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IRSTI: 68.85.39
UDC: 631.24
https://doi.org/10.52269/22266070_2025_1_188

DESIGNING A TECHNOLOGICAL SCHEME FOR THE DISPOSAL OF LIVESTOCK WASTE

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The article considers the issue of developing a technological model for processing livestock waste. An analysis of the problem of animal waste management has shown that raw manure waste without processing has a negative impact on the environment, causing soil poisoning, polluting the air, groundwater and is a source of infectious diseases. Ammonia is one of the most common pollutants emanating from livestock farms. This gas forms during the decomposition of organic residues such as manure and urine released by animals. It tends to accumulate in the lower layers of the atmosphere, posing threats to both ecosystems and human health. Analysis of the composition of animal husbandry waste has shown that animal waste is a valuable source of organic and mineral substances and, with appropriate processing, valuable

products such as fertilizers and additional energy such as biogas can be obtained from them. A scheme of a technological complex consisting of four modules is proposed for waste recycling. It is also planned to introduce a module for obtaining high-quality fertilizers through the enrichment of sludge formed during methanogenesis, followed by granulation. Based on a comparative analysis of existing methods and technologies, an optimal technological scheme for the production of biogas and organo-mineral fertilizers in livestock complexes has been developed and proposed.

Keywords: *energy, biogas, source, energy intensity, research.*

МАЛ ШАРУАШЫЛЫҒЫ ҚАЛДЫҚТАРЫН ҚАЙТА ӨҢДЕУДІҢ ТЕХНОЛОГИЯЛЫҚ СХЕМАСЫН ЖОБАЛАУ

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Мақалада мал шаруашылығы қалдықтарын қайта өңдеудің технологиялық моделін әзірлеу мәселесі қарастырылған. Мал шаруашылығы қалдықтарын өңдеу мәселесін талдау көрсеткендей, қалдықтар – өңделмеген көң қоршаған ортаға теріс әсер етеді, топырақтың улануын тудырады, ауаны, жер асты суларын ластайды және жұқпалы аурулардың көзі болып табылады. Аммиак – мал шаруашылығынан келетін ең көп таралған ластаушы заттардың бірі. Бұл газ жануарлар шығаратын көң мен зәр сияқты органикалық қалдықтардың ыдырау процесінде пайда болады. Ол атмосфераның төменгі қабаттарында жиналуға қабілетті, бұл экожүйеге де, адам денсаулығына да қауіп төндіреді. Мал шаруашылығы қалдықтарының құрамын талдау көрсеткендей, мал қалдықтары органикалық және минералды заттардың құнды көзі болып табылады және олардан тиісті өңдеу арқылы құнды өнімдер – тыңайтқыштар мен қосымша энергия – биогаз алуға болады. Қалдықтарды өңдеу үшін төрт модульден тұратын технологиялық кешен схемасы ұсынылған. Сондай-ақ, метаногенез процесінде пайда болатын шламды байыту, содан кейін түйіршіктеу арқылы жоғары сапалы тыңайтқыштар алу үшін модульді енгізу көзделеді. Қолданыстағы әдістер мен технологияларды салыстырмалы талдау негізінде мал шаруашылығы кешендерінде биогаз бен органоминералды тыңайтқыштарды алудың оңтайлы технологиялық схемасы әзірленіп, ұсынылды.

Түйінді *сөздер:* *энергия, биогаз, дереккөз, энергия сыйымдылығы, зерттеу.*

ПРОЕКТИРОВАНИЕ ТЕХНОЛОГИЧЕСКОЙ СХЕМЫ УТИЛИЗАЦИИ ОТХОДОВ ЖИВОТНОВОДЧЕСКОГО ХОЗЯЙСТВА

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В статье рассмотрен вопрос о разработке технологической модели переработки отходов животноводства. Анализ проблемы обращения с отходами животноводства показал, что отходы – сырой навоз без переработки – оказывают негативное воздействие на окружающую среду, вызывая отравление почв, загрязняют воздух, подземные воды и являются источником инфекционных заболеваний. Аммиак является одним из самых распространённых загрязнителей, исходящих от животноводческих хозяйств. Этот газ возникает в процессе разложения органических остатков, таких как навоз и моча, выделяемые животными. Он способен накапливаться в низших слоях атмосферы, что создаёт угрозы как для экосистем, так и для здоровья человека. Анализ состава отходов животноводства показал, что животноводческие отходы являются ценным источником органических и минеральных веществ и из них, при соответствующей переработке, можно получить ценные продукты – удобрения и дополнительную энергию – биогаз. Для переработки отходов предложена схема технологического комплекса, состоящая из четырех модулей. Также предполагается внедрение модуля для получения высококачественных удобрений через обогащение шлама, образующегося в процессе метаногенеза, с последующей грануляцией. На основе сравнительного анализа существующих методов и технологий разработана и предложена оптимальная технологическая схема получения биогаза и органоминеральных удобрений на животноводческих комплексах.

