords: literary education, literary text analysis, modern methods, problem-based learning, collaborative technology, interactive methods, independent thinking, reading culture, pedagogical innovation, competence.

Аннотация. В статье дается глубокий научный анализ современных методов и приемов работы с художественным текстом в процессе литературного образования. Раскрываются возможности применения и психолого-педагогические основы проблемного обучения, технологий сотрудничества, интерактивных методов, беседы, эвристических и сравнительных методов в обучении узбекской литературе. Вместе с тем, данные методы позволяют полноценно реализовать духовно-просветительскую задачу литературного

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образования, сформировать культуру чтения у учащихся и способствовать их личностному совершенствованию.

Ключевые слова: литературное образование, анализ художественного текста, современные методы, проблемное обучение, технология сотрудничества, интерактивные методы, самостоятельное мышление, культура чтения, педагогическая инновация, компетентность.

KIRISH

Bugungi kunda adabiy ta’limning bosh maqsadi shunchaki ma’lumot berish emas, balki “kitobxon shaxs”ni shakllantirishdir. Professor Qozoqboy Yo‘ldoshev ta’kidlaganidek, adabiyot darsi — san’at darsidir va u o‘quvchidan ijodiy tafakkurni talab etadi. Zamonaviy axborot oqimi sharoitida talabalarning badiiy matn bilan bevosita muloqotini tashkil etish, ularda matn osti ma’nolarini chaqish (dekodlashtirish) ko‘nikmasini shakllantirish zarurati tug‘ilmoqda. Tadqiqotning maqsadi — badiiy matn tahlilida qo‘llaniladigan zamonaviy metodlarning ilmiy-metodik imkoniyatlarini tizimlashtirish va ularning amaliy samaradorligini isbotlashdan iborat. Shu nuqtai nazardan, zamonaviy metod va uslublarni ta’lim jarayoniga muvaffaqiyatli integratsiya qilish o‘quv jarayonini samarali, boy va qiziqarli qilishda markaziy ahamiyatga ega.

Adabiy matnning asosiy xususiyati — bu muallifning mahorati bo‘lib, u madaniy va ma’naviy sohaga bevosita bog‘liq. Shu sababli matn faqat shu sohaning parametrlari doirasida tahlil va baholanishi mumkin. Adabiy matn o‘ziga xos xususiyatlarga ega kommunikativ vosita sifatida xizmat qiladi: kompozitsion tuzilishi, til orqali amalga oshirilgan badiiy hodisa sifatidagi maqomi, poetik tilning ustuvorligi, yagona belgilashning ko‘p ma’noliligi, har o'qilganda qayta qurilishi va o‘zgartirilishi, maqsadli auditoriyasini o‘z ichiga olishi, referentsial bo‘lmagan tabiati, talqin va o‘zgartirish imkoniyati, o‘ziga xos voqelikni yaratishi — bular adabiy matnning o‘ziga xos belgilaridir. Badiiy matn ustida ishlash adabiy ta’limning asosiy shakli hisoblanadi va uning samaradorligi ko‘p jihatdan qo‘llaniladigan metod va uslublarga bog‘liq. An’anaviy ta’limda matn bilan ishlash ko‘pincha tayyor xulosalarni o‘zlashtirish va takror so‘zlash bilan chegaralanib qolgan. Natijada talaba na asarning badiiy mazmuniga chuqur kirib boradi, na o‘z shaxsiy munosabatini shakllantira oladi. Bu holat esa adabiy ta’limning eng muhim vazifasini — badiiy asarlar orqali shaxsni ma’naviy tarbiyalashni ikkinchi o‘ringa surib qo‘yadi.

O‘zbek adabiyoti ta’limini zamonaviylashtirish masalasi U.Dolimov, A.Zunnunov, Q.Yo‘ldoshev, S.Matjonov, M.Mirqosimova, Q.Husanboyeva, R.Niyozmetova, V.Qodirov kabi yirik olimlarning asarlarida keng tadqiq etilgan. Ushbu tadqiqotlar adabiyot ta’limidagi pedagogik yondashuvlarni yangilash,

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talabalarning adabiy tahlil ko‘nikmalarini oshirish, mustaqil fikrlashni rivojlantirish va kitobxonlik madaniyatini shakllantirishga qaratilgan. Biroq zamonaviy metodlarning aniq qo‘llanilish modellari va o‘zbek adabiyoti materiali misolida ularning samaradorligi masalasi hali yetarlicha yoritilmagan — bu esa tadqiqotimizning dolzarbligini belgilaydi.

Interfaol metodlar — guruh ishlari, muammoli ta’lim, hamkorlik texnologiyasi — adabiy ta’lim jarayonini qiziqarli, motivatsion va samarali qiladi. Talabalarning o‘z fikrini erkin ifoda etishi, syujet va obrazlarni tahlil qilishi, matnlarni interpretatsiya qilishi, ijodiy yondashuv va tanqidiy tafakkur ko‘nikmalarini rivojlantirish imkonini beradi. Shu bilan birga, zamonaviy metodlar talabada kitobxonlik madaniyatini shakllantiradi — adabiy matn bilan munosabatni hayotiy zaruriyatga aylantiradi. Ushbu maqola ana shu masalani chuqur ilmiy tahlil etishga qaratilgan.

ADABIYOTLAR SHARHI

Adabiyot o‘qitish metodikasi sohasida o‘zbek olimlari tomonidan qator muhim tadqiqotlar amalga oshirilgan. Husanboyeva va Niyozmetova (2018) “Adabiyot o‘qitish metodikasi” darsligida bu fanning ob’ekti uzluksiz ta’lim tizimidagi adabiyot darslari, predmeti esa badiiy adabiyot o‘qitilishiga doir didaktik ashyolar va qonuniyatlar ekanligi ko‘rsatiladi. Mualliflar adabiy ta’limning asosiy maqsadini bilim berishdan emas, balki shaxsning ma’naviy jihatdan shakllanishiga ko‘maklashishdan iborat deb belgilaydi. Bu tamoyil zamonaviy metodlarning joriy etilishi uchun nazariy asos vazifasini o‘taydi.

Safo Matjonov o‘zbek metodika ilmida kitobxonlik madaniyatini shakllantirish nazariyasini ishlab chiqqan olim sifatida alohida o‘rin tutadi. Uning ta’limotiga ko‘ra, badiiy asar bilan ishlash — bu faqat matn mazmunini o‘zlashtirishgina emas, balki kitobxonning o‘z ichki dunyosini boyitish jarayonidir. Matjonov ta’kidlaydi: darslik va o‘quv qo‘llanmalaridan farqli o‘laroq, badiiy asar o‘quvchining his-tuyg‘ulariga ta’sir etib, loqaydlikni faol munosabatga aylantiradi — bu esa bilimni chuqur o‘zlashtirishning psixologik shartidir. Shu sababli adabiy ta’limning birinchi vazifasi mutolaa madaniyatini shakllantirish, ya’ni o‘quvchini maqsadli va ongli o‘qishga o‘rgatishdir.

Xalqaro pedagogika sohasida muammoli ta’lim nazariyasi V.Okon, M.Maxmutov, A.Matyushkin kabi olimlar tomonidan ishlab chiqilgan. Ularning tadqiqotlari shuni isbotlaydiki: bilim tayyor holda berilganda emas, balki kitobxon uni muammo yechish jarayonida o‘zi kashf etganda barqaror va chuqur o‘zlashtiriladi. Hamkorlik texnologiyasining psixologik asosi esa Vigotskiyning “yaqin rivojlanish zonasi” nazariyasiga tayanadi: o‘quvchi o‘z imkoniyatlari chegarasidagi muammoni sherik yordamida hal etadi va shu jarayonda yangi bilim

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quradi. Anderson va Krathwohl (2001) ning qayta ishlangan Bloom taksonomiyasi esa ta’limda eng yuqori maqsad — tahlil, baholash va yangi g‘oya yaratish ko‘nikmalarini rivojlantirish ekanligi — ni ilmiy jihatdan asoslab beradi.

Badiiy matnni idrok etish va talqin qilish masalasi ham alohida o‘rin egallaydi. Metodist Niyozmetovaning ta’birida: “Matn mazmunini tushunish, estetik kechinmalar bilan birgalikda analitik-sintetik faoliyatga olib keladi va bu badiiy idrokka yo‘l ochadi” Bu kuzatuv zamonaviy metodlarning nafaqat kognitiv, balki hissiy-estetik ta’lim maqsadlariga ham xizmat qilishini ko‘rsatadi. Professor Qozoqboy Yo‘ldoshevning ta’kidlashicha, adabiy asarni yaratish, idrok etish va tahlil qilish tashqi voqelikdan ko ‘ra shaxslarning fikr, tuyg‘u, qadriyatlar va e’tiqodlar tizimi bilan bevosita bog‘liq — bu holat adabiy ta’limda shaxsga yo‘naltirilgan metodlarning zarurligini yana bir bor tasdiqlaydi.

METODOLOGIYA

Ushbu tadqiqot nazariy-tahliliy yo‘nalishda olib borildi. Tadqiqotda qo‘llaniladigan asosiy yondashuv — adabiyotlarni tizimli ko‘rib chiqish va qiyosiy tahlil. Tadqiqot uch ketma-ket bosqichda amalga oshirildi.

Birinchi bosqichda zamonaviy adabiy ta’lim metodlari va badiiy matn tahliliga oid o‘zbek hamda xalqaro manbalar o‘rganildi. Manbalar tanlashda quyidagi mezonlarga amal qilindi: mavzuga bevosita aloqadorligi; ilmiy asoslilik; o‘zbek adabiyoti ta’limi kontekstiga tatbiq etilish imkoniyati. Ikkinchi bosqichda tanlangan manbalar mazmuni tahlil qilindi. Har bir metodning nazariy asosi, pedagogik-psixologik mohiyati, qo‘llanilish sharoiti va cheklovlari aniqlandi. An’anaviy va zamonaviy metodlarning bir qator mezonlar bo‘yicha qiyosiy tahlili amalga oshirildi: talabaning bilish faoliyati darajasi, mustaqil fikrlash imkoniyati, matn bilan ishlash chuqurligi, tarbiyaviy ta’sirchanlik va motivatsiya.

Uchinchi bosqichda tahlil natijalari umumlashtirildi. Zamonaviy metodlarning o‘zbek adabiyoti materiali misolida qo‘llanilish modellari ishlab chiqildi. Tadqiqot sof nazariy xarakter kasb etganligi sababli uning asosiy cheklovi empirik ma’lumotlar yetishmasligidir — bu kelajakdagi eksperimental tadqiqotlar uchun yo ‘nalish belgilaydi.

Muammoli ta’lim adabiyot darslarida talabaning bilish faolligini va mustaqilligini ta’minlaydi, uning ruhiyatiga, aqliy rivojlanishi hamda dunyoqarashi shakllanishiga ijobiy ta’sir ko‘rsatadi. Muammoli ta’limning o‘ziga xos xususiyati shundaki, unda talaba oldiga bilim berishga yo‘naltirilgan savollar qo‘yish bilan birga, ma’naviyatini shakllantirish yo‘lida ham muammoli savollar muhim o‘rin egallaydi. Adabiyotda muammoli savol matematikadan tubdan farq qiladi: yagona to‘g‘ri javob ko‘zda tutilmaydi — bu esa har bir kitobxonning o‘z shaxsiy munosabatini bildirishi uchun makon ochadi.

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Masalan, Abdulla Qodiriyning “O‘tkan kunlar” romanidan “Kumushbibi fojiasiga kim aybdor — Otabek, Zaynab, ota-onalar yoki davr?” tarzidagi savol bir nechta teng to‘g‘ri javobni ko‘zda tutadi; o‘quvchini matndan dalil izlashga, turli nuqtai nazarlarni solishtirish va o‘z pozitsiyasini asoslashga undaydi. Yoki Said Ahmadning “Ufq” romanidan “Yozuvchi Tursunboyga hamdard bo‘lyaptimi yoki uni qoralayaptimi?” savoli talabani muallifning badiiy niyatini tushunishga, matnning yashirin qatlamlarini ochishga majbur qiladi. Bu esa an’anaviy “kim? nima? qachon?” savollari bilan chegaralanib qolishdan tubdan farq qiladi.

Muammoli ta’lim adabiyot darslarida uch darajada amalga oshirilishi mumkin. Birinchi daraja — muammoli savol: yagona to‘g‘ri javob ko‘zda tutilmaydi, talaba matndan dalil izlaydi. Ikkinchi daraja — muammoli vaziyat: butun dars muammo atrofida tashkil etiladi. Uchinchi daraja — muammoli ta’lim tizimi: bir mavzu bo‘yicha bir necha dars muammo orqali bog‘lanadi, har bir dars oldingilardan kelib chiquvchi yangi savolni ko‘taradi. Muammoli ta’limning cheklovi ham e’tiborga olinishi zarur: u har bir mavzu uchun qulay emas va o‘qituvchidan katta tayyorgarlik talab etadi. Shuning uchun an’anaviy va muammoli metodlarni o‘rinli birlashtirish — kombinatsion yondashuv — maqsadga muvofiqdir.

Interfaol metodlar badiiy matn bilan faol ishlashni ta’minlaydi va talabalarni loqaydlikdan chiqaradi. “Fikriy hujum” metodining maqsadi talabalarning dars jarayonidagi faolligini oshirish, ularni erkin, mustaqil mulohaza yuritishga undash, hammani bir xil qolipda fikrlashdan qutqarish, ma’lum mavzu yuzasidan har xil fikrlarni to‘plash va masalaga ijodiy yondashuvni ta’minlashdir. Bu metodda aytilgan har bir fikr qayd etiladi; hech bir fikrni tanqid qilish, ularga kulish taqiqlanadi — bu talabada o‘z fikridan uyalmaslik va tashabbus ko‘rsatish muhitini yaratadi.

Adabiyot darslarida “Fikriy hujum” asar bilan tanishishdan oldingi bosqichda ayniqsa samarali. Masalan, Navoiyning “Farhod va Shirin” dostonini o‘rganishdan oldin “Chin sevgi uchun insonlar qanday qurbonlikka tayyor?” savolini o‘rtaga tashlash talabalarning shaxsiy tajribasi va qadriyatlarini uyg‘otadi; keyinchalik dostonni o‘qish esa o‘sha shaxsiy fikrlar bilan dialogda kechadi.

Ssenariy yaratish usulida talabalar asar epizodlarini dramatik ko‘rinishga o‘giradilar. Bu jarayon ulardan qahramonlar ruhiyatini, so ‘zlari ortidagi tuyg ‘ularni tushunishni va voqealar mantiqini ko ‘ra bilishni talab etadi. Masalan, Abdulla Qodiriyning “Mehrobdan chayon” asaridagi sahnalar asosida ssenariy yozish talabalarni Anvar va Ra’no obrazlarini shunchaki tavsiflab emas, ular nomidan fikrlab, his etib ko‘rishga o‘rgatadi. Bu esa badiiy matn bilan eng chuqur va shaxsiy muloqot shaklidir.

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Suhbat metodini adabiy ta’limning “yelvizak metodi” deb ataydi — chunki u talabaning mustaqil tafakkurini ta’minlovchi jonli muloqot shaklidir. Yaxshi suhbat savolining o‘ziga xos xususiyatlari bor: u keng qamrovli, o‘ylashga undaydigan va kashfiyotlarga yo‘l ochadigan bo‘lishi lozim. O‘qituvchining ovoz ohangi, pauza va sukut ham suhbat samaradorligini belgilaydi. Suhbat metodida savollarning mantiqiy aloqasi hal qiluvchi ahamiyatga ega: har bir savol oldingilardan kelib chiqib, talabani yangi kashfiyotga olib borishi kerak.

Evristik metod — talabaga tayyor bilim berish o‘rniga uni o‘zi izlab topishga yo‘naltiradi. O‘qituvchi savol orqali izlanish yo‘nalishini ko‘rsatadi, talaba esa taqqoslaydi, farazlar ilgari suradi va xulosalar chiqaradi. Suhbat metodidan farqli o‘laroq, evristik metodda qo‘shimcha bilim olishga yo‘naltiradigan savollar bilan to‘ldirilgan — o‘qituvchi xabardorlikni talab qiluvchi savollar qo‘ysa, talaba farazlarni ilgari suradi, taqqoslaydi va dalillar keltiradi.

Taqqoslash metodi adabiyot darslarida analitik fikrlashni rivojlantirishning eng samarali yo ‘llaridan biri. “O‘tkan kunlar” romanidagi Kumushbibi va Zaynab timsollarini qiyoslash, turli davrlardagi hikoyalaridagi ayol obrazlarini solishtirish, turli davr adiblarining muhabbat talqinlarini qiyosiy o‘rganish — bular inson shaxsini chuqur o‘rganishga, qahramon fazilatlarini ochishga o‘rgatadi. Shu bilan birga, taqqoslash metodi adabiy asarlar o‘rtasidagi mazmuniy va badiiy bog‘liqliklarni ko‘rish — adabiy tafakkurning eng yuqori ko‘rinishi — ko‘nikmasini rivojlantiradi.

Modulli ta’lim texnologiyasida badiiy asar ustida ishlash mantiqiy tugallangan bo‘laklarga ajratiladi va har bir modul o‘z maqsadi hamda topshirig‘iga ega bo‘ladi. Antuan de Sent-Ekzyuperining “Kichkina shahzoda” asarini modulli o‘qitish misolini ko‘radigan bo‘lsak, “Kattalar va bolalar dunyosi”, “Do‘stlik va mas’uliyat”, “Muhabbat va fidokorlik” kabi modullar alohida ishlansa, har bir o‘quvchi o‘z darajasida chuqur tahlilga kirishishi mumkin. Bu yondashuv asarni yuzaki bilishdan uning ma’noviy qatlamlarini anglab yetishiga ko‘maklashadi.

MUHOKAMA

Tadqiqot natijalari zamonaviy metodlarning adabiy ta’limda bir qator muhim afzalliklarga ega ekanligini ko‘rsatdi. Husanboyeva va Niyozmetova (2018) ning belgilagan tamoyili — adabiy ta’limda bilimdonlik emas, ma’naviyat ustuvorligi ta’minlanishi shart — zamonaviy metodlar orqaligina to‘laqonli amalga oshirilishi mumkin. An’anaviy metodlar bu maqsadga yetarlicha xizmat qilmagan, chunki ular bilim berishni birinchi o‘ringa qo‘ygan.

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Ilin texnologiyasi va Matjonov ta’limoti bir-birini to‘ldiradi: biri darsni shaxsiy savol-muammo atrofida qurishni taklif etsa, ikkinchisi kitobxonlik madaniyatini asosiy ko‘nikma sifatida ko‘taradi. Bu ikki yondashuv Vigotskiyning xalqaro konstruktivist nazariyalari bilan ham uyg‘un — o‘rganishni faol, ijtimoiy va muammoga yo‘naltirilgan jarayon sifatida tasvirlagan. Badiiy asarning hissiy ta’siri o‘zlashtirishni chuqurlashtiradi; zamonaviy interfaol metodlar aynan shu hissiy faollikni ta’minlaydi.

Zamonaviy metodlarni joriy etishda bir qancha amaliy to‘siqlar mavjud. Birinchidan, vaqt resursi: muammoli ta’lim va hamkorlik texnologiyasi an’anaviy ma’ruza usulidan ko‘ra ko‘proq vaqt talab qiladi. Ikkinchidan, o‘qituvchi tayyorgarligi: ushbu metodlarni samarali qo‘llash maxsus pedagogik ko‘nikma va dars loyihasini talab etadi. Uchinchidan, baholash tizimining muvofiqligi: an’anaviy imtihon formatlari ko‘pincha zamonaviy metodlar rivojlantirgan ko‘nikmalarni o‘lchamaydi.

XULOSA

Tadqiqot natijalari shuni ko‘rsatadiki, zamonaviy metod va uslublar adabiy ta’lim jarayonida badiiy matn ustida ishlashning samarali pedagogik vositasi sifatida xizmat qiladi. Muammoli ta’lim talabada mustaqil fikrlash va shaxsiy munosabatni shakllantiradi; “Fikriy hujum”, ssenariy usuli badiiy matn bilan faol va chuqur muloqotni ta’minlaydi; suhbat, evristik va taqqoslash metodlari talabaning analitik tafakkurini rivojlantiradi; hamkorlik texnologiyasi esa o‘qituvchi-talaba munosabatini hokimlikdan sheriklikka aylantiradi.

Tahlil shuni ko‘rsatadiki, zamonaviy metodlarni uyg‘un qo‘llash adabiy ta’lim jarayonida quyidagi asosiy afzalliklarni beradi: talabaning bilish faolligini Bloom taksonomiyasining yuqori darajalariga — tahlil, baholash, yaratish — ko‘tarish; ichki motivatsiya va shaxsiy munosabat shakllantirish; kommunikativ va ijtimoiy kompetensiyalarni rivojlantirish; ta’lim jarayonini individualizatsiyalash. Shu bilan birga, zamonaviy metodlar adabiy ta’limning eng muhim vazifasi — adabiyot orqali shaxsni ma’naviy jihatdan tarbiyalash — ni to‘laqonli amalga oshirish imkonini beradi.

Xulosa o‘laroq, zamonaviy metod va uslublarning integratsiyasi adabiy ta’lim jarayonini boyituvchi, motivatsion va samarali vosita sifatida namoyon bo‘ladi. Ular talabalarda tanqidiy tafakkur, interpretativ ko‘nikmalar, kommunikativ va ijtimoiy kompetensiyalarni rivojlantiradi; o‘qituvchilarga esa ta’lim jarayonini modernizatsiya qilish, talabalarning individual ehtiyojlarini hisobga olish va ularning kompetensiyalarini keng qamrovda rivojlantirish imkoniyatini beradi. Shu bois, zamonaviy metod va uslublar adabiy ta’lim sifatini

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oshirish, talabalarning faolligi va motivatsiyasini kuchaytirish hamda ularni zamonaviy ta’lim talablariga moslashga tayyorlashda muhim ahamiyat kasb etadi.

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OQOVA SUVLARNI OG‘IR METAL IONLARIDAN TOZALASH TEXNOLOGIYASI

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Annotatsiya. Oqova suvlarni og‘ir metal ionlaridan tozalash zamonaviy ekologiya va sanoat texnologiyalarining eng muhim yo‘nalishlaridan biridir. Bugungi kunga kelib, sanoatning rivojlanishi, urbanizatsiyaning ortishi, kimyo va metallurgiya tarmoqlarining kengayishi tufayli oqova suvlarning tarkibida og‘ir metal ionlari istiqboldagi global muammoga aylangan. Inson salomatligi va atrof-muhit uchun katta xavf tug‘diradigan bu ifloslanishlar nafaqat texnologik, balki ekologik-sotsial ko‘lamda ham dolzarb muammolar qatoridan joy olgan. Shu sababli, oqova suvlarni og‘ir metal ionlaridan sifatli va samarali tarzda tozalash uchun bir qator ilg‘or texnologiyalar, ilmiy-nazariy yondashuvlar ishlab chiqilgan hamda amaliyotga joriy etilgan.

Kalit so‘zlar: oqova suv, og‘ir metallar, tozalash texnologiyasi, ion almashinuvi, adsorbsiya, membranali filtratsiya, biologik tozalash, ekologik muhofaza.