Ключевые слова: *энергия, биогаз, источник, энергоемкость, исследование.*

Introduction. One of the most important factors of economic progress is the introduction of resource-saving technologies. Such technologies are aimed at minimizing the cost of fuel, energy, raw materials, materials, water and air needed for production. These include the use of recycled materials, waste recycling, energy recovery, and closed water cycles. This contributes to the conservation of natural resources and reduces the negative impact on the environment [1, p. 39].

In the modern world, the problem of waste disposal generated in agriculture, including the treatment and preparation of large volumes of manure and manure runoff, is becoming particularly relevant. These wastes can have a significant anthropogenic impact on ecosystems. By the end of the 20th century, livestock numbers in livestock farms were growing in many countries of the world, which was associated with the transition to industrial farming methods [2, p. 112096; 3, p. 1].

The main factors contributing to environmental pollution (atmosphere, soil, water) as a result of livestock farms are emissions into the air and wastewater. Air emissions generated by farms have a significant impact on both the state of the atmosphere and the level of pollution of surface waters. In livestock complexes, especially pig-breeding ones, the main sources of air pollution are rooms where animals are kept [4, p. 35].

Purpose, objectives. The research purpose is to reduce the anthropogenic impact on the environment caused by waste from livestock complexes by developing technologies for the production of organic mineral fertilizers and biogas. The research object are technologies for processing animal husbandry waste. The research subject is the development of a technology for processing livestock waste into organic fertilizers and biogas.

To achieve this purpose, the following objectives have been defined:

1. To study the problems associated with the management of livestock waste and their negative impact on the environment.

2. Analyze existing technologies and equipment for processing livestock waste, as well as methods for obtaining biogas and organic fertilizers.

3. To develop a technological scheme for the production of organic mineral fertilizers and biogas from livestock waste.

4. To evaluate the ecological and economic efficiency of the proposed technological complex.

Materials and methods of research. In Russia and Kazakhstan, research is actively underway in the field of recycling waste from livestock complexes to reduce anthropogenic impact on the environment. Scientists are developing technologies for the production of biogas and organic fertilizers, which contributes to solving environmental problems and improving agricultural efficiency. A study of the works of scientists: Popova A.I., Kuznetsova V.V., Kalmykova S.N., Abdullayeva K.S., Sagintayeva N. confirmed the diversity of trends in the progress of biogas production technologies. The most promising approaches include: improving the composition of the starter culture; specialized use of process activators; optimization of temperature conditions; development of unique designs of gas bioreactors (fermenters) and storage tanks (gas tanks); as well as increasing the stability and reliability of biogas plants in general [5, p. 35; 6, p. 2193].

One of the most common pollutants released by livestock facilities is ammonia (NH_3). This gas is formed as a result of the decomposition of organic waste, such as manure and animal urine, and can accumulate in the surface layer of the atmosphere, posing risks to ecosystems and human health.

During 2024, research was conducted at a pig breeding complex (108 thousand heads), located in Aktobe, Bestamak Livestock Complex LLP, and at a poultry complex (1800 thousand heads) in the Badam village in the South Kazakhstan region, Ordabasy Kus LLP. To measure the concentration of ammonia, a gas analyzer with high accuracy and sensitivity was used. Measurements were carried out in various areas of the complex, including animal husbandry, manure storage areas, as well as at distances of 2.5 km, 3.5 km and 5.0 km from the breeding facilities. The data was recorded over several weeks, taking into account various weather conditions and technological processes.

The concentration of ammonia (NH_3) was studied using a GANK-4 gas analyzer designed to measure the content of harmful gases in atmosphere. This device provides high measurement accuracy and a wide range of detectable concentrations, rendering it suitable for monitoring air pollution in areas affected by livestock facilities.

Results and discussion. The results of the ammonia (NH_3) concentration study conducted using a gas analyzer are shown in Table 1.