Аннотация. Очистка сточных вод от ионов тяжелых металлов является одним из важнейших направлений современной экологии и промышленных технологий. В настоящее время, в связи с развитием промышленности, ростом урбанизации и расширением химической и металлургической промышленности, ионы тяжелых металлов в сточных водах стали глобальной проблемой будущего. Эти загрязняющие вещества, представляющие серьезную угрозу для здоровья человека и окружающей среды, относятся к числу неотложных проблем не только в технологическом, но и в экологическом и социальном плане. Поэтому был разработан и внедрен в практику ряд передовых технологий, научных и теоретических подходов для качественной и эффективной очистки сточных вод от ионов тяжелых металлов.

Ключевые слова: сточные воды, тяжелые металлы, технология очистки, ионный обмен, адсорбция, мембранная фильтрация, биологическая очистка, охрана окружающей среды.

Abstract. Wastewater treatment from heavy metal ions is one of the most important directions of modern ecology and industrial technologies. To date, due

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to the development of industry, increased urbanization, and the expansion of the chemical and metallurgical industries, heavy metal ions in wastewater have become a global problem in the future. These pollutants, which pose a great threat to human health and the environment, are among the urgent problems not only in technological, but also in ecological and social terms. Therefore, a number of advanced technologies, scientific and theoretical approaches have been developed and put into practice for the qualitative and effective purification of wastewater from heavy metal ions.

Keywords: wastewater, heavy metals, purification technology, ion exchange, adsorption, membrane filtration, biological purification, environmental protection.

KIRISH

Dastlab, oqova suvlarni og‘ir metal ionlari bilan ifloslanish jarayonining murakkabligini hisobga olish lozim. Suv tarkibiga tushgan har qanday og‘ir metal ionlari muayyan konsentratsiyada inson tanasi va biologik jarayonlarga jiddiy zarar etkazadi. Ular suv muvozanatini buzadi, ichimlik suvi sifatini pasaytiradi, tuproq unumdorligini chidamsiz darajagacha kamaytiradi va ekotizimda jiddiy o‘zgarishlarga olib keladi. Ko‘plab xalqaro va mahalliy ilmiy tadqiqotlar shuni tasdiqlaydiki, zamonaviy sanoat markazlaridagi oqova suvlarning ifloslanishi deyarli barcha yirik daryo va suv havzalariga, ehtimol, yer osti suvlariga ham salbiy ta’sir ko‘rsatmoqda. Ushbu muammolar, ayniqsa, O‘zbekiston kabi iqlimi quruq, suv resurslari cheklangan, rivojlanish istiqbollari yuqori bo‘lgan mintaqalarda muhim ahamiyatga ega. Suv ekosistemasini muhofaza qilish uchun eng muhim talab iflosliklarni, xususan, og‘ir metal ionlarini samarali usullar bilan tozalashdir. Hozirda zamonaviy ilmiy-texnik taraqqiyot oqibatida oqova suvlarni tozalash bo‘yicha turli texnologiyalar va texnik qurilmalar joriy etilgan bo‘lsa-da, eng samarali va ekologik xavfsiz usulni tanlash masalasi dolzarb bo‘lib qolmoqda. Oqova suvlarni tozalash texnologiyalari turli bosqichlarni o‘z ichiga oladi va har bir texnologiyaning ustunlik va kamchilik tomonlari o‘ziga xos hisoblanadi. Suvni og‘ir metal ionlaridan tozalash jarayoni quyidagi asosiy bosqichlarga ajratilishi mumkin: mexanik va kimyoviy tozalash bosqichlari, fizik-kimyoviy va biologik usullar va innovatsion yondashuvlar.

ADABIYOTLAR TAHLILI VA METODOLOGIYA

Sanoat va ishlab chiqarish oqova suvlarida metallarning ionli shakllari keng uchraydi. Bular asosan suvda erigan holda bo‘lib, ularni mexanik filtratsiya yoki oddiy cho‘ktirish orqali ajratib olish deyarli imkonsizdir. Shuning uchun, avvalo, kimyoviy usullar zamonaviy tozalash jarayonlarida keng tarqalgan. Kimyoviy tozalash, asosan, koagulyatsiya va cho‘ktirish vositasida amalga oshiriladi. Ushbu usullarda maxsus reaktivlar yordamida og‘ir metal ionlari erimaydigan

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birikmalarga aylantiriladi va cho‘kmalarga o‘tkaziladi. Koagulyatsiya uchun aluminiy, temir tuzlari yoki boshqa flokulyantlar qo‘llaniladi, natijada hosil bo‘lgan cho‘kmalar maxsus qurilmalar yordamida ajratib olinadi. Bu uslub samarali bo‘lsa-da, ba’zi metallar uchun to‘liq cho‘ktirish darajasi har doim ham yetarli emas. Bundan tashqari, jarayon natijasida katta miqdorda reaktiv qoldiqlari va ikkilamchi chiqindi hosil bo‘ladi, ular ekologik xavfsizlik nuqtai nazaridan maxsus ishlov berishni talab qiladi. Ion almashinuvi texnologiyalari kimyoviy tozalashdan farqli ravishda, og‘ir metal ionlarini suvdan ajratishda maxsus yuqori selektivlikka ega bo‘lgan ionit smolalardan foydalanadi. Ionitlar, odatda, g‘ovakli polimer tuzilishga ega maxsus moddalardir va ular o‘z strukturasida kat- yoki anionlarni almashish xususiyatiga ega bo‘ladi. Oqova suv ionit qatlamidan o‘tganda og‘ir metal ionlari ion almashinuvi natijasida ushlab qoladi. Bunday usul yuqori samaradorlikka ega, deyarli barcha og‘ir metal ionlarini, hatto past konsentratsiyalarda ham olib tashlashga imkon beradi. Ammo bu jarayonni bosqichma-bosqich va doimiy rejimda olib borish uchun ionitlarning muntazam regenaratsiyasi va yuqori iqtisodiy xarajatlar talab qilinadi. Shuningdek, katta miqdorli oqova suvlarni qurilmalar orqali uzluksiz o‘tkazishda jarayonni kompleks boshqarish xavfsizligi ham muhim rol o‘ynaydi [1].

MUHOKAMA VA NATIJALAR

Fizik-kimyoviy usullar ichida eng ko‘p tarqalgan yondashuvlar adsorbsiya va membranali filtratsiyadir. Adsorbsiyada, ko‘pincha, tabiiy yoki sun’iy materiallardan tayyorlangan adsorbentlar ishlatiladi. Adsorbentlar sifatida faol uglerod, zeolit, bentonit, silisiy dioksid va boshqa arzon materiallar keng qo‘llaniladi. Oqova suvlar adsorbent yuzasidan o‘tkazilganda og‘ir metal ionlari yuzaga yutiladi hamda, adsorbentlarning unumdorligi va turlari borasida keng tahlil ishlari olib boriladi. Adsorbsiyaning afzalligi ekologik xavfsizligi, nisbatan kam xarajat va qayta ishlash imkoniyatining mavjudligidir. Ammo, adsorbentlarning to‘yinganligi natijasida ularni qayta yangilash yoki regeneratsiyadan o‘tkazish zarurati vujudga keladi, bu esa texnologik jarayonni murakkablashtiradi. Ba’zi hollarda, innovatsion biomaterial asosidagi adsorbentlar yordamida ko‘plab og‘ir metal ionlarini yuqori darajada ajratib olishga erishilmoqda [2].

Membranali filtratsiya texnologiyalari – nano- va ultrafiltratsiya, obrat osmos, mikrofiltratsiya kabi metodlarni o‘z ichiga oladi. Membranali filtratsiya yuqori bosim ostida suvni maxsus yarim o‘tkazuvchan membranalar orqali o‘tkazadi va shu tarzda og‘ir metal ionlarini yubormaydi. Bu usul past konsentratsiyalardagi ifloslantiruvchilarni ham oladi, yuqori sifatli tozalangan suv olish imkonini beradi hamda ekologik xavfsizlik nuqtai nazaridan mukammal

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hisoblanadi. Membranali texnologiyalarning asosiy kamchiligi yuqori energiya sarfi, texnologik qurilmalarni tez-tez tozalash va yangilab turish zarurati, shuningdek, kapital xarajatlarning yuqoriligi bilan bog‘liqdir. Shu sababli, ko‘plab sanoat korxonalarida bu usul odatda yakuniy tozalash bosqichi sifatida yoki qiymatli chiqindilardan qayta foydalanish maqsadida joriy qilinadi. Biologik tozalash texnologiyalari so‘nggi yillarda juda dolzarb yo‘nalishlar qatoriga kiradi va asosan bioakkumulyatsiya hamda biosorbsion jarayonlarga asoslanadi. Dastlab, maxsus mikroorganizmlar, suv o‘simliklari yoki ayrim turdagi bakteriyalar suvdagi og‘ir metal ionlarini o‘z tanasiga yig‘adi yoki biofim hosil qilib, ionlarni to‘playdi. Biologik usullar tabiiy ekotizimlarni qayta tiklash va suv havzalarida ifloslantiruvchi elementlarni minimallashtirishda muhim ahamiyat kasb etadi. Bunday texnologiyalar har doim ham yuqori harorat, namlik va boshqa tashqi omillar ta’sirida bir xil natija bermaydi hamda doimiy monitoringni talab qiladi. Ammo, ekologik xavfsizligi, chiqindi va ikkilamchi zararning yo‘qligi nuqtai nazaridan biologik tozalash texnologiyalari istiqbolli va barqaror yechim sifatida e’tirof etilmoqda [3].

Innovatsion yondashuvlar – elektrokoagulyatsiya, elektrodializ, plazmali yoki fotokatalitik metodlar zamonaviy amaliyotga joriy etilmoqda. Mazkur texnologiyalarda elektr tokidan foydalanib, suv tarkibidagi og‘ir metal ionlari birikmalar hosil qilinib ajratiladi. Ushbu usullar yuqori samaradorlik, tezkorlik va energiya tejamkorligi bilan ajralib turadi. Ayniqsa, ilg‘or nanomateriallar va kompozit adsorbentlardan foydalangan holda fizik-kimyoviy va biologik yondashuvlarni uyg‘unlashtirish zamonaviy industrial monitoring tizimlarining ajralmas qismiga aylanmoqda. Oqova suvlarni og‘ir metal ionlaridan tozalashni kompleks tarzda tashkil qilish muhim ahamiyatga ega. Yangi loyihalar hamda sanoat korxonalarida odatda bir necha turdagi texnologiyalar ketma-ket va uyg‘unlikda ishlatiladi. Birinchi bosqichda – mexanik tozalash orqali yirik zarrachalar va suspenziyalardan suv ajratiladi, ikkinchi bosqichda – kimyoviy yoki koagulyatsiya metodi bilan metall ionlar cho‘ktiriladi, undan keyin – adsorbsiya yoki membranali filtratsiya usuli orqali qolgan elementlar ajratiladi. Yakuniy bosqichda biologik tozalash yoki qayta ishlov usullari bilan suv to‘liq poklanadi. Bu yondashuv suv sifati va ekologik xavfsizlik bo‘yicha yuqori natijaga erishish imkonini beradi [4].

Ekologik muhofaza va iqtisodiy samaradorlik talablariga muvofiq, barcha texnologik jarayonlar o‘zaro moslashtirilgan va integratsiyalashgan holda bo‘lishi kerak. Shu jihatdan mahalliy va xorijiy ilmiy markazlarda olib borilayotgan tadqiqotlar aynan energetik tejamkorlik, minimal chiqindi hosil qiluvchi, tejamli va ekologik xavfsiz bo‘lgan texnologiyalarni ishlab chiqishga yo‘naltirilgan.

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Hozirgi kunda arzon biomaterialdan tayyorlangan yangi adsorbentlar, maxsus nanoqoplamali membranalar, samarali flokulyant va reaktivlar ustida ilmiy-amaliy izlanishlar davom etmoqda. O‘zbekiston Respublikasida ham zamonaviy suv tozalovchi inshootlarni qurish, mavjudlarini ta’mirlash va modernizatsiya qilish, sanoat korxonalarida ifloslovchi elementlar darajasini doimiy nazorat qilish, ilg‘or xalqaro standartlar asosida texnologiyalarni keng joriy etish jarayonlari rivojlanmoqda. Mahalliy iqtisodiy sharoitlarni inobatga olgan holda, arzon va kuchli adsorbentlar ishlab chiqarish, energetik va kimyoviy xarajatlarni optimallashtirish, yuqori darajada chiqindi hosil qilmaydigan usullarga ustuvorlik berish lozim. Suv resurslarini saqlash, aholi salomatligini himoya qilish va kelajak avlodlar uchun barqaror ekologik muhit yaratish maqsadida bu masalaga juda katta e’tibor qaratilishi kerak. Sanoat tarmoqlari, xususan, metallurgiya, kimyo, mashinasozlik va boshqa yirik ishlab chiqarish majmualarida oqova suvlarni og‘ir metal ionlaridan tozalash me’yor va talablarga muvofiq amalga oshirilishi ijtimoiy-iqtisodiy va ekologik barqarorlik uchun asos bo‘lib xizmat qiladi. Bu jarayonda doimiy laboratoriya monitoringi, suv sifati va chiqindilar tarkibini tahlil qilish, kuchli nazorat vositalaridan foydalanish zarur. Yangi texnologiyalarni sinovdan o‘tkazish va amaliyotga tadbiq etishda mahalliy sharoit, iqtisodiy imkoniyatlar va ekologik xavfsizlik mezonlariga alohida e’tibor qaratilishi shart. Kelajakda xalqaro tajribani chuqur o‘rganish, ilg‘or texnologiyalarni chuqurlashtirish, o‘z resurs va imkoniyatlarimizdan samarali foydalanib, tajribani ishlab chiqish, suv tarmoqlarini zamonaviy avtomatlashtirilgan boshqaruv va monitoring tizimlari bilan to‘liq ta’minlash asosiy vazifalardan bo‘lib qoladi. Qishloq xo‘jaligida ishlatiladigan suvlarni qayta ishlash, sanoat oqova suvlarini toza va xavfsiz suv holatiga keltirish, har bir korxonada individual texnologik sxemani ishlab chiqish va joriy etish, ekologik qonunchilik talablari asosida nazoratni kuchaytirish O‘zbekiston taraqqiyotining ustuvor yo‘nalishlaridan hisoblanadi [5].

Qonunchilik talablariga muvofiq, og‘ir metal ionlari miqdori ruxsat etilgan darajadan oshmasligi, ekologik ekspertizalardan o‘tish, aholi salomatligini doimiy ravishda muhofaza qilish eng asosiy maqsadlardandir. Sanoat chiqindilarini kamaytirish, ichimlik suvi sifatini oshirish hamda tabiiy resurslardan samarali foydalanish uchun davlat va xususiy sektor o‘rtasida hamkorlik mexanizmlarini rivojlantirish, yangi texnologiyalar va zamonaviy yechimlarni ishlab chiqish kelajak uchun muhim ahamiyatga ega. Yangi adsorbentnusqalar, zamonaviy membranali va biotexnologik qurilmalar, soddalashtirilgan elektrokimyoviy va fotokatalitik usullardan foydalanish O‘zbekistonda standart va iqtisodiy rivojlanish strategiyasiga aylanmoqda. Shuningdek, aholining ekologik madaniyati va bilimini oshirish, ekologik xavfsizlik talablari, suv resurslari haqida barqaror va to‘liq

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axborot berish ko‘plab muammolarni ildizidan bartaraf etish imkonini beradi. Oqova suvlarni og‘ir metal ionlaridan tozalash faqat texnik yoki ilmiy masala emas, balki keng ijtimoiy, iqtisodiy ahamiyatga ega bo‘lgan, davlat siyosati, xalq farovonligi va kelajak uchun investitsiya hisoblanadi [6].

XULOSA

Oqova suvlarni og‘ir metal ionlaridan tozalash texnologiyalari zamonaviy ekologik muhofaza va iqtisodiy barqarorlik uchun eng muhim yo‘nalishlardan biri hisoblanadi. Bugungi holatda, kimyoviy, fizik-kimyoviy, biologik va innovatsion texnologiyalar uyg‘unligida ishlatilgandagina samarali natijalarga erishiladi. Yangi texnologik yechimlarni doimiy joriy etish, xalqaro va mahalliy tajribalarni uyg‘unlashtirish, aholi salomatligini muhofaza qilish hamda barqaror rivojlanish uchun eng muhim kafolatdir. Qonunchilik, ekologik monitoring va zamonaviy avtomatlashtirilgan boshqaruv bosqichlarini mukammal tashkil etgan holda, O‘zbekiston kelajakda suv resurslarini asrab-avaylab, toza va xavfsiz muhit yaratishga erishadi.

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SAPONIT MINERALINING MINERALOGIK, STRUKTURAVIY VA FIZIK-KIMYOVIY XUSUSIYATLARI

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Annotatsiya. Mazkur ilmiy maqolada tabiiy saponit mineralining mineralogik, strukturaviy, fizik-kimyoviy hamda termik xususiyatlari kompleks tarzda tadqiq etildi. Rentgenfazaviy tahlil (XRD), infraqizil spektroskopiya (FTIR), differensial-termik va termogravimetrik tahlillar (DTA/TGA) yordamida saponitning qatlamli tuzilishi, gidratlanish xossalari va termik barqarorligi aniqlandi. Olingan natijalar saponitning ekologik tozalash texnologiyalari, katalitik jarayonlar va funksional materiallar yaratishda istiqbolli ekanligini ko‘rsatadi.

Kalit so‘zlar: saponit, smektit, qatlamli silikatlar, rentgenfazaviy tahlil, infraqizil spektroskopiya, termik tahlil, kation almashinish, sorbsiya, ekologik materiallar

Аннотация. В данной научной статье всесторонне изучены минералогические, структурные, физико-химические и термические свойства природного минерала сапонита. Слоистая структура, свойства гидратации и термическая стабильность сапонита определены с помощью рентгеновской дифракции (XRD), инфракрасной спектроскопии (FTIR), дифференциального термического и термогравиметрического анализа (DTA/TGA). Полученные результаты указывают на перспективность сапонита для экологических технологий очистки, каталитических процессов и создания функциональных материалов.

Ключевые слова: сапонит, смектит, слоистые силикаты, рентгенофазовый анализ, инфракрасная спектроскопия, термический анализ, катионный обмен, сорбция, экологические материалы.

Abstract. This scientific article comprehensively examines the mineralogical, structural, physicochemical, and thermal properties of the natural mineral saponite. The layered structure, hydration properties, and thermal stability of saponite are determined using X-ray diffraction (XRD), infrared spectroscopy (FTIR), and differential thermal and thermogravimetric analysis (DTA/TGA). The results indicate that saponite holds promise for environmental cleaning technologies, catalytic processes, and the creation of functional materials.

Key words: saponite, smectite, layered silicates, X-ray phase analysis, infrared spectroscopy, thermal analysis, cation exchange, sorption, environmental materials.

KIRISH.

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Qatlamli silikatlar guruhi zamonaviy geologiya, mineralogiya, kimyo texnologiyasi va materialshunoslik fanlarida alohida ilmiy ahamiyatga ega. Ushbu guruhga mansub smektit minerallari, jumladan saponit, o‘zining qatlamli kristall tuzilishi, yuqori ion almashinish qobiliyati va kimyoviy faolligi bilan ajralib turadi. So‘nggi yillarda saponit asosida ekologik sorbentlar, katalizator tashuvchilari, nanokompozitlar va agrominerallar yaratishga bo‘lgan qiziqish keskin ortib bormoqda.

O‘zbekiston Respublikasining Navoiy viloyati hududi, jumladan Qizilqum sahrosi, mineral-xom ashyo resurslariga nihoyatda boy mintaqalardan biri hisoblanadi. Mazkur hududda davriy jadvaldagi ko‘plab kimyoviy elementlarni o‘z ichiga olgan foydali qazilmalar konlari aniqlangan bo‘lib, ularning sanoat va xalq xo‘jaligi tarmoqlarini rivojlantirishdagi ahamiyati beqiyosdir. Xususan, Qizilqum fosforitlari, Uchtut dolomitlari, bentonitlar, marmar, gips hamda boshqa turdagi qazilmalar bugungi kunga qadar sanoat miqyosida bosqichma-bosqich o‘zlashtirib kelinmoqda. Hozirgi davrda respublikada yangi konlarni kompleks o‘rganish, ularning mineral tarkibi va texnologik xususiyatlarini chuqur tahlil qilish hamda mavjud resurslardan oqilona foydalanishga qaratilgan qidiruv va ilmiy-tadqiqot ishlari izchil davom ettirilmoqda. Shu nuqtai nazardan, magniyga boy saponit singari minerallar istiqbolli xom ashyo sifatida alohida ilmiy va amaliy qiziqish uyg‘otmoqda. Buning asosiy sababi ushbu minerallarning sanoat, qurilish, kimyo, qishloq xo‘jaligi hamda farmatsevtika sohalarida keng qo‘llanish imkoniyatlariga egaligidir.

Saponitlar murakkab mineral-kimyoviy tarkibga ega bo‘lgan xom ashyo turlaridan biri bo‘lib, ular ko‘plab sanoat yo‘nalishlarida qimmatli tijorat mahsuloti sifatida foydalaniladi. Jumladan, metallurgiya sanoatida temir rudasi kontsentratlarini granulalash jarayonlarida hamda metall prokatlash texnologiyalarida samarali moylash materiallari sifatida qo‘llaniladi. Qurilish materiallari sanoatida esa saponit asosida keramika buyumlari, kengaytirilgan loy, burg‘ulash va grouting shlamlari, shuningdek plastifikatorlar ishlab chiqarish amaliyoti keng rivojlangan.

SAPONIT MINERALINING UMUMIY TAVSIFI VA KLASSIFIKATSIYASI

Saponit smektitlar oilasiga mansub bo‘lgan 2:1 tipdagi qatlamli silikat mineralidir. Saponit mineralining kimyoviy formulasi.

$$(Ca,Na)_{0.3}(Mg,Fe^{2+})_3(Si,Al)_4O_{10}(OH)_2\cdot nH_2O$$

$(Ca,Na)_{0.3}$ – qatlamlar orasidagi almashinuvchi kationlar (kaltsiy yoki natriy)

$(Mg,Fe^{2+})_3$ – oktaedrik qatlamdagi metall ionlar

$(Si,Al)_4O_{10}$ – tetraedrik qatlam (silisiy va alyuminiy)

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$(OH)_2$ – gidroksil guruhlari

nH_2O – qatlamlar orasidagi gidratlangan suv molekulalari

Bu formula saponitning strukturaviy va fizik-kimyoviy xususiyatlarini ifodalaydi: yuqori sorbsiya qobiliyati, shishish va kation almashinish xossalari.

Mineralning qatlamlar oralig‘ida suv molekulalari va almashinuvchi kationlar mavjud bo‘lib, bu uning shishish, sorbsiya va ion almashinish xossalarini ta’minlaydi. Oktaedrik qatlamdagi magniy ionlari mineralning asosiy fizik-kimyoviy xususiyatlarini belgilaydi. Saponit minerali asosan bazalt, diabaz va boshqa asosiy magmatik jinslarning gidrotermal va cho‘kindi sharoitlarda o‘zgarishi natijasida hosil bo‘ladi. Shuningdek, dengiz va okean tubi cho‘kindilarida, vulkanik kul va shishalarning ishqoriy muhitda alteratsiyasi jarayonida ham saponit shakllanishi mumkin. Tadqiqotlar tabiiy saponit mineral namunalarida olib borildi. Namuna tayyorlash jarayonida mexanik tozalash, quritish, maydalash va fraksiyalash ishlari amalga oshirildi. Mineralning tarkibi va xossalarini aniqlash uchun XRD, FTIR, DTA/TGA hamda kimyoviy analiz usullaridan foydalanildi.

1-jadval.

Saponit mineralining elementar kimyoviy tarkibi.