Table 1 – The state of atmospheric air in the zones affected by livestock facilities operation (NH_3 air content)

Indicators	Pig farm (108 thousand. heads)	Poultry farm (1800 thousand. Heads)
NH_3 air content: at a distance of 2.5 km from the facilities	0.44 mg/m^3	0.32 mg/m^3
At a distance of 3.5 km from the facilities	0.22 mg/m^3	0.19 mg/m^3
At a distance of 5.0 km from the facilities	0.18 mg/m^3	0.12 mg/m^3

Based on a comparative analysis of technologies, equipment and process optimization methods, we have created a technological complex comprising four modules (see Figure 1): 1. An anaerobic digestion module for biogas production; 2. A module for the production of organo-mineral fertilizers; 3. A composting module; 4. A bio-desodorization module with the introduction of EM technologies.

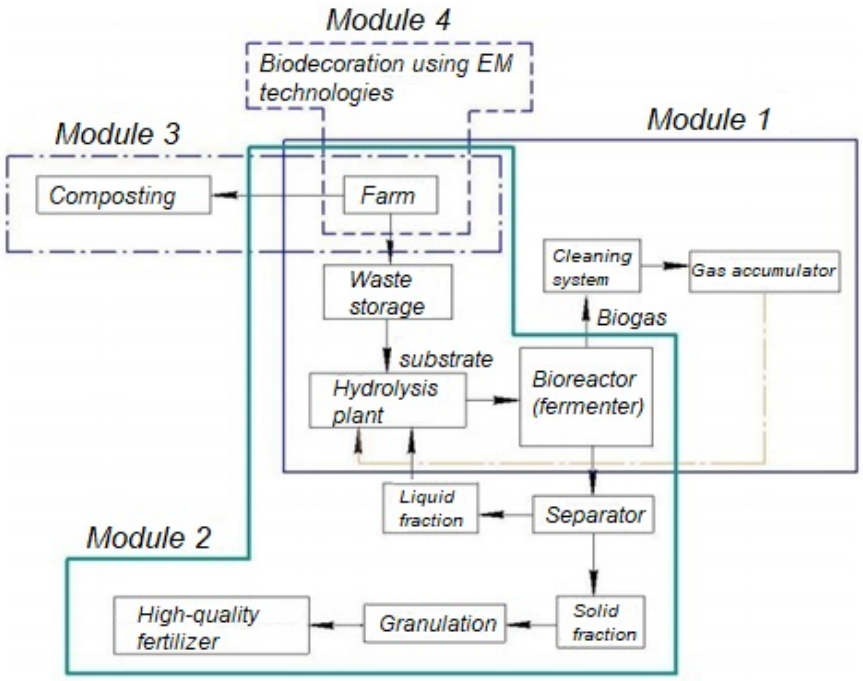

Figure 1 – Modules of the technological complex of deodorization, production of biogas and fertilizers from agricultural waste

Module 1 – The module of anaerobic fermentation, during which biogas is produced, is represented by the following technological scheme: waste storage – hydrolysis plant – bioreactor (fermenter) – biogas purification system – gas accumulator.

One of the key features of this plant is that the hydrolysis plant is separated from the bioreactor. Waste from the agro-industrial complex enters the storage tank, and then is sent to a hydrolysis plant located separately from the fermenter. In the hydrolysis plant, the process of hydrolysis – oxidation occurs under the influence of hydrolysis bacteria, which leads to the formation of fatty acids. After that, the resulting mass is sent to a fermenter, where methane-producing bacteria process fatty acids with the release of biogas [6, p. 2193, 7, p. 408].

A feature of the technology being implemented is the presence of a hydrolysis unit in the structure of a biogas plant. It is a sealed vessel with a heating system, a mixer, a pumping station and an inlet separator. The hydrolysis unit is connected to the fermenter, and the prepared biomass is fed into it constantly or at certain intervals. The maximum gas release is achieved by adding biomass corresponding to the decomposition level. The biomass supply is regulated automatically.

During the plant operation, biogas is released with the chemical composition shown in Table 2.

The specific heat of combustion of biogas ranges from 5,500 to 6,500 kcal/m^3. The energy potential of one cubic meter of biogas is comparable to the energy of 0.6 m^3 of natural gas, 0.74 liters of oil, 0.65 liters of diesel fuel and 0.48 liters of gasoline. The use of biogas also saves fuel oil, coal, electricity and other energy sources.

The installation of biogas plants contributes to the improvement of the environmental situation on farms, poultry houses and adjacent territories. This helps to avoid pollution of reservoirs such as gullies, lakes, ravines and rivers, thereby improving the ecology of habitats.