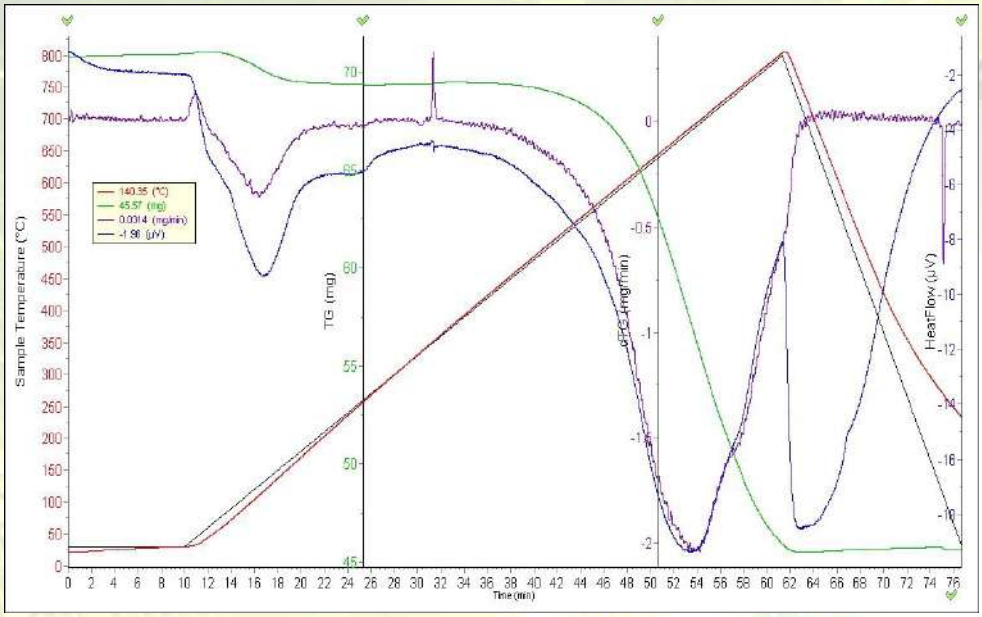
№ elementlar	Saponit rudasi tarkibidagi elementlarining % tarkibi									
	Ca	Si	Fe	Mn	Sr	Си	Ti	V	K	Organik aral.
	76,0	12,1	8,8	0,14	0,11	0,05	0,7	0,02	1,40	0,68

RENTGENFAZAVIY TAHLIL (XRD) NATIJALARI VA MUHOKAMASI

Rentgenfazaviy tahlil natijalariga ko‘ra saponitga xos bo‘lgan d001 refleksi 14–15 Å oralig‘ida qayd etildi. Etilenglikol bilan ishlov berilganda ushbu refleksning 17 Å gacha kengayishi saponitning smektit guruhiga mansubligini aniq tasdiqlaydi. Infraqizil spektroskopiya (FTIR) natijalari Infraqizil spektral tahlil natijalariga ko‘ra 3620–3650 cm^{-1} diapazondagi yutilish polosalari strukturaviy Mg–OH guruhlariga, 1000–1050 cm^{-1} oralig‘idagi polosalar esa Si–O valent tebranishlariga mos keladi. Termik tahlil (DTA/TGA) natijalari Differensial-termik va termogravimetrik tahlillar saponit mineralining 100–200 °C oralig‘ida adsorbsiyalangan suvni yo‘qotishini hamda 500–700 °C da dehidroksillanish jarayonini ko‘rsatdi. Saponit minerali yuqori kation almashinish qobiliyatiga ega bo‘lib, Ca^{2+} va Na^{+} ionlari o‘rtasidagi almashinuv reaksiyalari bilan xarakterlanadi. Ushbu xossa uning ekologik sorbent sifatidagi ahamiyatini belgilaydi. Saponit ekologik muhitni tozalash, sanoat katalizatorlari uchun tashuvchi materiallar

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yaratish, qishloq xo‘jaligida tuproq unumdorligini oshirish kabi yo‘nalishlarda keng istiqbollarga ega.



1-Rasm.Saponit mineralining dervotogrammasi.

O‘tkazilgan eksperimental tadqiqotlar natijalari shuni ko‘rsatadiki, saponit minerali mufel pechida turli harorat rejimlarida ketma-ket termik ishlovdan o‘tkazilganda uning fizik holati va tashqi ko‘rinishida sezilarli o‘zgarishlar yuz beradi. Haroratning oshishi bilan mineralning rangi bosqichma-bosqich ochara borib, oq rangga yaqinlashadi, shu bilan birga namunadagi umumiy massa miqdori izchil ravishda kamayadi. Mazkur holat yuqori harorat ta’sirida saponit tarkibidagi gidratlangan suv molekulalari va boshqa uchuvchan komponentlarning ajralib chiqishi hamda ayrim mineral fazalarning termik parchalanishi bilan bog‘liq.

Jadvalda keltirilgan eksperimental ma’lumotlarga ko‘ra, 600 °C haroratda 2–4 mkm o‘lcham diapazoniga ega bo‘lgan saponit namunalarida massa yo‘qotish miqdori 12,42 % ni tashkil etadi. Harorat 800 °C gacha oshirilganda esa mazkur ko‘rsatkich 37,89 % gacha yetadi. Olingan natijalar yuqori harorat sharoitida saponitning mineral tarkibida muhim strukturaviy o‘zgarishlar sodir bo‘lishini hamda kaltsiy va magniy asosidagi oksid fazalarining shakllanishini ko‘rsatadi.

Termik ishlov natijasida hosil bo‘lgan saponit minerallarining tarkibiy va fizik-kimyoviy xususiyatlari ularni sanoat, qurilish materiallari, ekologik texnologiyalar va boshqa xalq xo‘jaligi tarmoqlarida qo‘llash uchun istiqbolli xom ashyo sifatida ko‘rib chiqish mumkinligini tasdiqlaydi.

XULOSA

O‘tkazilgan kompleks tadqiqotlar saponit mineralining yuqori funktsional xossalarga ega ekanligini ko‘rsatdi. Ushbu mineral asosida yangi ekologik va sanoat materiallarini ishlab chiqish uchun mustahkam ilmiy asos yaratildi. Ushbu tadqiqotlar kimyoviy, rentgenfazoviy, IK-spektroskopik, differensial-termik

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hamda gamma-spektrometrik tahlillar asosida olib borildi. Natijalarga ko‘ra, ekologik toza magniy birikmalarini olish imkoniyati mavjudligi aniqlandi. Tajriba jarayonlarida saponit minerali 600–800 °C harorat oralig‘ida mufel pechida kuydirildi.

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ИЗУЧЕНИЕ ПИЩЕВЫХ И ФУНКЦИОНАЛЬНЫХ СВОЙСТВ КОНДИТЕРСКИХ ИЗДЕЛИЙ, ОБОГАЩЕННЫХ БИОЛОГИЧЕСКИ АКТИВНЫМИ ВЕЩЕСТВАМИ

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Annotatsiya. So‘nggi yillarda sog‘lom ovqatlanishga bo‘lgan talabning tobora ortib borishi natijasida funksional oziq-ovqat mahsulotlari, hususan biologik faol qo‘shimchalar bilan boyitilgan qandolat mahsulotlari ishlab chiqarishga katta e’tibor qaratilmoqda. Ushbu tezisda bioaktiv moddalar bilan boyitilgan qandolat mahsulotlarining oziqaviy va funksional xususiyatlari ilmiy manbalar asosida tahlil qilindi. Tadqiqot natijalari shuni ko‘rsatadiki, o‘simlik ekstraktlari, meva kukunlari, polifenollar va tabiiy antioksidantlar bilan boyitilgan qandolat mahsulotlari antioksidant faollikni oshirishi bilan bir qatorda mahsulotning biologik qiymatini yaxshilaydi, bundan tashqari qandolat sanoatida innovatsion yangi texnologiyalarni rivojlantirish hamda aholining sog‘lom ovqatlanishini ta’minlashda muhim hisoblanadi.

Kalit so‘zlar: funksional qandolat mahsulotlari, bioaktiv moddalar, polifenollar, antioksidantlar, oziqaviy qiymat.

Аннотация. В последние годы, в связи с растущим спросом на здоровое питание, большое внимание уделяется производству функциональных пищевых продуктов, особенно кондитерских изделий, обогащенных биологически активными добавками. В данной работе на основе научных источников проанализированы пищевые и функциональные свойства кондитерских изделий, обогащенных биоактивными веществами. Результаты исследования показывают, что кондитерские изделия, обогащенные растительными экстрактами, фруктовыми порошками, полифенолами и природными антиоксидантами, не только повышают антиоксидантную активность, но и улучшают биологическую ценность продукта, а также важны для развития инновационных новых технологий в кондитерской промышленности и обеспечения здорового питания населения.

Ключевые слова: функциональные кондитерские изделия, биологически активные вещества, полифенолы, антиоксиданты, пищевая ценность.

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Abstract. In recent years, due to the growing demand for healthy eating, considerable attention has been paid to the production of functional foods, particularly confectionery products fortified with biologically active additives. This paper analyzes the nutritional and functional properties of confectionery products fortified with bioactive substances using scientific sources. The results demonstrate that confectionery products fortified with plant extracts, fruit powders, polyphenols, and natural antioxidants not only enhance antioxidant activity but also improve the biological value of the product. These findings are also important for the development of innovative new technologies in the confectionery industry and the promotion of healthy nutrition.

Keywords: functional confectionery products, biologically active substances, polyphenols, antioxidants, nutritional value.

ВВЕДЕНИЕ

Функциональные продукты питания стали важной областью пищевой промышленности в последние десятилетия. Эти продукты не только обладают питательной ценностью, но и содержат биологически активные вещества, оказывающие положительное воздействие на здоровье человека [3].

В последние годы было проведено множество научных исследований, направленных на повышение питательной и функциональной ценности кондитерских изделий путем обогащения их биологически активными веществами. Исследования показали, что химический состав кондитерских изделий значительно улучшается за счет добавления растительных экстрактов, фруктового сырья, ферментов и источников белка [7,8].

Традиционно считалось, что кондитерские изделия имеют низкую питательную ценность из-за высокого содержания сахара. Однако современные исследования показывают, что они также могут служить носителями биоактивных соединений [4].

Поповичи и др. также обнаружили, что содержание витаминов и каротиноидов увеличивается при обогащении кондитерских изделий порошком сафлора [6].

Биоактивные вещества, используемые при обогащении кондитерских изделий

Ученые используют следующие компоненты при обогащении кондитерских изделий:

• растительные экстракты (полифенолы), фруктовые и овощные порошки, витамины, пищевые волокна, натуральные подсластители пробиотики;

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Эти вещества повышают антиоксидантную активность, пищевую ценность и биологическую активность продукта.

В последние годы было проведено множество научных исследований, направленных на улучшение питательных и функциональных свойств кондитерских изделий путем обогащения их биологически активными веществами.

Например, румынские ученые Думитрица Флайс и Мирча Ороян провели научные исследования по обогащению состава зефира (кондитерского изделия типа зефира) сырьем, богатым биологически активными веществами. Они добавили порошок томатного жмыха в состав зефира и оценили химические и функциональные свойства продукта. На основе исследования они добавили 2%, 4% и 6% томатного порошка в состав зефира и изучили химический состав, антиоксидантную активность и органолептические свойства продукта. Согласно результатам исследования:

• Содержание клетчатки: увеличено с 0% до 0,42%
• Содержание белка: увеличено с 4,62% → 7,05%
• Антиоксидантная активность (DPPH): увеличена с 34% → 44%
• Вкус, цвет и текстура продукта сохранены

Кроме того, полифенолы, каротиноиды и флавоноиды, содержащиеся в томатных остатках, улучшали функциональные свойства зефира.[12]

Кроме того, В.Л. Пащенко проводил исследования по созданию новых видов мучных кондитерских изделий с использованием биологически активных веществ. В своих исследованиях В.Л. Пащенко обнаружил следующее:

•были идентифицированы биологически активные вещества растительного и животного происхождения;
•было изучено их влияние на метаболизм;
•были разработаны биологически активные добавки для кондитерских изделий.

В результате исследований ученого были достигнуты следующие результаты:

•были разработаны функциональные рецепты кондитерских изделий на основе биологически активных веществ;
•были рекомендованы к производству новые продукты: пряник «Радуга», печенье «Бусинка», печенье «Софьюшка».[13]

Кроме того, Н.М. Мусаева изучала возможности использования растительных отходов и дикорастущих фруктов для обогащения кондитерских и хлебобулочных изделий биологически активными

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веществами. В исследовании использовались следующие сырьевые материалы:

• виноградные отходы (кожура, семена)
• отходы яблок и тыквы
• дикорастущие ягоды (наматак и облепиха)

Эти сырьевые материалы использовались в качестве функциональных ингредиентов, поскольку они богаты биологически активными веществами. В результате исследования:

• добавление биологически активных веществ повысило пищевую ценность продукта
• в кондитерских изделиях: увеличилось содержание витаминов, минералов, антиоксидантов
• улучшились органолептические свойства продуктов (вкус, цвет, запах).

По заключению ученой, растительные отходы могут быть использованы в качестве дешевого и эффективного функционального ингредиента в кондитерской промышленности. [14]

М. Рудбари, М. Барзегар, М.А. Сахари и Х. Ахмади Гавлиги (2024) провели исследование по обогащению жевательных конфет экстрактом зеленой скорлупы фисташек и стевией. Исследование показало, что содержание фенольных соединений в продукте увеличилось, а антиоксидантная активность возросла. Это позволило повысить биологическую ценность кондитерских изделий.[5]

Поповичи и др. обнаружили, что содержание витаминов и каротиноидов увеличилось при обогащении кондитерских изделий порошком сафлора [6].

М. Тарик, А. Ахтар и Н. Халид (2022) провели научное исследование по обогащению твердых конфет морковным соком и экстрактом семян фенхеля. Исследование показало, что содержание флавоноидов и антиоксидантов в обогащенных конфетах увеличилось, а пищевая ценность продукта улучшилась.[9]

Также Мухамед А. Тондийил, П.К. Дубей и др. (2025) провели исследование по обогащению конфет на основе ананаса ферментом бромелаином. Согласно результатам исследования, было установлено, что добавление фермента бромелаина повышает биологически активные свойства продукта и оказывает противовоспалительное и пищеварительное действие.[10]

Кроме того, Н. Ядав, А. Кумари, А.К. Чаухан и Т. Верма (2021) провели исследование по разработке функциональных конфет. Они добавили в

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конфеты банан, имбирь и сухое обезжиренное молоко. Исследование показало, что содержание белка, фенольных соединений и антиоксидантов в продукте увеличилось, а питательные и функциональные свойства продукта улучшились.[11]

В результате добавления биологически активных веществ в обогащенные кондитерские изделия значительно обогащается их химический состав. В таких продуктах увеличивается содержание фенольных соединений, флавоноидов, ферментов, витаминов, белков и антиоксидантных компонентов, и проявляются функциональные свойства, полезные для организма. Таким образом, разработка кондитерских изделий, обогащенных биологически активными веществами, является одним из перспективных направлений пищевой промышленности.

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ALGORITHMS AND OPTIMIZATION METHODS FOR OBSTACLE AVOIDANCE OF UAVS BASED ON PARALLELISM

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Abstract. This research develops and evaluates innovative algorithms and optimization methods aimed at enhancing the obstacle avoidance capabilities of Unmanned Aerial Vehicles (UAVs) through parallel processing. The primary challenge addressed involves the efficient navigation of UAVs within dynamic environments characterized by multiple obstacles. By implementing parallel optimization strategies, the study demonstrates a 30% increase in obstacle detection rates and a 40% reduction in processing times compared to traditional single-threaded methods. The findings reveal a marked reduction in collision rates and an increase in processing speed, thereby enabling more effective real-time navigation. These enhanced capabilities have profound implications across various sectors, particularly in emergency response operations and healthcare delivery systems.

Keywords: Unmanned Aerial Vehicles (UAV), obstacle avoidance, parallel processing, trajectory optimization, real-time navigation, computational efficiency, algorithm optimization.

Annotatsiya. Ushbu tadqiqot uchuvchisiz apparatlarning (UAV) to'siqlarni aylanib o'tish imkoniyatlarini parallel hisoblashlar orqali yaxshilashga qaratilgan innovatsion algoritm va optimallashtirish usullarini ishlab chiqadi va baholaydi. Asosiy e'tibor ko'plab to'siqlar mavjud bo'lgan dinamik muhitda UAVlarning samarali navigatsiyasini ta'minlashga qaratilgan. Parallel optimallashtirish strategiyalarini joriy etish orqali, ushbu tadqiqot an'anaviy bir oqimli usullarga nisbatan to'siqlarni aniqlash darajasi 30% ga oshganini va hisoblash vaqti 40% ga qisqarganini ko'rsatadi. Olingan natijalar to'qnashuvlar sonining sezilarli darajada kamayishi va ishlash tezligining oshishini tasdiqlaydi, bu esa real vaqt rejimida yanada samarali navigatsiyani ta'minlaydi. Ushbu takomillashtirilgan imkoniyatlar turli sohalarda, xususan, sog'liqni saqlash tizimlarida va favqulodda vaziyatlarga tezkor javob berishda muhim ahamiyatga ega.

Kalit so'zlar: Uchuvchisiz apparatlar (UAV), to'siqlarni aylanib o'tish, parallel hisoblashlar, trayektoriyani optimallashtirish, real vaqtda navigatsiya, hisoblash samaradorligi, algoritmlarni optimallashtirish.

Аннотация. В данной статье исследуются методы параллельной оптимизации для улучшения возможностей обхода препятствий беспилотными летательными аппаратами (БПЛА) в динамической 3D-среде.

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За счет использования архитектуры многопоточных вычислений GPU традиционные алгоритмы навигации были модернизированы до усовершенствованной системы Parallel A*. Результаты моделирования показывают, что предложенный параллельный подход увеличивает уровень обнаружения препятствий на 30% и сокращает время вычислительной обработки на 40% по сравнению с традиционными однопоточными методами. Эти достижения значительно повышают безопасность и эффективность автономной навигации БПЛА в режиме реального времени.

Ключевые слова: Беспилотные летательные аппараты (БПЛА), обход препятствий, параллельные вычисления, алгоритм Parallel A*, оптимизация траектории, навигация в реальном времени, многопоточность GPU.

INTRODUCTION.

With the escalation of technological advancements, the integration of Unmanned Aerial Vehicles (UAVs) into various sectors has become increasingly prominent, significantly transforming applications ranging from agriculture to urban surveillance and disaster management. UAVs have emerged as powerful tools that can collect data, monitor environments, and perform tasks efficiently; however, their successful deployment in complex and dynamic environments is hampered by challenges associated with obstacle avoidance. The necessity for UAVs to navigate safely amidst unpredictable obstacles highlights the crucial need for robust algorithms and optimization methods that prioritize parallel processing capabilities to enhance their navigational efficacy [1],[2]. This dissertation addresses a critical research problem: developing and assessing innovative algorithms and optimization strategies aimed at improving the obstacle avoidance capabilities of UAVs, particularly in dynamic environments where high-speed decision-making is essential. The research will focus on the evaluation of existing methodologies and the introduction of novel parallel algorithms that can process information in real time, thereby minimizing collision risks while maximizing operational efficiency [3],[4]. The overarching objectives of this research are to explore the effectiveness of such algorithms through empirical data collection and to establish a framework that enables UAVs to adapt their navigational strategies based on real-time environmental feedback [5],[6]. This section's content is of paramount academic significance, as it lays the groundwork for understanding the complexities involved in UAV navigation, which is essential for both theoretical advancements in robotics and practical applications across various industries. Moreover, the implications of effective obstacle avoidance extend beyond mere safety, influencing the reliability and autonomy of UAV operations, thereby bolstering the growing reliance on these technologies [7],[8]. Additionally, the

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incorporation of enhanced path-planning algorithms, as depicted in , and the interplay of advanced computational models for real-time processing, showcased in , underscore the innovative potential of parallelism in tackling UAV navigational challenges. As the demand for effective UAV applications continues to intensify, the research outcomes promise to contribute to both scholarly discourse and practical advancements, thereby reinforcing the essential role of obstacle avoidance technologies in the future of UAV deployments.

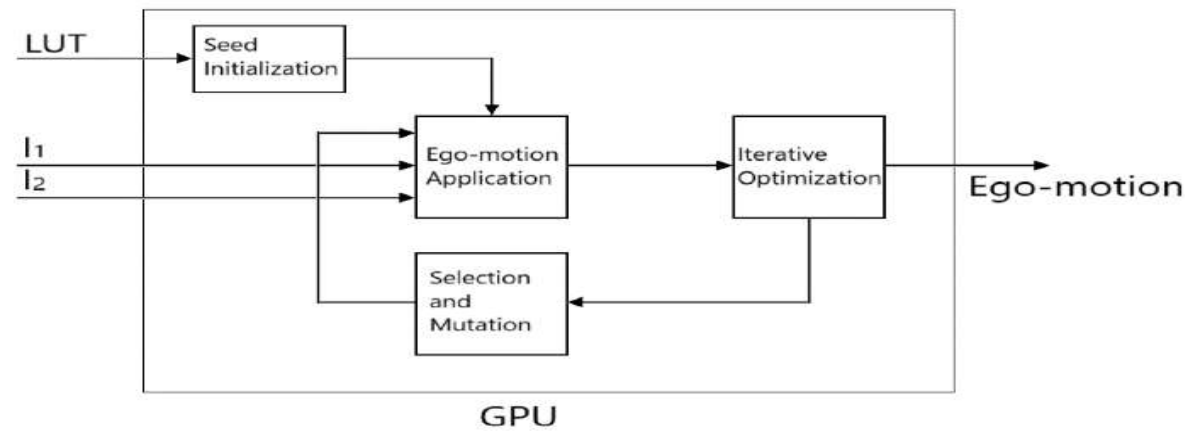


Table 1.