Table 2 – Chemical composition of biogas

Substance	Chemical formula	Content, %
Methane	CH_4	40,0…70,0
Carbon dioxide	CO_2	25,…55,0
Water vapor	H_2O	0…10,0
Nitrogen	N_2	< 5,0
Oxygen	O_2	< 2,0
Hydrogen	H_2	< 1,0
Hydrogen sulfide	H_2S	< 1,0
Ammonia	NH_3	< 1,0

Data on the amount of biogas (m^3) produced from one ton of waste are presented in Table 3.

Liquid fertilizer can be applied to the soil, dried and turned into granules, and if necessary also briquetted. By mixing it with various components in certain proportions, compost and soil mixtures suitable for greenhouses and so on can be obtained. We propose to add a module to the technological complex that will produce high-quality fertilizers by enriching the sludge formed during methanogenesis, followed by granulation of fertilizers. The use of such a fertilizer is economically efficient.

Table 3 – Biogas output from 1 ton of waste

Biomaterial, one ton	Biogas, m
Cattle slurry	45.00
Pig manure	60.00
Processed grain of the alcohol and beer industry	65.00
Cattle manure mixed with straw	70.00
Beetroot tops	75.00
Bird droppings	80.00
Beet production waste	88.00
Biological waste	100.00
Waste from sugar production	115.00
Waste from rye harvesting	165.00
Pig manure mixed with cattle manure	180.00
Production waste from feed beets	200.00
Corn silage	250.00
Grass silage	300.00
Slaughterhouse waste	350.00

Module 2 is a module for the production of organo-mineral fertilizers. The second module of the complex is aimed at developing a technology for producing organo-mineral fertilizers (see Figure 2). Based on the patent analysis, a scheme for the preparation and granulation of organo-mineral fertilizers from sludge obtained in a bioreactor was proposed.

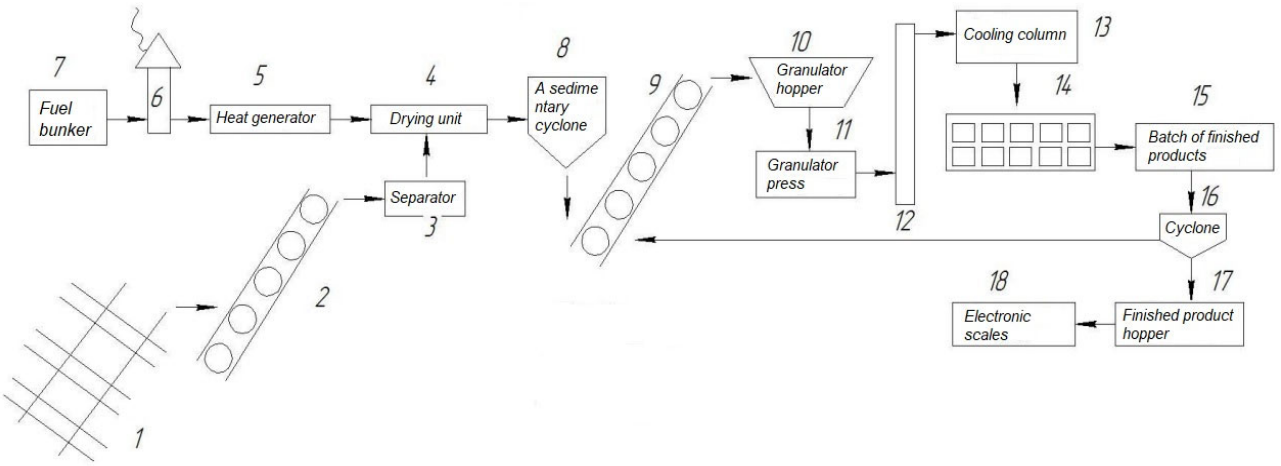

Figure 2 – Technology for the production of organo-mineral fertilizers.

1 – movable floor; 2, 9 – chain conveyor; 3 – separator; 4 – drying unit; 5 – heat generator; 6 – labor; 7 – storage hopper; 8 – sedimentary cyclone; 10 – granulator hopper; 11 – granulator press; 12 – noria; 13 – cooling column; 14 – sorting; 15 – noria for finished products; 16 – cyclone; 17 – hopper of finished products; 18 – electronic scales

Module 3 is a composting module. The third module of our technological complex is designed to produce compost (see Figure 3). As a result of the patent search, we have developed the design of a bio–fermenter composter, which is a rectangular structure made of bricks or other building materials equipped with a forced air supply system to the fermentation ointment. The work is carried out periodically.