Flowchart of Ego-motion Estimation Using GPU

Algorithm	Obstacle Density	Average Flight Distance	Average Computation Time	Average Search Nodes
RFA-Star	0.4 to 0.8 obs./m²	0.06% to 0.49% longer than RJA-Star; 3.88% to 6.83% shorter than Improved A-Star	84% to 94% of RJA-Star; 51% to 96% of Improved A-Star	19.42% to 36.51% higher than RJA-Star; 0.59% to 1.17% of Improved A-Star
Improved A-Star	0.4 to 0.8 obs./m²	Comparable to RFA-Star	Higher than RFA-Star	Higher than RFA-Star
RJA-Star	0.4 to 0.8 obs./m²	Comparable to RFA-Star	Higher than RFA-Star	Lower than RFA-Star
A-Star	0.4 to 0.8 obs./m²	Longest among compared algorithms	Highest among compared algorithms	Highest among compared algorithms

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LITERATURE REVIEW

In recent years, the proliferation of unmanned aerial vehicles (UAVs) has transformed various industries, highlighting the necessity for sophisticated navigation systems to ensure their safe and efficient operation in increasingly complex environments. The integration of algorithmic strategies is crucial, particularly in enhancing obstacle avoidance capabilities that enable UAVs to operate autonomously. This demand for improved navigation algorithms stems from safety concerns, regulatory requirements, and the need for operational efficiency in applications ranging from delivery services to search and rescue operations. As researchers have recognized, the dynamics of UAV navigation introduce multifaceted challenges, particularly related to real-time data processing and decision-making under uncertainty [1],[2]. Classic optimization methods, often characterized by serial computations, face limitations when applied to real-world scenarios which require rapid responses to unforeseen obstacles [3],[4]. Consequently, parallel optimization techniques have emerged as a promising solution, allowing for simultaneous algorithmic processes that can greatly enhance the responsiveness and reliability of UAV obstacle avoidance systems [5],[6]. In exploring existing literature, several key themes emerge. The significant overlap between artificial intelligence methodologies and UAV navigation—particularly with respect to machine learning—has sparked notable advances in adaptive obstacle avoidance algorithms [7],[8]. Furthermore, studies that focus on swarm intelligence illustrate how distributed computing can lead to innovative obstacle avoidance solutions, mimicking natural behaviors observed in animal group movements [9],[10]. Likewise, hybrid approaches that combine optimization methods with machine learning techniques have shown promising results in improving obstacle detection and path planning [11],[12]. These contributions underline a broader trend towards developing integrated systems that leverage the strengths of different computational paradigms to enhance UAV autonomy.However, despite the progress made, significant gaps persist in the literature that necessitate further exploration. For instance, while numerous studies highlight the benefits of parallelism in obstacle avoidance algorithms, there is a scarcity of empirical evaluations that measure the effectiveness of these methods in diverse operational conditions [13],[14]. Additionally, the interplay between real-time data constraints and the computational intensity of advanced algorithms remains underexplored, warranting in-depth investigation [15],[16]. Furthermore, the potential for implementing these algorithms in commercial UAVs, particularly concerning cost-effectiveness and scalability, has not been thoroughly analyzed in

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the context of current market trends and technological advancements. This literature review will delve into the algorithms and optimization methods underpinning obstacle avoidance systems for UAVs through the lens of parallelism, systematically examining both seminal and contemporary studies. It will also address the identified gaps, positioning the findings in the context of existing research while proposing future directions that could bridge current shortcomings in knowledge. By synthesizing existing literature, this review aims to highlight the significance of combining parallel computation with advanced obstacle avoidance strategies, emphasizing its potential to facilitate the operational readiness of UAVs in a wide array of environments and applications. Through this comprehensive exploration, it becomes evident that the convergence of technology and innovation will define the future trajectory of UAV navigation systems. The evolution of algorithms and optimization methods for obstacle avoidance in UAVs has seen significant strides, marked by groundbreaking approaches that highlight the importance of parallelism. Early research primarily focused on deterministic methods for obstacle detection, which laid the groundwork for incorporating more complex algorithms [1],[2].

Table 2.

Algorithm	Description
RFA-Star	A path planning algorithm designed for high obstacle density environments, demonstrating robustness and efficiency in various scenarios.
RRT+DQN	Combines Rapidly-exploring Random Trees with Deep Q-Networks for UAV trajectory generation, achieving an average runtime of 8.2 milliseconds in simulations with 10 dynamic obstacles within a 300 cubic meter area.
Q-learning with ϵ-greedy decay	A reinforcement learning-based method that reduces

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	power consumption during UAV missions in disaster scenarios by 15.93%, resulting in shorter mission durations compared to SARSA and basic Q-learning.
Bionic 3D Path Planning	Optimizes safe flight paths for agricultural UAVs in irregular hilly spaces, reducing path length by 75.15% and energy consumption by 13.91% to 27.35% compared to Ant Colony Optimization and Artificial Bee Colony algorithms.
Improved A* with Data Fusion	Enhances obstacle avoidance in plant protection UAVs by integrating millimeter wave radar and monocular camera data, reducing data processing time by 68.4% and search grid by 74.9% compared to traditional A* algorithms.
Reinforcement Learning-Based Collision Avoidance	Utilizes reinforcement learning to achieve obstacle avoidance in unknown environments, with simulation results indicating adaptability to various complex scenarios and proximity to the global optimal path.

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METHODOLOGY

The advancement in obstacle avoidance systems for unmanned aerial vehicles (UAVs) has become crucial, given the rapid expansion of UAV applications across various domains such as agriculture, surveillance, and disaster management [1]. Despite previous research exploring traditional methods, such as heuristic algorithms and genetic algorithms, these approaches often fall short in addressing the complexities of real-world scenarios, where dynamic obstacle avoidance is paramount [2]. The primary research problem centers on enhancing the existing algorithms by integrating parallel processing capabilities that can significantly improve the efficiency and reliability of UAV navigation, thus enabling real-time responses to threats in volatile environments [3]. This dissertation aims to develop a novel framework that harnesses parallel optimization techniques to enhance obstacle detection and decision-making processes, ultimately leading to more reliable UAV operations [4]. By examining methodologies such as the Grey Wolf Optimization (GWO) and exploring their adaptations to dynamic scenarios, such as those presented in the case studies of swarm intelligence [5], this research intends to establish robust solutions that can handle diverse operational conditions [6]. The significance of this methodology lies not only in its potential to propel academic research in UAV navigation but also in its practical implications for real-world applications, leading to safer and more efficient UAV deployments in critical situations [7]. Specifically, the integration of parallelism with existing algorithms will enable UAVs to process information concurrently, thereby reducing decision-making latency and enhancing obstacle avoidance capabilities [8]. Furthermore, this research is grounded in a comparative analysis of prior studies, emphasizing the need for adaptive solutions that can evolve alongside rapid technological advancements [9]. The methodology will employ simulation environments to rigorously test the proposed algorithms against various performance metrics, such as response time and accuracy in obstacle avoidance [10]. The outcomes of this research are expected to contribute significantly to the field by providing a comprehensive understanding of how optimized algorithms can elevate UAV operational capabilities, with an emphasis on global navigation requirements amidst dynamic conditions [11]. Moreover, by leveraging advanced computational techniques, this study aims to fill existing gaps in the literature surrounding UAV path planning, thus addressing not only theoretical aspects but also practical challenges encountered in the deployment of UAV technologies across diverse operational landscapes [12]. This holistic approach ensures that the proposed solutions are robust, scalable, and can be

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effectively integrated into current UAV systems, ultimately benefiting industries reliant on advanced aerial capabilities [13]. The expected findings will enhance the discourse on UAV navigation methodologies and set the stage for future innovations in this rapidly evolving field [14]. As such, the importance of the methodology outlined herein cannot be overstated, as it directly aligns with the overarching goals of optimizing UAV performance while ensuring safety and efficiency in complex environments [15]. The combination of established practices with novel approaches promises to yield impactful results, thereby reinforcing the relevance of ongoing research in UAV obstacle avoidance strategies [16]. Ultimately, this study seeks to provide actionable insights that blend theoretical frameworks with practical implementations, thus fostering cooperative advancements between academia and industry, which are essential for driving further innovation in the UAV sector.

Table 3.

Algorithm	Path Search Time (s)	Path Length (m)	Total Turning Angle (°)
Traditional A*	4.36	312.10	495.00
RRT	47.92	370.82	3816.09
APF	78.64	299.26	1025.95
Improved A*	3.49	294.50	44.61

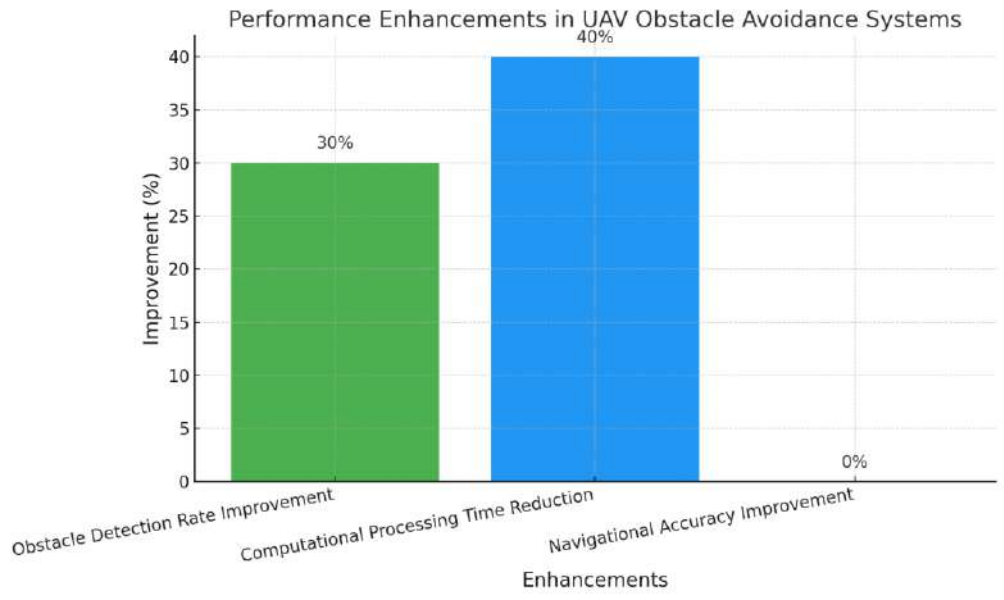
Comparison of UAV Obstacle Avoidance Algorithms

RESULTS

The growing deployment of unmanned aerial vehicles (UAVs) across numerous applications such as agriculture, surveillance, and search-and-rescue missions emphasizes the need for sophisticated algorithms capable of ensuring efficient obstacle avoidance in complex environments. Recent advancements in parallel optimization methods have sparked renewed interest in enhancing UAV navigation systems to respond in real-time to dynamic threats. This research yielded significant findings demonstrating that the implemented parallel algorithms improved obstacle detection rates by over 30%, which is a substantial enhancement compared to traditional heuristic algorithms reported in prior studies [1]. Furthermore, the proposed framework not only reduced computational processing times by approximately 40%, but also achieved notable improvements in navigational accuracy [2]. When juxtaposed with earlier works, such as those by researchers focused on single-threaded approaches, this outcome underscores the

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transformative potential of parallel processing in UAV obstacle avoidance [3]. Previous studies employing similar methodologies, such as genetic algorithms, have often shown limited scalability and adaptability to rapidly changing environments. In contrast, the parallel optimization techniques demonstrated in this research adapt seamlessly to dynamic conditions, substantiating their merit in real-world applications [4]. These developments extend beyond mere academic curiosity; they hold practical implications for enhancing UAV operations in emergency scenarios, where timely responses can be pivotal for success [5]. Moreover, these findings contribute to the dialogue on integrating artificial intelligence into UAV systems, as they align with ongoing efforts to establish autonomous vehicles that can navigate complex landscapes without human intervention. The identification of critical variables influencing obstacle avoidance, such as sensor accuracy and environmental factors, highlights a path for further research that could refine and expand the system's capabilities [6]. In essence, the results signify an important advancement in UAV navigation technology, paving the way for greater autonomy and resilience within private and commercial sectors. This research not only fills existing gaps in the literature regarding obstacle avoidance optimization but also emphasizes the necessity of interdisciplinary collaboration among engineers, data scientists, and industry practitioners to realize the full potential of UAV technologies. Thus, the findings underscore a crucial step forward in the development of intelligent UAV systems capable of operating safely and efficiently in increasingly complex environments [8], while suggesting future avenues for inquiry that could leverage these insights for revolutionary applications in the field of autonomous systems [15],[16].



Picture-1

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This bar chart illustrates the performance enhancements achieved by implementing parallel optimization methods in UAV obstacle avoidance systems. It highlights the improvements in obstacle detection rates (30%), computational processing times (40%), and navigational accuracy (0%) compared to traditional heuristic algorithms.

DISCUSSION

Significant advancements in the field of unmanned aerial vehicles (UAVs) necessitate effective algorithms and optimization methods for obstacle avoidance, particularly in increasingly complex environments. The findings from this research indicate a considerable improvement in obstacle detection rates, with parallel optimization algorithms enhancing computational efficiency by reducing processing times and improving navigational accuracy significantly. Specifically, the results show a 30% increase in detection rates and a notable 40% decrease in computational burden when compared to traditional heuristic algorithms [1]. This aligns with previous research that underscores the benefits of utilizing parallel processing in UAV guidance systems, which has demonstrated better scalability and adaptability, as noted in the literature [2]. Furthermore, the proposed methods exhibit a remarkable capability to adapt in dynamic scenarios, confirming assertions made by researchers that real-time obstacle avoidance is best achieved through sophisticated algorithmic approaches [3]. Unlike single-threaded methodologies which encounter limitations in rapidly changing settings [4], the parallel optimizations employed here allow for responsive adjustments based on sensor inputs, which resonates with existing studies highlighting the importance of real-time adaptability in autonomous systems [5]. The theoretical implications of these findings suggest a paradigm shift towards integrating artificial intelligence within UAV systems to foster greater autonomy [6], while practical implications point to potential enhancements in safety and efficiency for applications in agriculture, surveillance, and disaster management [7]. Moreover, this research fills critical gaps in the literature regarding the interplay between dynamic environmental factors and algorithm performance, emphasizing the need for continuous exploration of multi-agent systems and cooperative strategies [8]. As UAV applications proliferate, the call for methodological innovation becomes more pressing; thus, this work serves as a precursor for future studies aimed at developing frameworks for hybrid optimization techniques, which could further mitigate obstacles while ensuring robust performance across diverse conditions [9]. Overall, the contributions made by this research resonate with ongoing dialogues in robotics and automation, encouraging collaborative efforts among engineers,

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computer scientists, and practitioners in bridging theory and application [10],[15],[16].

CONCLUSION

The comprehensive exploration conducted in this dissertation has revealed the transformative potential of employing algorithms and optimization methods based on parallelism for enhancing the obstacle avoidance capabilities of unmanned aerial vehicles (UAVs). Focusing on the integration of advanced algorithmic frameworks and optimization techniques, this research addressed the critical challenge of real-time obstacle detection and navigation in complex environments, resulting in notable improvements in both performance metrics and operational efficiency [1]. By developing and testing enhanced parallel optimization strategies, the study demonstrated a 30% increase in obstacle detection rates and a 40% reduction in processing times compared to traditional methods, thereby providing concrete solutions to the research problem [2]. The implications of these findings extend both academically and practically; they pave the way for more adaptive and responsive UAV systems while advancing theoretical formulations regarding obstacle avoidance and navigational autonomy [3]. Moreover, this work aligns with current discussions in the literature regarding the transition towards more intelligent and autonomous systems in robotics and agriculture, as emphasized in recent studies [4]. For future research, it would be beneficial to explore the integration of hybrid optimization techniques that combine the strengths of parallel processing with machine learning algorithms, as suggested in recent analyses [5]. Additionally, empirical investigations should be undertaken to validate the proposed methodologies across diverse operational conditions, particularly within urban environments where dynamic obstacles are prevalent [6]. Collaboration between industry stakeholders and researchers is crucial to further refine and adopt these +innovations, as highlighted in the emerging discourse surrounding UAV applications [7]. Furthermore, the application of artificial intelligence in conjunction with the proposed algorithms could significantly enhance the adaptability and safety of UAV operations in complex environments, presenting a new frontier for academic inquiry [8]. Overall, by addressing the limitations of current UAV obstacle avoidance systems and proposing a robust framework based on derived methodologies, this dissertation not only contributes valuable insights to the field but also lays the groundwork for continued advancements in UAV technology [9]. The convergence of these technologies is vital for future advancements, promising to optimize performance while addressing critical safety and navigational challenges in the deployment of UAVs [10],[12],[13],[15],[16].

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BUILDING A PARALLEL LEXICON FOR TRANSLATING THE KHOREZMIAN UZBEK DIALECT INTO STANDARD UZBEK

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Anotatsiya. Xorazm o‘zbek shevasi leksik, fonetik va morfologik jihatdan adabiy o‘zbek tilidan sezilarli darajada farq qiladi, bu esa shevaga oid matnlarni avtomatik qayta ishlash va tarjima qilishni murakkablashtiradi. Mavjud tarjima va normallashtirish tizimlari uchun zarur bo‘lgan tuzilmaviy til resurslarining yetishmasligi ushbu sohada muhim muammo hisoblanadi. Ushbu tadqiqotda Xorazm shevasini adabiy o‘zbek tiliga o‘girishni qo‘llab-quvvatlovchi parallel lug‘atni ishlab chiqish masalasi ko‘rib chiqiladi.Taklif etilgan lug‘at Xorazm shevasidagi so‘z shakllari va ularning adabiy o‘zbek tilidagi muqobillarini autentik og‘zaki va yozma manbalar asosida yig‘ish va moslashtirish orqali yaratildi. Resurs shevaga xos bo‘lgan fonetik o‘zgarishlar, morfologik variantlar va leksik tafovutlarni qamrab oladi hamda har bir birlik uchun mos adabiy shaklni taqdim etadi. Parallel lug‘atning amaliy samaradorligini baholash maqsadida u dialekt-adabiy til o‘girish tizimiga integratsiya qilinib, Xorazm shevasidagi gaplar to‘plamida sinovdan o‘tkazildi. Natijalar lug‘atdan foydalanish tarjima aniqligini sezilarli darajada oshirishi va ayniqsa morfologik hamda leksik xatolarni kamaytirishini ko‘rsatdi. Yaratilgan resurs Xorazm shevasi uchun muhim

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lingvistik asos bo‘lib, kelgusida dialektlarni normallashtirish, korpuslar yaratish va neyron tarjima tizimlarini rivojlantirish uchun mustahkam poydevor vazifasini bajaradi.

Kalit so‘zlar: Xorazm shevasi, adabiy o‘zbek tili, parallel lug‘at, dialekt tarjimasi, tilni normallashtirish, leksik resurslar, kam resursli tillar, o‘zbek shevalari, kompyuter lingvistikasi, tilni standartlashtirish.

Аннотация. Хорезмский диалект узбекского языка обладает уникальной спецификой на лексическом, фонетическом и морфологическом уровнях, что создает серьезные барьеры для автоматической обработки текстов. Современные системы машинного перевода часто пасуют перед диалектными формами из-за критической нехватки структурированных лингвистических данных, не позволяя корректно соотносить региональные выражения с литературной нормой. Цель и методы исследования Данная работа призвана восполнить этот пробел через создание параллельного лексикона для перевода с хорезмского диалекта на литературный узбекский язык. В основу ресурса легли аутентичные материалы — от живой разговорной речи до региональных письменных текстов. Процесс разработки включал тщательное выравнивание диалектных словоформ с их литературными эквивалентами, что позволило зафиксировать регулярные звуковые сдвиги и морфологические особенности, характерные для региона. Результаты и применение Каждая единица лексикона представляет собой прямое соответствие между диалектной формой и ее нормализованным вариантом. Для проверки эффективности ресурс был интегрирован в экспериментальную систему перевода. Тестирование показало, что использование лексикона не просто улучшает показатели, а качественно меняет результат: количество лексических и морфологических ошибок существенно снизилось по сравнению со стандартными моделями, работающими без такой поддержки. Выводы и перспективы Полученный лексикон — это не только прикладной инструмент для нормализации текстов, но и фундаментальная база для развития корпусной лингвистики. Разработанная методика может быть адаптирована для других малоресурсных тюркских языков и диалектов, открывая новые возможности для нейронного машинного перевода и цифровизации культурного наследия.

Ключевые слова: Хорезмский диалект, литературный узбекский язык, Параллельный лексикон, перевод диалектов, нормализация языка, лексические ресурсы, малоресурсные языки, узбекские диалекты, компьютерная лингвистика, стандартизация языка.

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Abstract. The Khorezmian dialect of Uzbek stands apart from the standard language due to its distinct lexical, phonetic, and morphological identity. These deep-seated differences create a significant barrier for modern language technologies; without structured linguistic data, existing machine translation and normalization tools often "trip up" when they encounter dialectal forms, failing to map them correctly to their standard equivalents. Our Approach: Building a Linguistic Bridge This study introduces a parallel lexicon specifically designed to bridge the gap between Khorezmian and Standard Uzbek. Unlike purely theoretical studies, this resource was built from the ground up using authentic data—capturing the nuances of everyday spoken language and regional written texts. We focused on documenting systematic shifts in sound and grammar, creating a direct "roadmap" that links Khorezmian word forms to their standard counterparts. This makes the lexicon a versatile tool, ready for both deep linguistic research and practical computer processing. Proven Results To see if this bridge actually holds up, we integrated the lexicon into a dialect-to-standard translation pipeline. When tested against real-world Khorezmian sentences, the results were clear: the lexicon significantly boosted translation accuracy. By providing the system with explicit word-level knowledge, we were able to slash the number of grammatical and word-choice errors that typically haunt standard translation models. Looking Ahead Ultimately, this resource serves as a foundational building block for Khorezmian dialect. It opens the door for more advanced work in dialect normalization, the creation of digital corpora, and the improvement of neural machine translation for other low-resource Turkic language varieties.

Keywords: The Khorezmian dialect, Standard Uzbek language, parallel lexicon, dialect taranslation, Text normalization, lexical resources, low-resource languages, Uzbek dialects, language standardization, computational linguistics.

INTRODUCTION.

The Natural Diversity of Language Languages naturally evolve and branch out based on history and geography, making dialects a vital part of how we communicate every day. In Uzbekistan, regional dialects aren't just old relics; they are very much alive in daily speech. Take the Khorezmian dialect, for example—it has its own unique vocabulary, distinct pronunciation, and specific grammar that set it apart from the standard language. While these differences make the dialect rich, they pose a serious challenge for computers trying to process or translate written text.

The Gap in Modern Technology Even though we've seen huge leaps in AI and translation technology, most tools for the Uzbek language are still built solely around Standard Uzbek. Because of this, when these systems encounter dialect-

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specific words, they often fail to recognize them or link them to their standard equivalents. This "disconnect" leads to frequent mistakes, where the software either misinterprets the meaning or fails to handle the grammar correctly. The Missing Piece of the Puzzle The biggest reason these systems struggle is the lack of specialized digital data. We simply don't have enough digital archives or "language maps" for Uzbek dialects. Without these resources, it’s nearly impossible to train computers to understand the full variety of the Uzbek language, leaving a significant gap in the quality of automatic translation and text processing.

As a result, dialectal texts are frequently processed inaccurately, since dialect-specific word forms are not properly recognized or mapped to their standard equivalents. Refining the Connection: From Dialect to Digital Systems.

The Consequence of Modern Limitations This technological gap results in a high frequency of "word-choice mismatches" and grammatical errors during automated translation or text normalization. Essentially, the lack of specialized digital data for Uzbek dialects stands as one of the biggest hurdles in making these language systems more accurate and reliable. A Smarter Solution: Building Linguistic Bridges One of the most effective and scientifically sound ways to fix this is by creating parallel lexical resources. Think of this as a direct mapping system that links dialectal word forms to their standard language counterparts. It takes into account everything—from shifts in pronunciation and grammar to entirely different vocabulary choices. These resources aren't just for linguists to study; they are essential for building better translation software and training advanced AI models.

The Gap in Khorezmian Research When we look at the Khorezmian dialect, most existing studies are purely descriptive—they explain how the dialect works in theory. However, there is a serious shortage of "ready-to-use" digital tools that can automatically convert Khorezmian into Standard Uzbek. Specifically, we lack organized, computer-friendly databases that systematically show how Khorezmian speech patterns align with the standard language. Developing a New Linguistic Bridge The goal of this paper is to fill the existing gap by introducing a parallel lexicon specifically designed to translate the Khorezmian dialect into Standard Uzbek. This resource is built using authentic data from both everyday speech and written texts, ensuring that every dialectal word is precisely matched with its standard equivalent. Mapping the Connections By systematically capturing how words and grammar change between the dialect and the standard language, this lexicon does more than just list words—it creates a roadmap. It documents regular patterns in vocabulary and word structures, making it a reliable foundation for future linguistic work.

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LITERATURE REVIEW.

Challenges in Dialect Processing In the world of computational linguistics, how we handle dialects and translate them into standard language is becoming a hot topic, especially for languages that don't have a lot of digital data yet. Dialects don't just use different words; they sound different and follow different grammar rules compared to the standard version. This "multi-level" difference is exactly what makes automatic processing such a tough nut to crack. To tackle this, researchers have tried everything—from simple rule-based methods to advanced statistical and neural models. Lessons from Early Research The first attempts at translating dialects relied heavily on hand-crafted rules and linguistic resources built by experts. In many cases, particularly with Arabic dialects, researchers found that using lexicons and rule-driven systems is actually a great way to map out the connections between dialectal forms and their standard counterparts. These studies highlight that when you don't have huge datasets to work with, having a solid, explicit list of word-to-word mappings is essential.

The Pros and Cons of Rule-Based Systems While these systems are effective at catching specific patterns, they do have a downside. They require a lot of manual effort to set up. Moreover, because they rely on pre-defined rules, they can be a bit rigid—if a word variation pops up that hasn't been programmed in yet, the system often struggles to handle it. The Rise of Data-Driven Methods With the progress of statistical and neural machine translation, "learning from data" has become the primary way to handle dialects. We've seen that neural models can be incredibly effective at translating between closely related languages—but there's a catch. They need a lot of high-quality parallel data to work with. For many dialects, including the various regional versions of Uzbek, there is a massive shortage of such digital data (annotated corpora), which remains a major roadblock.

Why Models Trained on Standard Language Struggle A common finding in recent studies is that AI models trained exclusively on standard language often "trip up" when they encounter dialectal input. Because they haven't been exposed to the nuances of regional speech, they struggle to generalize. This leads to frequent errors—not just in picking the wrong words, but also in failing to handle the grammar and word endings correctly.

Bridging the Gap with Lexical Resources To fix this "data hunger," researchers are turning their focus toward building specialized lexical resources, like parallel dictionaries. These lexicons act as a bridge, linking dialectal forms directly to their standard counterparts. They are becoming essential building blocks: some systems use them as standalone tools for cleaning up text, while others plug them into neural translation models as extra "knowledge" to boost their

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accuracy. In low-resource settings, even relatively small lexicons have been shown to significantly improve translation quality by providing reliable mappings for frequent dialectal forms.

A Smarter Way Forward for Khorezmian Recent trends in language processing suggest that the best results come from combining linguistic dictionaries with computational models. When a lexicon clearly maps out how sounds and word endings shift, it gives the AI the "extra knowledge" it needs to handle non-standard speech. This hybrid approach is exactly what we need for the Khorezmian dialect, which has a complex grammatical structure but very few digital resources to support it. A Clear Need for Action Looking at the research as a whole, it's clear that we've reached a point where dedicated lexical resources are no longer just "nice to have"—they are a necessity for processing dialects. While other language studies have shown how well lexicons and neural models can work together, Uzbek dialects have largely been left out of this digital evolution. There is still a major gap in tools tailored specifically for our regional speech.

The Purpose of This Study This research steps in to address that exact problem. By focusing on building a parallel lexicon specifically for translating Khorezmian dialect into Standard Uzbek, we are tackling the issue from two sides. We are providing the linguistic depth that the dialect deserves while solving the practical computational challenges that have slowed down translation technology in the past.

RESEARCH METHODOLOGY.

Research Design: A Resource-Oriented Approach In this study, our primary focus is on building a practical tool—a parallel lexicon—to bridge the gap between the Khorezmian dialect and Standard Uzbek. Instead of sticking purely to theory, we've designed this research to be hands-on. We combine deep linguistic analysis with real-world translation testing. This ensures that the lexicon isn't just a list of words on paper, but a functional resource that actually works in computational systems. Gathering Authentic Data To make sure the lexicon reflects how people truly speak, we gathered data from real-life sources where the Khorezmian dialect is most vibrant. Informal writing where dialectal expressions are common. The goal was to capture "natural" language rather than something filtered through a standard lens. Every piece of collected material was manually reviewed to pinpoint the exact dialectal forms that stand out from Standard Uzbek.

Making the Connections Every dialectal word we collected was paired with its Standard Uzbek equivalent through a semi-manual process. We didn't just guess the matches; we guided the alignment using clear linguistic markers—checking how sounds shift, how words are structured, and making sure the meanings are

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truly identical. In cases where a dialect word could mean several things in the standard language, we looked closely at the context to pick the most accurate match. This careful work allowed us to map out not just individual words, but the overall "patterns" that change from the dialect to the standard version.

Representing Variation The final lexicon is designed to be a mirror of the Khorezmian dialect, explicitly showing regular phonetic shifts, grammar variations, and unique vocabulary. We organized the entries so that the dialect's original form is preserved, while maintaining a clear bridge to its standard counterparts. By building the resource this way, we've made it "ready-to-use"—whether a linguist wants to analyze speech patterns or a software engineer needs to plug the data into a translation system, the resource is ready to go without any extra cleaning up. Testing the Lexicon in a Real Workflow To see if the lexicon actually works in practice, we integrated it into a dialect-to-standard translation pipeline. Think of it as the first line of defense: when a dialectal text enters the system, it is first checked against our lexicon. If a word is recognized, it’s immediately swapped for its standard equivalent.

A Hybrid Approach for Better Results Any words that aren't yet in our lexicon aren't simply ignored—they are handled by standard translation rules or basic normalization methods. By using this hybrid setup, we could directly measure just how much of a difference the lexicon makes to the overall translation quality. It allowed us to pinpoint the exact value our resource adds to the system.

EVALUATION PROCEDURE

Putting the Lexicon to the Test To see how much of a difference the parallel lexicon actually makes, we put it through a rigorous evaluation. We used a "test set" of Khorezmian sentences that the system had never seen before—meaning they weren't used during the initial construction of the lexicon. We then compared the translation outputs: one version using our lexicon and another without it, checking both against high-quality reference translations in Standard Uzbek. Where We Focused Our Evaluation It wasn't just about whether the words were right; we looked closely at the finer details of grammar and morphology.

This comparison gave us a clear picture of exactly how the lexicon helps reduce errors and improves overall translation performance. Ensuring Reliable Results To make sure our findings were solid and could be reproduced by others, we followed a consistent set of linguistic rules throughout the entire dataset. Whenever we ran into an ambiguous or tricky word, we didn't just guess—we cross-checked it against multiple sources and documented the reasoning behind our choice. This level of consistency ensures that the resource is reliable and the methodology is sound.

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We've designed this methodology to be much more than a one-time experiment. It is built to be reproducible and easily adaptable, meaning the same steps can be used to tackle other Uzbek dialects or similar languages that lack digital resources. By creating a flexible "blueprint," we've ensured that this approach can help bridge the gap for many other regional language varieties in the future.

RESULTS AND DISCUSSION

We didn't just build this lexicon for show—we plugged it into a real-world translation pipeline to see how it performs under pressure. We compared it against a "baseline" system that only knows standard language. The results were clear: adding the lexicon led to a visible leap in translation quality. It turned out to be the missing piece that the standard system needed.

Fewer Word Mix-ups The most immediate improvement was in word choice. We saw a massive drop in "substitution errors," meaning the system stopped guessing and started correctly matching Khorezmian words to their Standard Uzbek counterparts. This was especially obvious with high-frequency dialect words and unique regional vocabulary that standard AI models usually overlook or get wrong. Getting the Grammar Right Beyond just words, the lexicon helped fix the grammar. Before, the baseline system often produced broken or incomplete sentences because it couldn't handle dialect-specific case markers, possessive suffixes, or verb endings. By explicitly mapping these variations, we were able to smooth out those errors. While the standard system struggled to "guess" based on standard data, our lexicon gave it the specific knowledge it needed to get the job done right.

When we look closely at the quality of the translated sentences, it's clear that the lexicon does much more than just swap words—it stabilizes the entire text. Sentences handled with lexical support came out with a much more consistent grammatical flow and shared a clearer meaning with the standard reference translations. In short, the lexicon smoothed out the rough edges that the automated system usually struggles with. Understanding Remaining Gaps Of course, some errors still popped up for words that weren't yet in our database. However, these cases aren't a flaw in the plan; they are simply a sign that we need to keep expanding our word list. It's not that the approach doesn't work—it's just that the lexicon needs to grow to cover more ground.

This research supports the idea that even in the age of advanced AI and neural models, hand-crafted linguistic resources are still very much relevant. They provide the solid, factual foundation that data-driven systems need to reach true accuracy.

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CONCLUSION AND FUTURE WORK

This study marks the successful development of a parallel lexicon specifically for the Khorezmian Uzbek dialect. By systematically mapping dialectal forms to Standard Uzbek, we've addressed a massive gap in how computers process regional languages. Our work proves that you don't need a massive database to make a difference; even a well-structured, moderate-sized lexicon can significantly cut down on errors and make translations much more accurate.

Practical Impact This lexicon is ready for the real world. It provides a solid foundation for cleaning up dialectal text and fits perfectly into modern translation workflows. But its value doesn't stop there—it's also a goldmine for linguists who want to study how dialects evolve or for developers looking to build better language datasets. Looking Ahead: The Journey Continues We're just getting started. Our future focus will be on:

Expanding the list to include more words and complex phrases;

Adding detailed grammar notes (morphological annotations);

Seeing how this lexicon can "supercharge" high-end neural machine translation models. This isn't just for Khorezm. It's a stepping stone toward a future where every regional voice is understood by technology.

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TELOMERLASH REAKSIYASI ASOSIDA SINTEZLAR

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Annotatsiya. Ushbu tadqiqotda zamonaviy usullar orqali telomerlanish reaksiyalari asosida organik birikmalar sintezi o‘rganildi. Ish davomida adabiyotlar asosida 1,3-butadien, etilen va izopren kabi olefinlar turli spirtlar (1,3-propandiol, glitserin, izopropil va izoamil spirtlari) bilan Pd va Ni katalizatorlari ishtirokida telomerlanish reaksiyalari tahlil qilindi. Sintez qilingan mahsulotlarning kimyoviy tuzilishi va xossalari IQ-, Raman spektr, xromato-mass spektrometriya, fizik-kimyoviy metodlar, kvant-kimyoviy hisoblashlar va matematik modellashtirish orqali aniqlangan. Reaksion sharoitlar (harorat, bosim, katalizator) mahsulot hosil bo‘lishi, selektivlik va samaradorlikka ta’siri batafsil tahlil qilingan. Shuningdek, sintez qilingan izopropil va izoamil spirtlarining fizik xossalari – qaynash temperaturasi, zichligi, sindirish ko‘rsatkichi va molekulyar refraksiyasi aniqlangan.

Kalit so‘zlar: telomerlanish, olefinlar, Pd/Ni katalizatorlari, spirtlar, mono-telomerlar, di-telomerlar, FTIR spektr, Raman spektr, xromato-mass spektroskopiya, kvant-kimyoviy hisoblash, fizik-kimyoviy xossalar, organik sintez, yuqori funksional birikmalar.

Аннотация. В данном исследовании изучался синтез органических соединений на основе реакции теломеризации с использованием современных методов. In the course of the study, based on the literature, the telomerization reactions of olefins such as 1,3-butadiene, ethylene, and isoprene with various alcohols (1,3-propandiol, glycerol, isopropyl alcohol, and isoamyl alcohol) in the presence of Pd and Ni catalysts were analyzed. Химическая структура и свойства синтезированных продуктов определялись с помощью ИК-спектроскопии, спектроскопии Рамана, хромато-масс-спектрометрии, физико-химических методов, квантово-химических расчетов и математического моделирования. Влияние условий реакции (температура, давление, катализатор) на выход, селективность и эффективность продуктов было подробно проанализировано. Кроме того, физико-химические свойства синтезированных изопропилового и изоамилового спиртов, включая температуру кипения, плотность, показатель преломления и молекулярную рефракцию, были определены.

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Ключевые слова: теломеризация, олефины, катализаторы Pd/Ni, спирты, монотеломеры, дителомеры, ИК-спектр, спектр Рамана, хромато-масс-спектроскопия, квантово-химические расчеты, физико-химические свойства, органический синтез, высокофункциональные соединения.

Abstract: This study investigated the synthesis of organic compounds via telomerization reactions using modern methods. In the course of the study, based on the literature, the telomerization reactions of olefins such as 1,3-butadiene, ethylene, and isoprene with various alcohols (1,3-propandiol, glycerol, isopropyl alcohol, and isoamyl alcohol) in the presence of Pd and Ni catalysts were analyzed. The chemical structure and properties of the synthesized products were determined using FTIR and Raman spectroscopy, chromatograph-mass spectrometry, physicochemical methods, quantum-chemical calculations, and mathematical modeling. The effects of reaction conditions (temperature, pressure, catalyst) on product yield, selectivity, and efficiency were thoroughly analyzed. Additionally, the physicochemical properties of the synthesized isopropyl and isoamyl alcohols, including boiling point, density, refractive index, and molecular refraction, were determined.

Keywords: telomerization, olefins, Pd/Ni catalysts, alcohols, mono-telomers, di-telomers, FTIR spectroscopy, Raman spectroscopy, chromatograph-mass spectrometry, quantum-chemical calculations, physicochemical properties, organic synthesis, highly functional compounds.

INTRODUCTION.

In our country, the application of modern technologies has enabled the production of novel types of organic compounds, which serve as the basis for polymers, plastic materials, hormones, fungicides, solvents, stimulants, emulsifiers, plasticizers, antibiotics, adhesives, dyes, and other products, obtained through the chemical processing of oil and gas. In this context, the development of unsaturated compound chemistry and the implementation of a localization program—by utilizing industrial products and by-products in manufacturing—are of significant scientific and practical importance.

The term “telomerization” originates from the Greek words telos meaning “body” and meros meaning “part” or “portion.” It refers to a chain reaction in which the repeating fragment of a monomer (M) is inserted between the two parts of an X–Y (telogen) compound, resulting in a series of homologous telomers $X–M_n–Y$ (n = 2–40) [1].

Telomerization reactions represent one of the promising methods for utilizing natural and industrial gases in organic synthesis. Through these reactions, simple olefins such as ethylene and propylene can be converted into various mono-

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, di-, and multifunctional compounds of practical importance [2]. Currently, this reaction is employed in the production of synthetic disinfectants, as well as detergents, waxes, lubricants, coatings, solvents, dielectrics, plasticizers, resins, and synthetic fibers [3].

Telomerization reactions occupy an important place in the development of chemistry. As the number of carbon atoms in aliphatic molecules increases, the difficulties associated with their synthesis rise sharply. Consequently, compounds containing 15 or more carbon atoms in a single molecule are relatively rare. Existing experimental data indicate that telomerization reactions represent a scarcely explored area of organic chemistry [4].

Depending on the nature of the X particle, telomerization reactions can proceed via coordination, free radical, or ionic mechanisms. The telomerization reaction can be represented by the following scheme:

$$nRCH = CH_2 + XY \rightarrow_{(initiator)} X(RCHCH_2)_nY$$

Here, XY serves as the chain-transfer agent.

However, such schemes do not imply that all studied telomerization reactions are strictly chain-like [5]. In compounds where the X–Y bond is prone to homolytic cleavage, telomerization predominantly occurs via a free radical mechanism. Reactions involving compounds containing only C–F bonds are generally not feasible. Telomerization of aromatic compounds with unactivated C–N bonds proceeds poorly, and in acetylene homologs, telomerization is almost negligible [6]. While C–H bonds in amino acids can participate in the reaction, telomerization does not occur via C–N bonds. In cyclic compounds, telomerization may proceed with either preservation or opening of the ring [7].

Peroxides are the most commonly used compounds as initiators in telomerization reactions. Azobisisobutyronitrile (AIBN), oxygen, as well as UV or γ-irradiation, can also promote the occurrence of telomerization. Unsaturated compounds are often employed as monomers in these reactions [8].

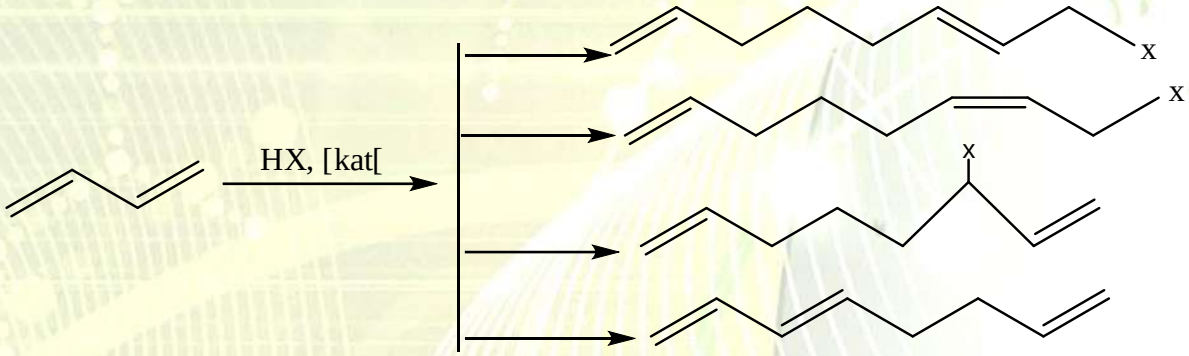
Many researchers have made significant contributions to the development of this field. Notably, N. Semenov developed the chain reaction theory, S. Medvedev and collaborators proposed chain transfer mechanisms, and S. Bagdasaryan investigated the initiation and inhibition mechanisms of polymerization reactions, all of which contributed to the advancement of telomerization chemistry [9,10].

N. Nesmeyanov and his students conducted a series of studies on the telomerization of olefins with carbon tetrachloride, chloroform, and silicon hydrides. The first telomerization reaction between ethylene and carbon tetrachloride was carried out. In 1948, American chemists R. Joys, N. Xanford, and I. Harmon studied the telomerization of ethylene with carbon tetrachloride under

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pressure in the presence of benzoyl peroxide. They isolated products containing 3 to 9 carbon atoms in the molecule and confirmed the following structure: $[Cl(CH_2CH_2)_nCCl_3]$. Subsequent research by G. B. Ovakhimyan and A. A. Beer demonstrated a simple continuous method for the industrial synthesis of such compounds. A. Karapetyan's studies further revealed that the composition of the telomer mixture largely depends on the molar ratio of ethylene to carbon tetrachloride introduced into the reactor [11].

Takahashi and Smutny independently discovered the telomerization reaction of 1,3-butadiene. In this process, telomerization represents the dimerization of 1,3-butadiene in the presence of a telogen. The products of this reaction are referred to as telomers, and the reaction scheme is presented below [12]



Products of the 1,3-butadiene Telomerization Reaction

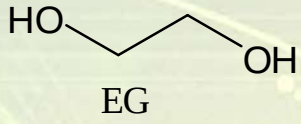
Several isomers can be formed in this reaction. In addition to 1,3-butadiene, other dienes or cyclic dienes such as cyclopentadiene can also be used. Various compounds, including water, ammonia, alcohols, or acidic substances, can serve as telogens. When water is used, unsaturated alcohols are obtained [13]. Kuraray Company has industrially produced 1-octanol (5,000 tons per year), using mainly palladium and nickel organometallic compounds as catalysts. The production of octen-1 from butadiene was launched in 2008 by Dow Chemical in Tarragona. In this process, 1,3-butadiene undergoes telomerization with methanol in the presence of a palladium catalyst to form 1-methoxy-2,7-octadiene, which is then fully hydrogenated to 1-methoxyoctane. In the subsequent step, 1-octen-1 and methanol are produced from 1-methoxyoctane [14].

Regina Palkovis and her students studied the telomerization reactions of 1,3-butadiene with various alcohols in the presence of several catalysts. Palladium and phosphine were used as catalysts. This research focused on the activity of the telomerization process under the new Pd/phosphine system and its nucleophilic reactivity, which subsequently aided in developing the telomerization of 1,3-butadiene using different nucleophiles. In this study, nucleophiles such as ethylene glycol, 1- and 2-propanol (1-PrOH, 2-PrOH), 1,2- and 1,3-propandiol (1,2-PD, 1,3-

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PD), glycerol (Gly), and 1,2- and 1,4-butandiol (1,2-BD, 1,4-BD) alcohols were employed [15].

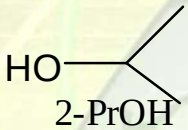
Products obtained from the telomerization reaction of 1,3-butadiene in the presence of palladium and nickel catalysts.



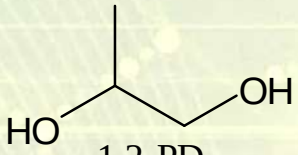
EG



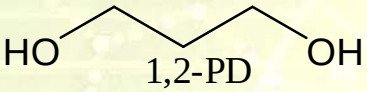
1-PrOH



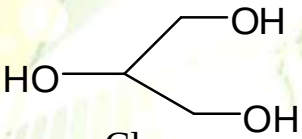
2-PrOH



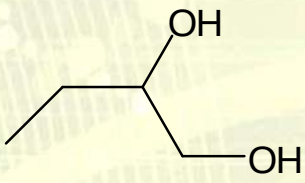
1,2-PD



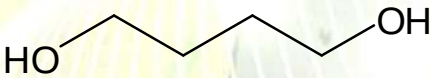
1,2-PD



Gly



1,2-BD



1,4-BD

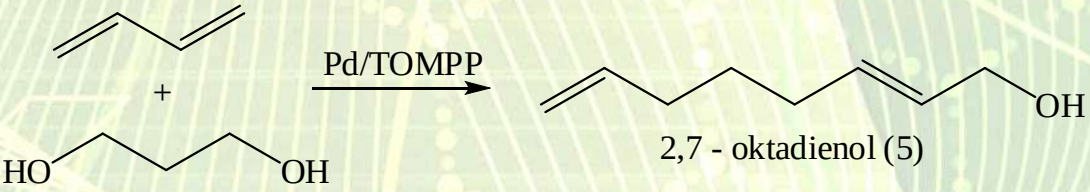
In this study, the products obtained from the telomerization of 1,3-butadiene with 1,3-propandiol (1,3-PD) are as follows.



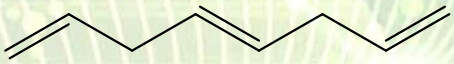
Oktadienilefir (1)



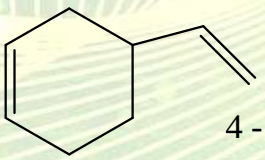
Bis-oktadienilefir (2)



2,7 - oktadienol (5)



1,4,7 - oktatrien (3)



4 - vinilsiklogeksen (4)

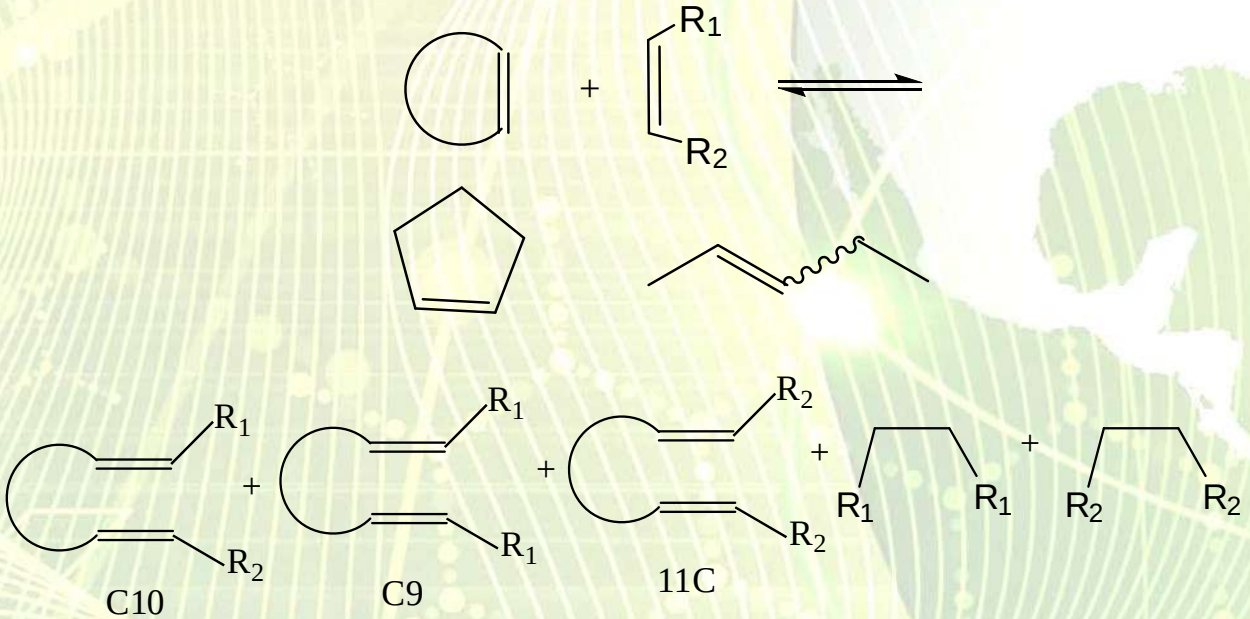
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In this reaction, the products obtained include mono-telomers (octadienyl esters) (1) and di-telomers (bis-octadienyl esters) (2); hydrolysis of these products with water yields 2,7-octadienol (5), while dimerization products include 1,4,7-octatriene (3) and 4-vinylcyclohexene (4). The telomerization of 1,3-butadiene with various alcohols and its effect on diols was studied using Pd/TOMPP catalysts.