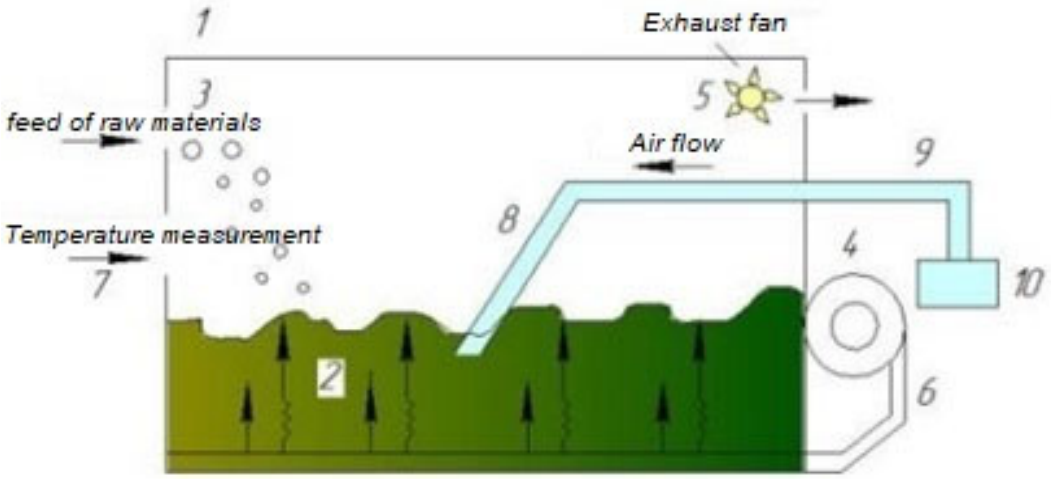

Figure 3 – Compost production technology (third module).

1 – room for fermentation of raw materials, 2 – working mixture, 3 – gates; 4 – pressure fan; 5 – exhaust fan; 6 – pressure duct system; 7 – orifices for temperature measurement; 8 – oxygen meter rod; 9 – flexible hose; 10 – oxygen meter.

To speed up the composting process, it is recommended to use bioactive additives. Specially developed biologics may include EM preparations, enzymes and microorganisms obtained from compost or specially selected strains – destructors of cellulose, lignin, proteins and other biopolymers [8, p. 67; 9, p. 123036]. Additives based on local compost microflora can be obtained using a cumulative culture on compostable materials, for example, in devices with mechanical mixing and aeration. The resulting crop is added to the bulk of the compost. This approach can be applied to accelerate the decomposition and neutralization of materials contaminated with xenobiotics (for example, pesticides and petroleum products). It is also possible to reduce the composting time by irrigating the compost with an aqueous extract from the already prepared compost.

As for the 4th module of bio-desodorization, the use of EM technologies to eliminate odors and improve the microclimate in livestock complexes seems to be the most promising. Specially created effective microbiological preparations can significantly reduce the level of unpleasant odors in such rooms. Analysis of food waste, such as raw pig and cattle manure, indicates that they are a valuable source of organic and mineral substances. With proper processing, they can be used for the production of fertilizers and biogas, which is a promising direction in solving the problem of waste recycling and environmental pollution [10, p. 1080].

The calculation of the parameters of a biogas plant, which is designed for processing organic waste in order to obtain biogas and biofertilizers, was performed using the following methodology. It includes calculations of reactor volumes, feedstock loading, water quantity, biogas output, as well as a description of the reactor design requirements and the biogas collection system. This technique enables to calculate the main parameters of a biogas plant, including reactor volume, feedstock loading, biogas output, and design requirements. It is aimed at optimizing waste recycling processes, obtaining biogas and biofertilizers, as well as reducing the environmental burden.

The proposed technical characteristics of the plant include the following components: a 20 m^3 feedstock hopper, a 25 m^3 reactor, a 60 m^3 fertilizer storage tank, process tanks, pumps and a 50 kW gas boiler. The unit has a capacity of 5 m^3 per day for raw materials and 200 m^3 per day for gas (or 72,000 m^3 per year). The potential energy produced is 1.20 Gcal (5.02 GJ) per day or 438 Gcal (1,830 GJ) per year. The productivity of the biogas power plant for fertilizers reaches 1,825 tons per year. With an application rate of 0.5 t/ha, this volume is sufficient to process 3,750 hectares of agricultural land. The use of highly effective organic fertilizers makes it possible to increase yields by 50-100%, depending on the crop, and also to almost completely abandon the use of chemical fertilizers.