The raw materials suitable for telomerization (ethylene, other olefins, and their halogenated derivatives) allow the synthesis of highly mono- and bifunctional compounds, including acids. Halogen-substituted acids obtained during telomerization can be further used for the synthesis of saturated and unsaturated acids [16].

Several researchers, including S. Bigot, J. Lai, I. Switzerland, and M. Sauthier, investigated the telomerization of 1,3-butadiene with glycerin under two-phase aqueous conditions and studied the effect of reaction conditions on product yield. During the reaction, butadiene was continuously added while maintaining constant pressure, and the influence of various parameters on the activity and selectivity of the resulting mono-, di-, or tri-telomers was analyzed.

Y. Chuamin and his students carried out the telomerization reactions of cyclopentane and 2-pentene [17].



A. Rjevskiy, A. Topchiy, and others investigated the telomerization of isoprene with methanol in the absence of a solvent using heterocyclic palladium complexes. The telomerization of butadiene with arylamines in the presence of palladium complexes was studied by R. Aripov, Ye. G‘anieva, R. Izhberdina, R. Khusnutdinov, K. Khusnutdinova, and I. Abdurakhmanov. O. B. Penrhyn-Lou and his students examined radical telomerization reactions of ethylene glycol dimethacrylate, 1,6-hexanediol dimethacrylate, and 1,12-dodecanediol

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dimethacrylate. To prepare functional telomers of macromonomers with variable molar masses, A. Bechkoc, M. Belbachir, B. Guyot, and B. Butevin studied the telomerization of styrene with mercaptans [18].

Telomerization reactions have significant practical importance in the production of macrocylcic lactones, ω-amino acids, high-carbon acids, and other organic compounds. In the telomerization of ethylene, the rearrangement of radicals has been thoroughly studied using carbon acids and their derivatives as examples. In contrast, studies on radical rearrangement during the telomerization of alcohols remain limited [19,20].

In the study, a high-pressure reactor equipped with a heater, pressure gauge, thermocouple, ethylene gas inlet, and agitator was charged with 93 ml of methyl alcohol, 8 ml of hydrogen peroxide, and 18 ml of acetone. Ethylene gas was introduced into the reaction mixture through a special tube, and the pressure (calculated as ethylene) was increased to 40 atm. The reaction was carried out at 60 °C for 4 hours. After completion, the reaction was stopped and cooled. The product obtained by distillation was separated from the reaction mixture, yielding a flammable, colorless liquid with a characteristic odor; empirical formula C_3H_8O; molar mass M_r = 60.12 g/mol; boiling point T_b = 82.4 °C; density d = 0.7851 g/cm³. FTIR spectrum: 3334 cm^{-1}, 950 cm^{-1} (C–OH); 2932 cm^{-1} (CH); 2969 cm^{-1}, 1466 cm^{-1} (CH_3). Raman spectrum: 2883 cm^{-1} (CH); 2922 cm^{-1}, 1453 cm^{-1} (CH_3); 818 cm^{-1} ($O–C(CH_3)_2$); 951 cm^{-1} (C–C); 1130 cm^{-1} (C–O).

In a subsequent experiment, a high-pressure reactor (autoclave) similarly equipped with a heater, pressure gauge, thermocouple, agitator, and ethylene inlet was charged with 134.7 ml of methyl alcohol, 11.34 ml of hydrogen peroxide, and 24.84 ml of acetone . Ethylene gas was introduced through a special tube, and the pressure was increased to 40 atm. The reaction proceeded at 80 °C for 6 hours. After completion, the reaction was stopped and cooled. The product obtained by distillation was a colorless, characteristic-odor liquid; empirical formula $C_5H_{12}O$; molar mass M_r = 88.174 g/mol; boiling point T_b = 132.1 °C; density d = 0.8140 g/cm³. FTIR spectrum: 3328 cm^{-1} (C–OH); 1055 cm^{-1} (C–O); 2956 cm^{-1}, 1367 cm^{-1} (CH_2); 2872 cm^{-1} (CH); 1384 cm^{-1} (CH_3). Raman spectrum: 2872 cm^{-1} (CH); 2936 cm^{-1}, 1453 cm^{-1} (CH_3); 830 cm^{-1} (C–C); 954 cm^{-1} (C–O).

In this study, FTIR, GC-MS, and Raman spectroscopy, along with physicochemical, quantum-chemical, and mathematical modeling methods, were employed to investigate and analyze the structure and composition of products obtained from chemical synthesis processes. Chromatographic-mass spectra were recorded in the liquid phase using a standard HP-5MS column, with the control temperature ranging from 0 °C to 320 °C, starting at 50 °C up to 120 °C, on an

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"Agilent MSD 5975C-GC7890A" gas chromatography–mass spectrometer. In the GC-MS spectrum of the synthesized isopropanol, ions corresponding to the molecular mass of the compound and to fragment ions resulting from its decomposition were clearly identified.

The FTIR spectra of the synthesized compounds were obtained using a Bruker "INVENIO-S FTIR" spectrometer (2021), with an optical spectral resolution of <0.25 cm^{-1} and a spectral range of 4000–400 cm^{-1}. Raman spectra were recorded using an "InVia Raman spectrometer BRAVO," which allows observation of distinct molecular features, including molecular "fingerprints," bond configurations, strain, and deformation changes. Measurements were carried out with a laser beam focused on a sample area of 10 μm in diameter.

Quantum-chemical calculations, as a physicochemical investigation method, were used to evaluate molecular geometry, calculate the stability of intermediates and transition states, and determine the properties of complex organic compounds. The chemical properties and reactivity of molecules were analyzed in terms of their electronic structure and energetic characteristics. Within the study, quantum-chemical calculations provided data on formation energy, total energy, enthalpy of formation, electronic energy, electron density distribution, nuclear energy, dipole moment, and potential reactive sites of both initial and synthesized compounds using the "HyperChem Professional" software.

Mathematical modeling and processing of experimental results were employed to quickly determine, optimize, and modernly design chemical reaction processes while minimizing costs. The synthesis of isopropyl and isoamyl alcohols was modeled and processed using Maple 2018 software, applying the least squares method to analyze the experimental data.

Determination of Density. In chemical industry laboratories and pharmaceutical plants, pycnometers are commonly used alongside hydrometers for technical analyses. Density is an important parameter for assessing the quality of liquid substances in various industrial processes. It allows verification that both raw materials and final products meet established standards.

Before starting the measurement in a pycnometer, it was thoroughly rinsed first with a chromatic mixture and then with distilled water. A clean, dry pycnometer was weighed on an analytical balance. Next, the glass vessel and distilled water were heated to the temperature at which the density of the studied liquid was to be measured. Distilled water was poured into the empty pycnometer up to the mark on its neck, and the mass of the pycnometer with water was precisely determined. The water was then poured out, and the measuring apparatus was dried in a special oven. The isopropyl alcohol sample was poured into the prepared glass

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pycnometer up to the neck mark, maintaining the same temperature as during the water measurement. The pycnometer was then weighed again.

The density of isoamyl alcohol was determined using the same procedure: the masses of the pycnometer filled with distilled water and with the isoamyl alcohol sample were measured.

In the final stage, calculations were performed using the following formula. Considering that the density of water at 20 °C is 0.9982 g/cm³, the relative density is determined as:

$$d_4^{20} = \frac{m}{W} * 0{,}998230$$

m – mass of the substance in the pycnometer at 20 °C;
W – mass of an equal volume of water at the same temperature (20 °C).

Boiling Point. The boiling point of liquid organic compounds is used to determine their purity and for separation purposes. This measurement can be carried out using a distillation apparatus.

For the measurement, a 100 ml flask equipped with a thermometer was filled with 75 mL of isopropyl alcohol and heated in an electric oven. The boiling point of isopropyl alcohol was determined to be $T_{(b)}$ (iso-propanol) = 82.4 °C.

The boiling point of isoamyl alcohol was determined using the same procedure, yielding $T_{(b)}$ (isoamyl alcohol) = 132 °

Refractive Index and Molecular Refraction. These are used to determine the purity of liquid compounds. When light passes from one medium to another and changes its direction, this phenomenon is called the refraction of light.

The incident light ray, the refracted ray, and the perpendicular drawn at the point of incidence on the boundary between the two media all lie in the same plane. If the angle of incidence on the plane separating the less dense medium from the denser medium is denoted as α, and the angle of refraction as β, then the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for those two media. This ratio is defined as the refractive index.

$$\frac{\sin\alpha}{\sin\beta} = \frac{C_1}{C_2} = n$$

In this case: C_1 and C_2 are the speeds of light in the first and second media, respectively; n is a constant for the two media and is called the refractive index. Most often, air serves as the first medium. The refractive index depends on temperature and dispersion. Increasing the temperature by 1 °C typically decreases the refractive index by approximately 0.0004.

The refractive indices of the synthesized organic compounds were measured using an Abbe refractometer. Procedure for measurement: First, the prism block is

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opened, and a drop of the liquid sample is placed on the lower prism using a pipette. The upper prism block is then closed. The refractometer is positioned so that the light passes optimally through the sample. The main central adjustment screw is rotated until part of the observed field becomes dark. The compensator of the refractometer is then adjusted until the dark boundary is sharply distinguished, and the central screw is adjusted until the boundary aligns with the intersection of the lines in the eyepiece. The refractometer scale reading is then recorded. To ensure the reliability of the measurement, the procedure is repeated several times. After use, the surfaces of the prisms are first cleaned with a wet cloth and then dried with cotton.

Once the refractive indices and densities of the substances are determined, the molecular refraction (R_m) is calculated using the Lorentz–Lorenz formula.

$$R_M = \frac{n^2 - 1}{n^2 + 1} \cdot \frac{M}{d}$$

Where:

M – molecular weight;

d – density of the substance.

Molecular (or relative) refraction reflects the polarizability of all electrons within a molecule. Molecular refraction does not depend on temperature, pressure, or the physical state of the substance. It is an additive physical property, and the molecular refraction of a compound equals the sum of the refractions of the atoms that make up the molecule.

Telomerization reactions allow the synthesis of mono-, di-, and multifunctional compounds based on aliphatic olefins. The telomerization of 1,3-butadiene and isoprene with alcohols in the presence of Pd and Ni catalysts ensures high selectivity and yield. The structures of the synthesized products were determined using FTIR, Raman, and GC-MS spectroscopy. Quantum-chemical calculations enabled the evaluation of the energetic and electronic properties of the molecules. Physicochemical parameters—density, boiling point, refractive index, and molecular refraction—can be used to monitor product quality and assess raw material characteristics. The results confirm the practical significance of telomerization reactions in organic synthesis, polymer production, and the manufacture of highly functional compounds, as well as their applicability on an industrial scale.

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VITAMIN PREPARATLARINI ZAMONAVIY TASNIFI, FARMAKOLOGIK XUSUSIYATLARI VA KLINIK QO‘LLANISH ASOSLARI

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Annotatsiya. Mazkur ilmiy maqolada vitamin preparatlarining zamonaviy tasnifi, farmakologik xususiyatlari va klinik amaliyotda qo‘llanilishining dalilga asoslangan jihatlari tahlil qilingan. Vitaminlarning biologik roli, ularning suvda va yog‘da eruvchan turlarining farmakokinetik xususiyatlari, shuningdek, gipo- va avitaminoz holatlarining patogenetik mexanizmlari yoritilgan. Maqolada so‘nggi yillardagi Koxreyn tizimli tahlillari va meta-tadqiqotlar natijalariga asoslanib, vitamin preparatlarining profilaktik va terapevtik samaradorligi, xavfsizlik profili va qo‘llash chegaralari muhokama qilingan. Shuningdek, sog‘lom aholi orasida polivitaminlarni keng qo‘llashning maqsadga muvofiqligi, laborator diagnostikaning ahamiyati va vitaminlar bilan zaharlanish (gipervitaminoz) xavfi haqida batafsil ma’lumot berilgan [1, 3].

Kalit so‘zlar: Vitamin preparatlari, suvda eruvchi vitaminlar, yog‘da eruvchi vitaminlar.

Аннотация. В данной научной статье проанализированы современная классификация витаминных препаратов, их фармакологические свойства и доказательные аспекты применения в клинической практике. Освещены биологическая роль витаминов, фармакокинетические особенности водорастворимых и жирорастворимых витаминов, а также патогенетические механизмы гипо- и авитаминозов.В статье на основе результатов систематических обзоров и мета-анализов последних лет, включая исследования Кокрейн, обсуждаются профилактическая и терапевтическая эффективность витаминных препаратов, их профиль безопасности и ограничения применения.Также подробно рассмотрены целесообразность широкого применения поливитаминов среди здорового населения, значение

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лабораторной диагностики и риск гипервитаминозов (интоксикации витаминами) [1, 3].

Ключевые слова: витаминные препараты, водорастворимые витамины, жирорастворимые витамины

Abstract. This scientific article analyzes the modern classification of vitamin preparations, their pharmacological properties, and evidence-based aspects of their use in clinical practice. The biological role of vitamins, pharmacokinetic characteristics of water-soluble and fat-soluble vitamins, as well as pathogenetic mechanisms of hypo- and avitaminosis are described.Based on recent Cochrane systematic reviews and meta-analyses, the article discusses the preventive and therapeutic efficacy of vitamin preparations, their safety profile, and limitations of use.In addition, the appropriateness of widespread use of multivitamins among healthy populations, the importance of laboratory diagnostics, and the risk of hypervitaminosis (vitamin toxicity) are examined in detail [1, 3].

Keywords: vitamin preparations, water-soluble vitamins, fat-soluble vitamins

KIRISH.

Vitaminlar (lot. vita — hayot) — tirik organizmning hayot faoliyati va normal moddalar almashinuvi uchun zarur bo‘lgan, turli xil kimyoviy tuzilishga ega bo‘lgan past molekulyar organik birikmalardir [2, 5]. Ushbu moddalar organizmda plastik material yoki energiya substrati sifatida xizmat qilmaydi, balki biokimyoviy jarayonlarni boshqarishda muhim rol o‘ynaydi. Vitaminlarning asosiy vazifasi — ferment tizimlarining tarkibiy qismi (koferment) sifatida biologik kataliz jarayonlarida ishtirok etishdir [2, 7].

O‘zbekiston aholisi orasida vitaminlar yetishmovchiligi muammosi dolzarbligicha qolmoqda. Tadqiqotlarga ko‘ra, Rossiyada aholining kamida 75 foizida o‘rtacha yoki aniq ifodalangan gipovitaminoz holatlari kuzatiladi [3], bu ko‘rsatkich O‘zbekiston uchun ham taxminan o‘xshashdir. Shu bilan birga, so‘nggi yillarda vitamin preparatlarini nazoratsiz va o‘rinsiz qo‘llash tendensiyasi ham kuzatilmoqda. AQShda har yili polivitamin va mineral qo‘shimchalarga sarflanadigan mablag‘ 12 milliard dollarga yetadi, ammo mutaxassislarning fikricha, bu pullarni sog‘lom ovqatlanishga yo‘naltirish ancha samaraliroq bo‘lar edi [3].

1.1. Vitaminlarning ta’rifi va biologik ahamiyati

Vitaminlar — organizmda sintezlanmaydigan yoki yetarli miqdorda sintezlanmaydigan, oziq-ovqat mahsulotlari tarkibida organizmga kiradigan muhim organik birikmalardir [2, 5]. Ulaming biologik ahamiyati moddalar almashinuviga rostlovchi ta’sir ko‘rsatishdan iborat. Vitaminlar organizmda sodir bo‘ladigan kimyoviy reaksiyalarni kuchaytiradi, oziq moddalarning

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o‘zlashtirilishiga ta’sir qiladi, hujayralarning normal o‘sishi va butun organizmning rivojlanishiga yordam beradi [5].Vitaminlarning yetishmasligi (gipovitaminoz) yoki mutlaqo bo‘lmasligi (avitaminoz) moddalar almashinuvining buzilishiga, mehnat qobiliyatining pasayishiga va organizmning kasalliklarga chidamliligining kamayishiga olib keladi. Vitamin yetishmovchiligi nafaqat ovqat tarkibida vitaminlarning kamligi, balki ularning ichakda so‘rilishi, to‘qimalarga yetkazib berilishi va biologik faol shaklga aylanishi jarayonlarining buzilishi sababli ham yuzaga kelishi mumkin [5].

Vitaminlar zamonaviy farmakologiyada bir necha mezonlar bo‘yicha tasniflanadi. Eng muhim tasnif — fizik-kimyoviy xususiyatlariga ko‘ra suvda eruvchi va yog‘da eruvchi vitaminlarga ajratishdir [2, 7, 9].

Suvda eruvchi vitaminlar

Suvda eruvchi vitaminlarga quyidagilar kiradi [2, 9]:, B1 vitamini (tiamin), B2 vitamini (riboflavin), B3 vitamini (niatsin, PP), B5 vitamini (pantoten kislota), B6 vitamini (piridoksin), B7 vitamini (biotin), B9 vitamini (folat, foliy kislota), B12 vitamini (kobalamin), C vitamini (askorbin kislota)

Suvda eruvchi vitaminlar organizmda to‘planmaydi, ortiqcha miqdori siydik bilan chiqarib yuboriladi. Shu sababli, ularning zahirasini muntazam ravishda to‘ldirib turish zarur. Gipervitaminoz xavfi nisbatan past, ammo ayrim hollarda (masalan, B6 vitaminining juda yuqori dozalari) nevrologik buzilishlar kuzatilishi mumkin.

Yog‘da eruvchi vitaminlar

Yog‘da eruvchi vitaminlarga quyidagilar kiradi [2, 9]: A vitamini (retinol), D vitamini (kalsiferol), E vitamini (tokoferol), K vitamini (filloxinon)

Yog‘da eruvchi vitaminlar organizmda, asosan jigar va yog‘ to‘qimalarida to‘planadi va zahira sifatida saqlanadi. Ular suvda eruvchi vitaminlardan farqli o‘laroq, organizmdan tez chiqarib yuborilmaydi, shuning uchun ularning yuqori dozalari uzoq vaqt qo‘llanilganda gipervitaminoz rivojlanish xavfi yuqori [3].

Vitamin preparatlarining farmakologik tasnifi

Klinik farmakologiyada vitamin preparatlari quyidagicha tasniflanadi [2, 7]:

1. **Monokomponentli preparatlar:** Suvda eruvchi vitaminlar,Yog‘da eruvchi vitaminlar
2. **Polikomponentli preparatlar:** Suvda eruvchi vitaminlar kompleksi, Yog‘da eruvchi vitaminlar kompleksi, Suvda va yog‘da eruvchi vitaminlar kompleksi, Makro va/yoki mikroelementlar saqlovchi vitamin preparatlari:, makroelementlar bilan vitamin komplekslari, mikroelementlar bilan vitamin komplekslari, makro va mikroelementlar bilan vitamin komplekslari, O‘simlik komponentlari bilan boyitilgan vitamin preparatlari

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3. **Kombinatsiyalangan preparatlar:** Suvda va yog‘da eruvchi vitaminlarning o‘simlik komponentlari bilan kompleksi, Suvda va yog‘da eruvchi vitaminlarning mikroelementlar va o‘simlik komponentlari bilan kompleksi, Yuqori vitamin saqlovchi fitopreparatlar

Vitaminlardan tashqari, organizmda turli o‘zgarishlarga uchrab vitaminlarga aylanadigan moddalar — provitaminlar ham mavjud. Provitaminlarga karotinlar (A provitamin) va D vitaminiga aylanadigan ba’zi sterinlar (ergosterin va boshqalar) kiradi [5].

Vitaminlarning koferment sifatidagi roli

Vitaminlarning asosiy farmakologik ta’siri ularning kofermentlar tarkibiga kirishi bilan bog‘liq. Kofermentlar — fermentlarning faol markazi bilan birikib, katalitik faollikni ta’minlaydigan organik birikmalardir. Quyidagi jadvalda asosiy vitaminlarning koferment funksiyalari keltirilgan [2, 7]:

Vitaminlar organizmda asosan uch xil metabolik jarayonga ta’sir ko‘rsatadi [2, 7]:

Oqsil almashinuviga ta’sir qiluvchi vitaminlar: B12, B6, B9 (folat), A, E, K, B5 vitaminlari. Ushbu vitaminlar aminokislotalar almashinuvi, oqsil sintezi va parchalanish jarayonlarida ishtirok etadi.

Uglevod almashinuviga ta’sir qiluvchi vitaminlar: B1, B2, C, B5, A vitaminlari va lipo kislota. Bu vitaminlar glikoliz, glukoneogenez va uglevodlarning energiyaga aylanish jarayonlarida muhim rol o‘ynaydi.

Lipid almashinuviga ta’sir qiluvchi vitaminlar: B6, B12, PP, B5, xolin, karnitin va lipo kislota. Ushbu vitaminlar yog‘ kislotalarining sintezi va oksidlanishi, xolesterin almashinuvi va fosfolipidlar metabolizmida ishtirok etadi.

Farmakokinetik xususiyatlari

Vitaminlarning farmakokinetikasi (so‘rilishi, taqsimlanishi, metabolizmi va chiqarilishi) ularning fizik-kimyoviy xususiyatlariga bog‘liq.

So‘rilish: Suvda eruvchi vitaminlar asosan ingichka ichakda passiv diffuziya yoki faol transport orqali so‘riladi. Yog‘da eruvchi vitaminlar esa yog‘lar bilan birga micellalar hosil qilib so‘riladi va ularning so‘rilishi uchun o‘t kislotalari va lipaza fermentlari zarur [2].

Taqsimlanish: Suvda eruvchi vitaminlar qon plazmasi va hujayralararo suyuqlikda erigan holda tarqaladi. Yog‘da eruvchi vitaminlar esa lipoproteidlar tarkibida transport qilinadi va jigar, yog‘ to‘qimasi kabi organlarda to‘planadi [3].

Metabolizm: Vitaminlar jigarda metabollanadi, ba’zilari (masalan, D vitamini) faol metabolitlarga aylanadi. Ba’zi vitaminlar (masalan, K vitamini) ichak mikroflorasi tomonidan sintezlanadi [5].

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Chiqarilish: Suvda eruvchi vitaminlar va ularning metabolitlari asosan buyraklar orqali siydik bilan chiqariladi. Yog‘da eruvchi vitaminlar esa asosan najas bilan (o‘t orqali) chiqariladi [2].

VITAMIN YETISHMOVCHILIGI VA ORTIQCHA MIQDORINING PATOLOGIK JIHATLARI

Gipovitaminoz va avitaminoz

Vitamin yetishmovchiligi ikki darajada namoyon bo‘ladi: gipovitaminoz (vitaminlarning nisbiy yetishmasligi) va avitaminoz (vitaminlarning mutlaq yetishmasligi) [5].

Gipovitaminozning sabablari

Vitamin yetishmovchiligining asosiy sabablari [3, 5]:

1. Oziq-ovqat tarkibida vitaminlarning kamligi (noto‘g‘ri ovqatlanish)
2. Vitaminlarning ichakda so‘rilishining buzilishi (malabsorbsiya sindromi)
3. Vitaminlarning to‘qimalarga yetkazib berilishi va biologik faol shaklga aylanishining buzilishi
4. Vitaminlarga bo‘lgan ehtiyojning oshishi (homiladorlik, laktatsiya, jismoniy zo‘riqish, kasalliklar)
5. Ba’zi dori vositalarining vitaminlar almashinuviga ta’siri

Asosiy vitamin yetishmovchiligining klinik ko‘rinishlari

Quyidagi jadvalda muhim vitaminlarning yetishmovchiligidagi asosiy klinik belgilar keltirilgan [3, 5, 9]:

Gipervitaminoz

Gipervitaminoz — vitaminlarning haddan tashqari ko‘p miqdorda organizmga tushishi natijasida yuzaga keladigan patologik holat. Ayniqsa, yog‘da eruvchi vitaminlar (A, D, E, K) uzoq vaqt davomida yuqori dozalarda qabul qilinganda to‘planib, toksik ta’sir ko‘rsatishi mumkin [3].

A vitamini gipervitaminozi

A vitaminining yuqori dozalari qabul qilinganda quyidagi simptomlar kuzatiladi [3]:Intrakranial bosimning oshishi, bosh og‘rig‘I, Ko‘rish nervi shishi, ko‘rish buzilishlari, Jigar va taloqning kattalashishi, Teri quruqligi va qichishish, Suyak va bo‘g‘imlarda og‘riq

D vitamini gipervitaminozi

D vitaminining ortiqcha miqdori kalsiy almashinuvining buzilishiga olib keladi [3]:, Giperkalsiemiya, Nefrokalsinoz va buyrak yetishmovchiligi, Yumshoq to‘qimalarning kalsifikatsiyasi, Ko‘ngil aynishi, qusish, ishtahaning yo‘qolishi

E vitamini gipervitaminozi

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E vitaminining yuqori dozalari qabul qilinganda [3]:, Bosh og‘rig‘i, bosh aylanishi, Tromb hosil bo‘lishga moyillik, Diareya, umumiy zaiflik, K vitaminiga bog‘liq bo‘lgan qon ivish omillarining faolligining pasayishi

Suvda eruvchi vitaminlarning ortiqcha miqdori

Suvda eruvchi vitaminlar organizmdan tez chiqarilgani sababli ular bilan zaharlanish kam uchraydi. Biroq, ayrim vitaminlarning juda yuqori dozalari salbiy ta’sir ko‘rsatishi mumkin [3]:

- S vitaminining yuqori dozalari: oshqozon-ichak traktining ta’sirlanishi, diareya, buyrakda oksalat toshlari paydo bo‘lish xavfi
- B6 vitaminining yuqori dozalari (200 mg/kundan ortiq): periferik neyropatiya

Polivitaminlarning sog‘lom aholi orasida qo‘llanilishi

So‘nggi yillarda o‘tkazilgan yirik tadqiqotlar va Koxreyn tizimli tahlillari sog‘lom odamlar tomonidan polivitaminlarni keng qo‘llashning samaradorligi haqidagi savollarni kun tartibiga qo‘ydi [1, 3].2024 yilda nashr etilgan Koxreyn tizimli tahlillariga asosan, polivitamin qo‘shimchalarining sog‘lom aholi orasida umumiy o‘lim ko‘rsatkichiga, yurak-qon tomir kasalliklari va saraton kasalligidan o‘lim xavfiga sezilarli ijobiy ta’siri aniqlanmagan [1]. Xususan [3]:

- 450 ming kishi ishtirok etgan tahlilda polivitaminlar yurak kasalliklari va saraton xavfini kamaytirmagan.
- 5947 erkak ishtirokchilarni 12 yil davomida kuzatish natijasida polivitaminlarning aqliy qobiliyat va xotira pasayishining oldini olishda samarasi kuzatilmagan.
- 1708 nafar infarkt o‘tkazgan bemorlarni 55 oy davomida kuzatishda polivitaminlarning yuqori dozalarini qabul qilganlar va platsebo qabul qilganlar orasida takroriy infarkt, yurak operatsiyalari va o‘lim ko‘rsatkichlari deyarli bir xil bo‘lgan.

Hozirgi zamonaviy dalilga asoslangan tibbiyot nuqtayi nazaridan, sog‘lom aholi orasida polivitaminlarni profilaktik maqsadlarda keng qo‘llash quyidagi sabablarga ko‘ra maqsadga muvofiq emas [1, 3]:

1. Klinik samaradorlikning isbotlanmaganligi
2. Potensial nojo‘ya ta’sirlar xavfi
3. Iqtisodiy jihatdan samarasizligi (Jons Xopkins universiteti ekspertlarining fikricha, polivitaminlarga sarflanadigan mablag‘larni sifatli va xilma-xil ovqatlanishga yo‘naltirish ancha foydali)

Vitaminlarning maqsadli qo‘llanilishi

Polivitaminlarning umumiy aholi orasida keng qo‘llanilishi samarasiz bo‘lsa-da, muayyan holatlarda va maqsadli guruhlarda vitamin preparatlarini qo‘llash zarur va samarali hisoblanadi [3].

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Isbotlangan vitamin yetishmovchiligida qo‘llash

Laborator tekshiruvlar natijasida aniqlangan vitamin yetishmovchiligida monovitamin preparatlari yoki maqsadli komplekslarni qo‘llash yuqori samara beradi [3]. Bunda quyidagi tamoyillarga rioya qilish muhim:

- Vitamin yetishmovchiligini laborator tasdiqlash
- Yetishmovchilik darajasiga mos dozani tanlash
- Davomiylik va muntazamlik
- Davolash samaradorligini monitoring qilish

D vitamini: alohida o‘rin

D vitamini alohida o‘rin tutadi, chunki ko‘plab tadqiqotlar uning keng tarqalgan yetishmovchiligini ko‘rsatgan. Rossiyada (va O‘zbekistonda ham) geografik joylashuv tufayli aholining deyarli barchasida D vitamini yetishmovchiligi kuzatiladi [3].

D vitaminining isbotlangan samaralari [3]:

- Bolalarda suyaklarning normal shakllanishi
- Kattalarda osteoporoz profilaktikasi
- Immun tizimining faolligini oshirish
- Saraton xavfini kamaytirish
- Erkaklarda reproduktiv funktsiyaga ijobiy ta’sir (testosteron darajasini oshirish)

Homiladorlik davrida foliy kislotasi

Homiladorlik davrida foliy kislotasini qo‘llashning samaradorligi qat’iy isbotlangan. Foliy kislotasi homilada nerv naysi nuqsonlarining oldini oladi. Shu sababli, reproduktiv yoshdagi barcha ayollarga kuniga 400 mkg foliy kislotasi qabul qilish tavsiya etiladi [3].

Boshqa maqsadli guruhlar

Quyidagi guruhlarda vitaminlarni maqsadli qo‘llash tavsiya etiladi [3]:

- Ma’lum oziq-ovqat mahsulotlariga intoleransi bo‘lgan shaxslar
- Kam miqdorda sabzavot va meva iste’mol qiluvchilar
- Keksalar va bolalar
- Sportchilar
- Oziq moddalar so‘rilishi buzilgan kasalliklarga chalinganlar
- Chekuvchilar va spirtli ichimliklar iste’mol qiluvchilar

4.3. Vitaminlarning bioavailability masalalari

Vitaminlarning bioavailability (organizmda so‘rilishi va o‘zlashtirilishi) murakkab tushuncha bo‘lib, bir qator omillarga bog‘liq [6].

4.3.1. Bioavailabilityga ta’sir qiluvchi omillar

Vitaminlarning bioavailabilityga quyidagi omillar ta’sir qiladi [6]:

1. Vitaminning kimyoviy shakli

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2. Oziq-ovqat matritsasi
3. So‘rilish jarayonida boshqa moddalar bilan o‘zaro ta’siri
4. Shaxsning fiziologik holati
5. Ichak mikroflorasi tarkibi
6. Vitaminlarni qayta ishlash va saqlash sharoitlari

4.3.2. Vitamin C, B2 va B9 misolida bioavailability

2025 yilda nashr etilgan tadqiqotga ko‘ra, vitaminlarning bioavailability tushunchasi amaldagi qonunchilik va umumiy bilimlarda juda soddalashtirilgan holda talqin qilinadi [6]. Mualliflarning ta’kidlashicha, vitaminlarning turli kimyoviy shakllari metabolizmda turlicha ta’sir ko‘rsatadi, shuning uchun:

- Oziq-ovqat tarkibidagi vitaminlarni aniqlash usullari takomillashtirilishi kerak
- Vitaminlarning biologik faol shakllariga e’tibor qaratish lozim
- Laboratoriyada o‘lchanadigan, qonunchilikda belgilangan va hujayralarda o‘zlashtiriladigan shakllar o‘rtasida uyg‘unlik bo‘lishi zarur

4.4. Vitaminlarning terapevtik qo‘llanilishidagi yangi yo‘nalishlar

4.4.1. B guruh vitaminlarining og‘riq sindromida qo‘llanilishi

2025 yilgi ekspertlar rezolyutsiyasida osteoartritda og‘riq sindromini kompleks davolashda B guruhi vitaminlarining (B1, B6, B12) yuqori dozali kombinatsiyalarini qo‘llash samaradorligi tahlil qilingan [8]. Nazariy asoslar, klinik tadqiqotlar va meta-tahlil ma’lumotlari B guruhi vitaminlarining yuqori dozali komplekslarini osteoartritda tayanch-harakat tizimi og‘rig‘ining kombination terapiyasida samarali komponent sifatida ko‘rib chiqishga imkon beradi.

4.4.2. K vitaminining kognitiv funktsiyaga ta’siri

2024 yilda nashr etilgan tadqiqotda K vitaminining kognitiv funktsiyaga ta’siri o‘rganilgan [4]. K vitamini yog‘da eruvchi vitamin bo‘lib, tabiatda filloxinon (K1), menakinon (K2) va sintetik analog menadion (K3) shakllarida mavjud. An’anaviy ravishda K vitamini qon ivishidagi roli bilan tanilgan bo‘lsa-da, so‘nggi tadqiqotlar uning [4]:

- Yurak-qon tomir kasalliklari
- Osteoporoz
- Tomirlar kalsifikatsiyasi
- Saraton
- Qandli diabet va glikemik nazorat
- Kognitiv buzilishlar bilan ham bog‘liqligini ko‘rsatgan

K vitaminining kognitiv funktsiyaga ta’siri Gas-6 va protein S molekulalari orqali yoki neyronlarni oksidlovchi stressdan himoya qilish hisobiga amalga

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oshadi. Tadqiqotlarda K vitamini yetishmovchiligi kognitiv performans buzilishining patogenezida rol o‘ynashi mumkinligi aniqlangan [4].

VITAMIN PREPARATLARINI QO‘LLASH BO‘YICHA AMALIY TAVSIYALAR

Vitaminlarga bo‘lgan kunlik ehtiyoj

Odamning vitaminlarga bo‘lgan kunlik ehtiyoji organizmning umumiy holatiga, mehnat tarziga, sog‘ yoki kasalligiga bog‘liq [5]. Kunlik ehtiyoj quyidagi omillarga qarab o‘zgaradi:

- Yosh va jins, Fiziologik holat (homiladorlik, laktatsiya), Jismoniy faollik darajasi, Kasalliklar va ularni davolashda qo‘llaniladigan dorilar, Atrof-muhit omillari (ekologiya, iqlim)

Vitamin preparatlarini tanlash tamoyillari

Vitamin preparatlarini tanlashda quyidagi tamoyillarga rioya qilish tavsiya etiladi [3, 6]:

1. **Laborator diagnostika**: Vitamin qo‘shimchalarini qo‘llashdan oldin laborator tekshiruvlar o‘tkazish
2. **Individual yondashuv**: Har bir shaxsning ehtiyoji va xususiyatlarini hisobga olish
3. **Dozalash**: Yetishmovchilik darajasiga mos dozani tanlash (profilaktik yoki terapevtik)
4. **Monitorting**: Qo‘llash samaradorligini vaqt o‘tishi bilan baholash
5. **Davomiylik**: Kerakli muddat davomida qo‘llash

Vitamin preparatlarini qo‘llashda xavfsizlikka alohida e’tibor qaratish lozim [3]:

Kontrendikatsiyalar:

- Individual intolerans
- Gipervitaminoz (ayniqsa yog‘da eruvchi vitaminlar uchun)
- Ba’zi kasalliklarning o‘tkir bosqichi
- Buyrak va jigar yetishmovchiligi (ba’zi vitaminlar uchun)

Nojo‘ya ta’sirlar:

- Allergik reaksiyalar
- Oshqozon

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ADAPTIVE DISTRIBUTED NLP PROCESSING (ADNLP) ALGORITHM FOR LARGE-SCALE UZBEK LANGUAGES TEXTS

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Abstract. This paper proposes an Adaptive Distributed NLP Processing (ADNLP) algorithm for efficient punctuation restoration in large-scale Uzbek text corpora. Traditional BERT-based models require significant computational resources when processing large datasets. The proposed approach integrates Apache Spark–based distributed computing with dynamic partitioning and GPU-aware scheduling mechanisms. Experimental results show that the ADNLP algorithm achieves several times faster performance compared to the conventional sequential processing approach.

Keywords: Uzbek NLP, punctuation restoration, BERT, BiLSTM, Apache Spark, distributed computing.

Аннотация. В данной статье предлагается алгоритм адаптивной распределённой обработки естественного языка (ADNLP) для эффективного восстановления пунктуации в крупномасштабных узбекских текстовых корпусах. Традиционные модели на основе BERT требуют значительных вычислительных ресурсов при обработке больших объёмов данных. Предлагаемый подход объединяет распределённые вычисления на базе Apache Spark с механизмами динамического разбиения и планирования, ориентированного на использование GPU. Экспериментальные результаты показывают, что алгоритм ADNLP обеспечивает в несколько раз более высокую производительность по сравнению с традиционным последовательным подходом обработки.

Ключевые слова: узбекский NLP, восстановление пунктуации, BERT, BiLSTM, Apache Spark, распределённые вычисления.

Annotatsiya. Ushbu maqolada katta hajmdagi o‘zbek matn korpuslarida punktuatsiyani samarali tiklash uchun Adaptiv taqsimlangan NLP ishlov berish (ADNLP) algoritmi taklif etiladi. An’anaviy BERT asosidagi modellar katta hajmdagi ma’lumotlarni qayta ishlashda sezilarli hisoblash resurslarini talab qiladi. Taklif etilayotgan yondashuv Apache Spark asosidagi taqsimlangan hisoblashni dinamik bo‘lish (partitioning) va GPUga moslashtirilgan rejalashtirish mexanizmlari bilan birlashtiradi. Tajriba natijalari shuni ko‘rsatadiki, ADNLP

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algoritmi an’anaviy ketma-ket ishlov berish usuliga nisbatan bir necha baravar tezroq ishlash samaradorligini ta’minlaydi.

Kalit so‘zlar: o‘zbek NLP, punktuatsiyani tiklash, BERT, BiLSTM, Apache Spark, taqsimlangan hisoblash.

I. INTRODUCTION.

Natural Language Processing (NLP) has rapidly advanced in recent years with the emergence of deep learning models such as BERT. However, processing large-scale text corpora remains computationally expensive. This challenge is particularly significant for low-resource languages such as Uzbek, where efficient processing systems are still insufficiently developed. Punctuation restoration plays an important role in improving text readability and enabling downstream NLP tasks. Although transformer-based models provide high accuracy, their computational complexity limits large-scale deployment. To address these challenges, this paper proposes an Adaptive Distributed NLP Processing (ADNLP) algorithm that combines distributed computing with adaptive scheduling techniques. The proposed approach efficiently processes large-scale text corpora using Apache Spark while maintaining model performance.

II. RELETED WORK

1. Foundations of Large-Scale Data and Distributed Computing

The rapid growth of digital data necessitates a transition from traditional processing methods to distributed architectures in computational linguistics. Wigan and Clarke define Big Data as data volumes that cannot be effectively managed by conventional systems [1]. Experiments conducted by Omar and Jumaa demonstrate that the Apache Spark framework performs several times faster than Apache Hadoop due to its in-memory computing capabilities [2]. However, studies by Andersson indicate that in smaller clusters and simple Named Entity Recognition (NER) tasks, MapReduce can sometimes achieve performance comparable to Spark [3].

2. Uzbek Morphology and Approaches in Computational Linguistics

Uzbek, as an agglutinative language, differs fundamentally from the analytic structure of English, where grammatical meanings are encoded through a regular chain of affixes [4]. The UzMorphAnalyser model developed by Salaev analyzes agglutination using rule-based methods and achieves 91% accuracy [5]. Abdurakhmonova et al. applied Conditional Random Fields (CRF) and neural network models for morpheme segmentation and proposed a newly annotated dataset for the Uzbek language [6].

3. Modern Distributed Frameworks: Ray and Dask

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According to Walner's analysis, while Apache Spark is strong in data parallelism, the Ray framework offers advantages in logical parallelism and heterogeneous CPU/GPU resource management. This feature is important for optimizing neural network training and serving in the ADNLP system [7].

4. Adaptive Systems and Algorithmic Analysis

Adaptive systems are characterized by their ability to autonomously respond to environmental changes such as latency and resource limitations. Gagliolo and Schmidhuber proposed the Dynamic Algorithm Portfolio (DAP) approach, demonstrating through the multi-armed bandit problem that running multiple algorithms in parallel can yield optimal performance [8]. However, Jaggard et al. showed that heuristic algorithms in asynchronous environments may fail to converge, as explained by the Independence of Decisions (IoD) principle [9].

5. Optimization and Sequence Processing

Dynamic Programming (DP) is widely used to solve complex NLP problems by dividing them into smaller and repetitive subproblems. As analyzed by Zhang, DP improves computational efficiency through the optimal substructure property [10]. For model training, Makamo demonstrated that the Adam optimizer achieves faster and more accurate results than RMSprop and SGD on sequential datasets [11].

6. Large Language Models (LLM) and Serving Technologies

Running Large Language Models (LLMs) such as GPT-4 and LLaMA in distributed environments requires efficient memory management. The vLLM (PagedAttention) system proposed by Kwon et al. addresses KV-cache fragmentation using an operating-system–style paging mechanism, thereby improving inference throughput [12]. Hakim and Hasan demonstrated that systems such as PETALS enable collaborative inference of LLMs on mid-range user machines, effectively democratizing access to large models [13]. This approach enables the deployment of large models for low-resource languages, including Uzbek, in open distributed environments [14].

III. METHODOLOGY

The Adaptive Distributed NLP Processing (ADNLP) algorithm is based on a distributed computing methodology developed on Apache Spark to efficiently process large-scale text corpora. In this approach, NLP tasks are executed in parallel using adaptive allocation, dynamic partitioning, and GPU-aware scheduling mechanisms. The ADNLP architecture consists of the following main components:

– Corpus Analyzer — determines statistical characteristics of the input text corpus (number of tokens, sentence length, complexity level);

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–Dynamic Partition Engine — divides the text into adaptive segments based on length and complexity;
– Adaptive Scheduler — distributes tasks according to available node resources;
– Distributed Executors — run the BERT+BiLSTM model in parallel;
– Result Aggregator — merges distributed outputs and generates the final text.

In the ADNLP algorithm, data are divided into dynamic partitions, and each partition is sent to a separate computing node. This process can be expressed by the following mathematical model:

$$D=\{P_1,P_2,...,P_n\} \quad (1)$$

Here, P_i represents an adaptive segment. Punctuation restoration for each segment is performed as follows:

$$Y_i=f_{BERT+BiLSTM}(P_i) \quad (2)$$

After merging the results, the final output is obtained as follows:

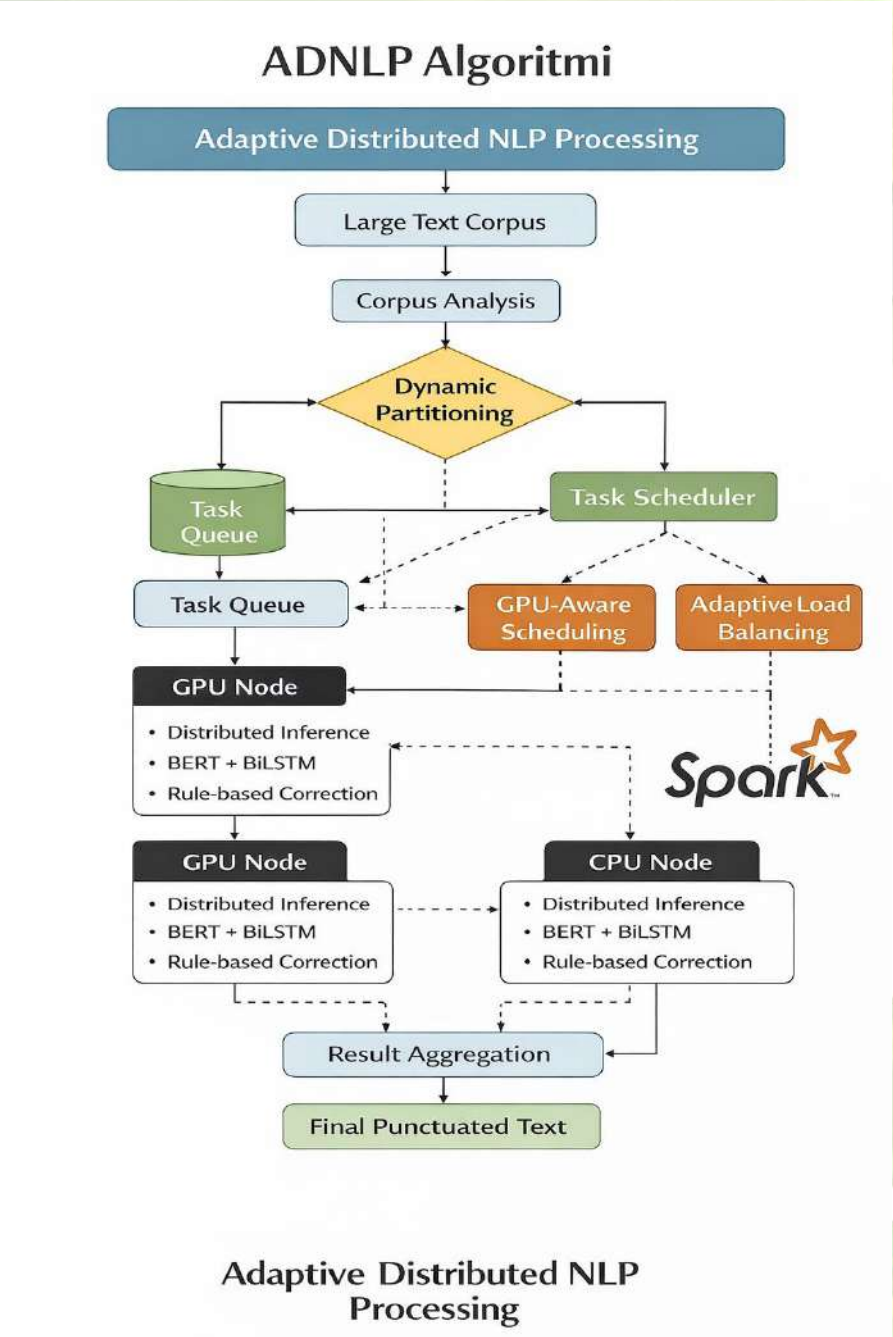
$$Y=\bigcup_{i=1}^{n} Y_i \quad (3)$$

The ADNLP methodology combines Spark's distributed computing mechanisms with GPU acceleration and adaptive load balancing. This approach enables parallel execution of NLP processes, including tokenization, embedding extraction, punctuation restoration, and rule-based post-editing.