The paper provides an analysis based on a calculation methodology, which is a financial and economic analysis aimed at evaluating the effectiveness of an investment project. The main characteristics of the methodology are: assessment of the economic efficiency of the project, comparison of costs and income, including taxes, determination of net profit and payback period of investments. This technique includes the following steps: 1. calculation of expected profit (conditional annual savings); 2. calculation of income tax; 3. calculation of net profit; 4. calculation of the payback period for capital investments.

The use of a biogas plant provides the following economic advantages: reduction of heating and electricity costs; the possibility of selling environmentally friendly organic fertilizers obtained during processing; sale of surplus biogas; elimination of the cost of placing droppings on the territory of a poultry farm in accordance with the standards of payment for the disposal of production and consumption waste.

Conclusions. Reducing the anthropogenic impact on the environment from livestock waste is possible due to the introduction of technologies for processing manure into biogas and organic fertilizers. Analysis of the issue has shown that untreated manure stored in fields negatively affects the environment: it pollutes the soil, air, groundwater and promotes the spread of infections. At the same time, animal husbandry waste (pig manure, cattle manure, bird droppings) contain valuable organic and mineral substances that can be converted into fertilizers and biogas during processing.

A promising area is the search for effective recycling technologies that will not only eliminate environmental issues, but also allow us to obtain useful products. For this purpose, the existing waste recycling methods were analyzed. The method of microbiological fermentation in thermophilic mode is recognized as the most effective, which reduces the processing time to 5-7 days and reduces the volume of construction of equipment structures.

A technological scheme is proposed that includes four modules: anaerobic digestion to produce biogas, the production of organo-mineral fertilizers, composting and bio-desodorization using EM technologies. A special feature of the plant is the separation of hydrolysis and methanogenesis, which prevents peroxidation of the medium and increases the stability of the process. Additionally, sludge enrichment and granulation of fertilizers are proposed, which increases their efficiency.

Calculations have shown that the implementation of the complex is economically and environmentally beneficial: the payback period is 2.7 years. The main income is provided by reducing the cost of waste storage and fertilizer sales. Thus, the proposed complex not only reduces anthropogenic load, but also increases the economic efficiency of livestock enterprises.

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МРНТИ:68.85.81
УДК-631.3
https://doi.org/10.52269/22266070_2025_1_194

ПРИМЕНЕНИЕ ВЫСОКОПРОЧНЫХ МАТЕРИАЛОВ ПРИ ИЗГОТОВЛЕНИИ СЕЛЬСКОХОЗЯЙСТВЕННОЙ ТЕХНИКИ

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В данной статье проведен анализ особенностей эксплуатации сельскохозяйственной техники с целью повышения ее надежности и долговечности. Актуальность исследования обусловлена необходимостью улучшения эксплуатационных характеристик сельхозмашин в условиях интенсивного использования и повышенных требований к их эффективности. Цель работы заключается в разработке решений, направленных на интеграцию высокопрочных материалов, легких конструкций и современных антикоррозионных покрытий для оптимизации работы сельскохозяйственного оборудования. Научная значимость определяется исследованием перспектив применения инновационных технологий, таких как нанопокрытия, самовосстанавливающиеся и биоразлагаемые материалы, способствующих продлению срока службы техники и снижению эксплуатационных затрат. Практическая значимость заключается в возможности внедрения предложенных решений производителями сельхозтехники, что приведет к повышению их конкурентоспособности и устойчивости. Методология исследования включает анализ материалов, экспериментальные испытания конструкций и оценку экологических последствий применения новых технологий. Основные результаты демонстрируют значительное улучшение эксплуатационных характеристик сельхозмашин, подтверждая, что интеграция передовых материалов и технологий способствует повышению эффективности, экологичности и экономической рентабельности сельскохозяйственного производства. Ценность проведенного исследования заключается в предоставлении научно обоснованных рекомендаций для устойчивого развития сельскохозяйственной отрасли и минимизации негативного воздействия на окружающую среду.

Ключевые слова: *сельскохозяйственная техника, высокопрочные материалы, антикоррозионные покрытия, нанопокрытия, долговечность, инновационные технологии.*

АУЫЛ ШАРУАШЫЛЫҒЫ ТЕХНИКАЛАРЫН ӨНДІРУ БАРЫСЫНДА ЖОҒАРЫ БЕРІКТІ МАТЕРИАЛДАРДЫ ҚОЛДАНУ

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