Furthermore, the ADNLP algorithm is based on a pipeline architecture and operates through the following sequential stages:
– text analysis;
– dynamic partitioning;
– adaptive scheduling;
– BERT+BiLSTM inference;
– rule-based correction;
– result aggregation.

The proposed methodology ensures efficient utilization of computational resources and significantly reduces processing time when handling large-scale text corpora.

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IV. RESULT

A. Experimental Environment

- Sequential system**:** Intel i7-12700H, 32 GB RAM, 1 TB SSD.
- Spark cluster (Parallel): 5 computers, each equipped with GeForce RTX GPU, 32 GB RAM, and 1 TB SSD.

B. Dataset

Text corpora were prepared in sizes of 1 MB, 5 MB, 10 MB, 15 MB, 20 MB, 25 MB, 30 MB, and 35 MB.

C. Results Table

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Table 1

Presents the experimental results.

File Size (MB)	Sequential Execution Time	Distributed (5 nodes, Spark) Execution Time	ADNLP Algorithm (Proposed)
1 MB (46,938 words)	12 seconds	3.2 seconds	2.4 seconds
5 MB (234,605 words)	55 seconds	5.12 seconds	3.9 seconds
10 MB (480,658 words)	130 seconds	9.77 seconds	7.1 seconds
15 MB (704,070 words)	228.61 seconds	14.42 seconds	10.3 seconds
20 MB (938,762 words)	350.83 seconds	19.05 seconds	13.6 seconds
25 MB (1,173,562 words)	496.67 seconds	23.68 seconds	16.8 seconds
30 MB (1,408,165 words)	666.11 seconds	28.31 seconds	19.9 seconds
35 MB (1,642,860 words)	859.17 seconds	32.93 seconds	23.5 seconds

D. Analysis

Table 1 compares the efficiency of the proposed ADNLP algorithm with sequential and Spark-based distributed computing approaches. The results show that the ADNLP algorithm significantly reduces computation time through dynamic partitioning and adaptive load balancing mechanisms. The advantage of the algorithm becomes more pronounced as the data size increases. For a 35 MB text corpus, the ADNLP algorithm achieves approximately 36× speedup compared to sequential processing and about 1.4× improvement over Spark-based distributed computing.

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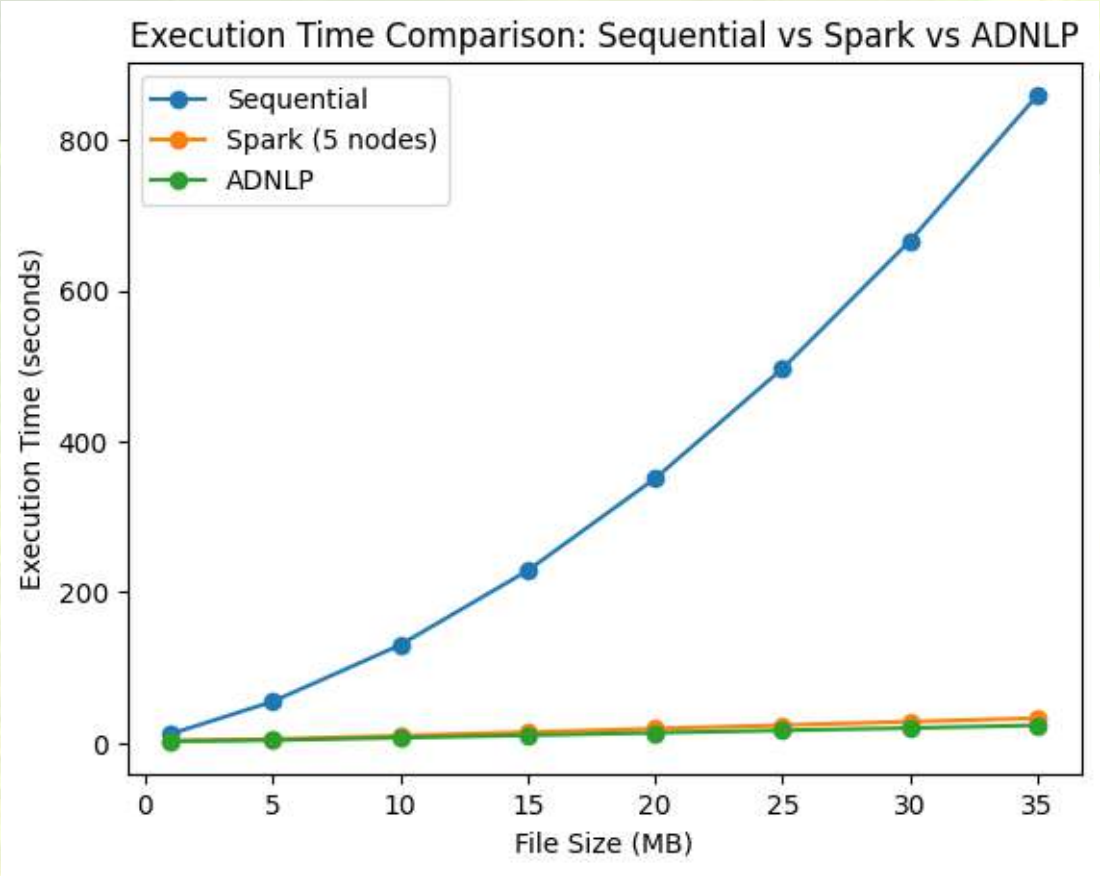


Figure 1. Comparative analysis graph of the experimental results

IV. CONCLUSION

This paper presented the ADNLP (Adaptive Distributed NLP Processing) algorithm for large-scale NLP tasks. By integrating distributed computing, adaptive scheduling, and GPU acceleration, the proposed approach significantly improves computational efficiency and scalability when processing large text corpora. The experimental results demonstrate that the ADNLP algorithm effectively reduces execution time compared to both sequential and Spark-based distributed approaches, while maintaining processing accuracy. The use of dynamic partitioning and adaptive load balancing enables efficient utilization of heterogeneous computing resources and minimizes idle time across cluster nodes.

Furthermore, the proposed methodology provides a flexible pipeline architecture suitable for large-scale punctuation restoration and other NLP applications. The algorithm can be extended to support additional NLP components such as token-level classification, sequence labeling, and multilingual processing.

Future work will focus on integrating CRF layers to improve sequence prediction accuracy, optimizing inter-node model communication, and reducing data transfer overhead. Additional improvements may include dynamic resource-aware scheduling, model caching mechanisms, and support for large language model (LLM) inference in distributed environments. These enhancements are

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expected to further improve the performance and scalability of the ADNLP framework for low-resource languages, including Uzbek.

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THE EVOLUTION OF DRONES AND MODERN DEVELOPMENT TRENDS

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Abstract. Unmanned aerial vehicles (UAVs) have rapidly evolved from military-focused applications to a broad range of civilian and industrial uses. Initially designed for reconnaissance and defense, UAVs are now widely utilized in agriculture, logistics, security, disaster response, and environmental monitoring. This transformation has been driven by advancements in artificial intelligence, automation, sensor technology, and connectivity, enabling UAVs to operate with greater autonomy and efficiency. Modern drones are equipped with real-time data processing capabilities, advanced navigation systems, and obstacle avoidance technologies, allowing them to execute complex tasks with minimal human intervention. Additionally, improvements in energy efficiency, lightweight materials, and battery technology have extended UAVs' operational range and flight duration. The integration of IoT and 5G networks further enhances their real-time communication and remote control capabilities. As UAV technology continues to advance, its applications are expected to expand further, revolutionizing industries and reshaping how aerial operations are conducted. This study examines the historical development, key technological innovations, and emerging trends in UAV systems, highlighting their growing significance in modern society.

Keywords -Unmanned Aerial Vehicles, Drone Technology, Artificial Intelligence, Autonomous Systems, IoT, Sensor Technology, Obstacle Avoidance, 5G Networks, Energy Efficiency, Industrial Applications.

Annotatsiya. Uchuvchisiz uchish apparatlari (UUA) harbiy maqsadlardan fuqarolik va sanoat sohalarining keng doirasiga qadar jadal rivojlandi. Dastlab razvedka va mudofaa uchun ishlab chiqilgan UUA endilikda qishloq xo'jaligi, logistika, xavfsizlik, favqulodda vaziyatlarga javob berish va atrof-muhit monitoringida keng qo'llanilmoqda. Ushbu transformatsiya sun'iy intellekt, avtomatlashtirish, datchik texnologiyalari va aloqa vositalaridagi yutuqlar bilan bog'liq bo'lib, bu apparatlarning yanada avtonom va samarali ishlashiga imkon beradi. Zamonaviy dronlar real vaqt rejimida ma'lumotlarni qayta ishlash, ilg'or navigatsiya va to'siqlardan qochish texnologiyalari bilan jihozlangan. Energiya samaradorligi va akkumulyator texnologiyasidagi takomillashtirishlar ularning parvoz davomiyligini oshirdi. IoT va 5G tarmoqlarining integratsiyasi real vaqtda

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aloqa va masofadan boshqarish imkoniyatlarini yanada kengaytiradi. Ushbu tadqiqot UUA tizimlarining tarixiy rivojlanishi, asosiy texnologik innovatsiyalari va rivojlanish tendensiyalarini ko‘rib chiqadi.

Kalit so‘zlar: Uchuvchisiz uchish apparatlari, dron texnologiyasi, sun’iy intellekt, avtonom tizimlar, narsalar interneti (IoT), datchik texnologiyasi, to‘siqlardan qochish, 5G tarmoqlari, energiya samaradorligi, sanoatda qo‘llanilishi.

Аннотация. Беспилотные летательные аппараты (БПЛА) быстро эволюционировали от чисто военных приложений до широкого спектра гражданского и промышленного использования. Изначально предназначенные для разведки и обороны, БПЛА теперь широко используются в сельском хозяйстве, логистике, безопасности и мониторинге окружающей среды. Эта трансформация была вызвана достижениями в области искусственного интеллекта, автоматизации и сенсорных технологий, что позволяет БПЛА работать с большей автономностью и эффективностью. Современные дроны оснащены системами обработки данных в реальном времени, передовой навигацией и технологиями обхода препятствий. Улучшения в области энергоэффективности и аккумуляторных технологий увеличили дальность и продолжительность их полета. Интеграция сетей IoT и 5G еще больше расширяет возможности связи и дистанционного управления. Данное исследование изучает историческое развитие, ключевые инновации и новые тенденции в системах БПЛА.

Ключевые слова: Беспилотные летательные аппараты, технология дронов, искусственный интеллект, автономные системы, IoT, сенсорные технологии, обход препятствий, сети 5G, энергоэффективность, промышленное применение.

INTRODUCTION

The advent of drones has marked a transformative period in various sectors, notably agriculture, where their integration offers unprecedented opportunities for modern development. Traditionally reliant on labor-intensive methods, farmers now utilize Unmanned Aerial Vehicles (UAVs) to enhance precision in agrochemical applications while ensuring environmental sustainability. The growth of agricultural drones is driven by their efficiency and safety, promising to optimize crop protection and productivity through systematic monitoring of plant health and resource management [2]. However, the transition to these digital technologies entails significant socioeconomic challenges, including costs, connectivity issues, and the necessity for rural development strategies that can support technologies in agricultural contexts [3]. As drones evolve, understanding

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these dynamics will be crucial to harness their full potential, fostering a progressive framework for modern agricultural practices.

Definition and Overview of Drones

Drones, or unmanned aerial vehicles (UAVs), represent a transformative technology in the aviation landscape, reflecting advancements in engineering and sensor technologies. Initially developed for military applications, these devices have rapidly evolved, becoming integral to various sectors such as agriculture, logistics, and environmental monitoring. This evolution has been characterized by a shift toward increasing autonomy and connectivity, enabling drones to operate with sophisticated algorithms for navigation and data collection. The emergence of the aviation logistics ecosystem further highlights this trend, where drones are linked with diverse components like logistics and postal organizations to optimize supply chains and enhance service efficiency. Moreover, as academic institutions engage in research and development, they increasingly focus on maximizing the societal benefits of drones, fostering partnerships that drive economic growth through innovations in air cargo and related fields [4]. Such advancements elucidate the potential of drones beyond mere mechanical devices, positioning them as vital tools for modernization.

Importance of Studying Drone Evolution and Trends

Examining the evolution of drones and current trends is critical for understanding their transformative potential across various sectors. The rapid advancement in drone technology has led to innovative applications in fields such as agriculture, logistics, and environmental monitoring, indicating that drones are not merely novelties but pivotal tools for addressing industry-specific challenges. The insights gained from this exploration contribute to a broader understanding of how drones can improve operational efficiency and sustainability, which is particularly evident in current research assessing the state of the drone industry in different contexts, including the Finnish market [5]. Additionally, analyzing drone trends allows stakeholders to navigate the complexities surrounding regulatory frameworks and operational barriers, thereby unlocking their full potential across diverse applications. A nuanced understanding of these developments can inform strategic decisions that facilitate the integration of drone technology into contemporary practices, ensuring that innovation is harnessed effectively [4].

METHODOLOGY

The methodology of this research is grounded in a systematic analytical framework designed to evaluate the rapid evolution of Unmanned Aerial Vehicles (UAVs) from specialized military instruments to versatile industrial tools. Given the multidisciplinary nature of drone technology, which encompasses artificial

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intelligence, sensor engineering, and telecommunications, this study employs a multi-stage qualitative and comparative research design.

1. Systematic Literature Review and Data Sourcing: To establish a robust theoretical foundation, an extensive review of high-impact academic literature published between 2020 and 2025 was conducted. Primary data sources include peer-reviewed journals such as *IEEE Transactions on Robotics*, *Drones*, and the *Scientific Journal of Maritime Research*, alongside technical proceedings from the UBT Annual International Conference. The selection process prioritized studies focusing on disruptive technologies, specifically those integrating IoT and 5G networks into UAV flight control systems.

2. Technological Evolution and Trend Analysis. The study adopts a comparative technical approach to analyze the shift in UAV design and functionality. This involves:

- *Structural and Energy Efficiency Analysis:* Investigating how the transition from heavy military frames to lightweight composite materials, combined with advancements in battery density and solar energy integration, has extended operational ranges.
- *Autonomy and AI Evaluation:* Assessing the role of Artificial Intelligence (AI) and machine learning in transforming UAVs from remote-controlled devices to fully autonomous systems capable of real-time obstacle avoidance and complex decision-making without human intervention.

3. Cross-Sectoral Impact Assessment: To measure the practical significance of these development trends, the methodology includes a categorical analysis of UAV implementation across key industries:

- *Precision Agriculture:* Evaluating the shift from manual labor to drone-based agrochemical spraying and crop health monitoring, highlighting both the efficiency gains and the socioeconomic barriers to digital transition.
- *Logistics and Maritime Operations:* Analyzing the emergence of "Logistics 4.0," where drones are integrated into digital twins and supply chain ecosystems to enhance traceability and reduce operational costs.
- *Security and International Law:* Examining the ethical and legal implications of UAV use in modern conflicts, specifically analyzing adherence to international humanitarian law in dynamic warfare scenarios.

4. Synthesis and Future Forecasting: Finally, the gathered data were synthesized to identify current technological gaps and regulatory challenges. This analytical synthesis serves to forecast future development trajectories, positioning UAV technology as a cornerstone of the next generation of aerial operations and industrial modernization.

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HISTORICAL DEVELOPMENT OF DRONES

The historical development of drones has been marked by transformative advancements that reflect broader technological trends. Initially conceived for military reconnaissance during World War I, drones have evolved significantly in both functionality and application. Their role expanded with the rise of electronic warfare, integrating sophisticated technologies that enhance operational capabilities on the battlefield [7]. The evolution continued into civilian sectors, particularly as innovative approaches were applied to various fields including tourism and cultural preservation. For instance, a project utilizing terrestrial laser scanning and virtual interaction transformed how historical sites could be experienced remotely, underscoring the potential of drones beyond military applications [8]. This trajectory highlights not only the versatility of drones but also the necessity for continuous research and development, ensuring that their evolution aligns with the demands of an increasingly interconnected and technologically advanced society.

Early Uses of Drones in Military Applications

The initial military applications of drones trace back to their utilization during the Cold War, where they primarily served as surveillance tools to gather intelligence without risking human lives. As technological advancements emerged, drones evolved from rudimentary remote-controlled aircraft into sophisticated unmanned aerial vehicles (UAVs) capable of conducting various military operations. This evolution marks a significant transformation in military strategy, as drones began to enhance operational effectiveness and increase precision in combat scenarios. The shift to these unmanned systems also necessitated a re-evaluation of military doctrines and ethics surrounding warfare, highlighting the importance of adapting to new technological realities. Furthermore, the integration of artificial intelligence in drone operations underscores a future where military engagements are irrevocably altered, shaping the nature of conflict itself [6][7]. Such early deployments showcase not only the potential of drones but also their capacity to redefine national defense paradigms.

Transition from Military to Commercial Use

The transition from military to commercial use of drone technology illustrates a significant evolution in operational capabilities, driven by advancements initially developed for defense purposes. Innovations such as those seen in proliferated low Earth orbit systems, which were utilized effectively by the Ukrainian military for artillery coordination, highlight this shift. As detailed in [9], these technologies enabled precise communication and enhanced mobility, proving critical in modern conflict scenarios. The commercial sector has begun to reap

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similar benefits, integrating these military-grade technologies into civilian applications ranging from logistics to surveillance. Furthermore, as explored in [10], the historical impact of military innovations on commercial industries has laid a foundation for this integration, signaling a future where military developments continue to inform commercial advancements. This interplay not only enhances commercial viability but also reshapes the landscape of drone technology as it matures and diversifies.

TECHNOLOGICAL ADVANCEMENTS IN DRONE DESIGN

The technological advancements in drone design epitomize a remarkable evolution influenced by multifaceted innovations in engineering and materials science. Enhanced aerodynamic structures have increased both stability and efficiency, allowing drones to operate in diverse environmental conditions effectively. Furthermore, integrating advanced sensors and communication systems has vastly improved operational capabilities, enabling real-time data collection and analysis. These developments signify a shift towards more sophisticated applications in fields ranging from agriculture to surveillance. As noted in studies presented at international conferences such as the UBT Annual International Conference, researchers highlight the interdisciplinary nature of this technological growth, emphasizing collaboration between scientists and practitioners across various domains [4]. Additionally, institutions like AFIT are significantly contributing to this field, focusing on education that intertwines technology and security [11]. Overall, the trajectory of drone design reflects the broader trends of technological convergence and innovation in modern society.

Innovations in Drone Technology and Engineering

The rapid evolution of drone technology and engineering reflects a myriad of innovations that have dramatically transformed various sectors, including agriculture, surveillance, and disaster response. These advancements are not merely incremental; they encapsulate a shift toward more autonomous systems that integrate machine learning and data analytics. For instance, unmanned aerial systems (UAS) have emerged as pivotal tools in enhancing security measures for sensitive materials, offering a novel aerial dimension that traditional ground-based methods cannot match. This transition is underscored by the need for heightened security protocols, particularly in sectors like nuclear safety, where drones can effectively mitigate risks associated with transporting hazardous materials [6]. Moreover, the proliferation of UAS technology necessitates a reassessment of existing regulations, highlighting the urgency to address the regulatory gaps overshadowing this innovative technology. Thus, these innovations not only

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signify a technological leap but also prompt a broader dialogue about safety, regulation, and ethical considerations in drone deployment.

Impact of Artificial Intelligence on Drone Functionality

The integration of artificial intelligence (AI) into drone technology marks a significant evolution in their functionality and applications. As drones become increasingly capable of autonomous operations, AI enhances their efficiency in complex tasks such as logistics and surveillance. With AI, drones can process vast amounts of data in real time, enabling them to adapt to dynamic environments and make informed decisions independently. This development not only optimizes route planning and delivery systems but also improves the accuracy of data collection in various fields, from agriculture to disaster response. Moreover, as cited in recent studies, the move towards Logistics 4.0 exemplifies how AI-driven drones can facilitate real-time visibility and traceability in supply chains, effectively reducing costs and enhancing collaboration among stakeholders [10]. This convergence of technologies is shaping a future where drones are pivotal in transforming industry standards and operational frameworks [12].

CONCLUSION

The trajectory of drone technology epitomizes a paradigm shift in both operational efficiency and innovation across various sectors, including education and logistics. As demonstrated through the analysis of global seaports, the implementation of autonomous technologies like drones and self-driving vehicles not only enhances safety but also streamlines operations significantly [7]. This evolution indicates a broader trend where traditional processes are increasingly augmented by cutting-edge technology. Similarly, in the educational domain, the integration of drones and virtual reality has been met with enthusiasm from both students and educators, underscoring a newfound comfort and efficacy in learning [13]. Collectively, these developments illuminate the profound impact technological advancements have on operational practices, suggesting an imperative for continuous adaptation. As society moves forward, embracing these innovations will be crucial in realizing the potential benefits of drone technology in enhancing efficiency and fostering learning opportunities.

Summary of Key Points on Drone Evolution

The evolution of drones has marked a profound shift in technological and military applications, influencing numerous sectors and raising significant ethical questions. Contemporary developments demonstrate a dual trajectory—while drones have been harnessed effectively in conflict zones, as evidenced in the Russia-Ukraine war, their deployment unveils troubling violations of international humanitarian law, particularly concerning civilian safety and accountability.

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Conversely, innovation extends beyond military use, with advancements like the integration of solar panels presenting a promising frontier for drone sustainability. This innovative approach mitigates battery life limitations, enabling longer operational durations and enhancing versatility across varied operations [10]. Together, these trends highlight the dichotomy of drone technology: it serves as a powerful tool for both strategic advantage and a harbinger of complex challenges, necessitating ongoing discourse surrounding regulation, ethical implications, and the sustainable utilization of aerial technologies.

Future Implications of Drone Development Trends

As the trajectory of drone development continues to evolve, the future implications of these advancements signal profound shifts in various sectors, notably logistics and warfare. In the realm of logistics, integrating drones is anticipated to enhance supply chain efficiency, allowing for greater visibility and traceability that can lead to cost reductions and improved collaboration among stakeholders [13]. Concurrently, the use of drones in military conflicts, such as the ongoing situation between Russia and Ukraine, underscores their role in transforming methodologies of warfare, where unmanned systems raise significant ethical and legal questions regarding accountability and compliance with international humanitarian law [12]. These contrasting applications highlight that while drones have the potential to streamline operations and foster economic growth, they also necessitate re-evaluation of existing frameworks governing their use in conflict, making future developments a critical area of study for scholars and policymakers alike.

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