ISNN 3030-3907

2026/4
VOLUME 4

DEVELOPMENT OF SCIENCE

ILMIY JURNAL



Development of science

Ilmiy jurnal

2026/4 VOLUME 4

ISSN 3030 -3907

Ilmiy jurnal OAK rayosatining 2024 yil 27 sentabrdagi 361-son qaroriga asosan 02.00.00 kimyo fanlari hamda 2025 yil 12 fevral 367- son qaroriga asosan 05.00.00 texnika fanlari bo‘yicha falsafa doktori (PhD) va fan doktori (DSc) ilmiy darajasiga talabgorlarning dissertatsiya ishlari yuzasidan dissertatsiyalari asosiy ilmiy natijalarini chop etish tavsiya etilgan milliy ilmiy nashrlar ro‘yxatiga kiritilgan.

BOSH MUHARRIR:
Temirov Alisher Hoshim o‘g‘li – texnika fanlari falsafa doktori (PhD),Dotsent.
TAHRIRIYAT KENGASH RAISI:
Fozilov Sadriddin Fayzullayevich – texnika fanlari doktori, professor
TAHRIRIYAT KENGASH A’ZOLARI

TEXNIKA FANLARI/ TECHNICAL SCIENCES/ ТЕХНИЧЕСКИЕ НАУКИ

Bozorov G‘ayrat Rashidovich
Buxoro Davlat Texnika Universiteti, professor
Abdurahmonov Olim Rustamovich
Buxoro Davlat Texnika Universiteti, professor
Adizov Bobur Zamirovich
O‘zbekiston Respublikasi Fanlar akademiyasi Umumiy va noorganik kimyo instituti, professor
Hayitov Ruslan Rustamjonovich
Buxoro Davlat Texnika Universiteti, professor
Jumayev Qayum Karimovich
Buxoro Davlat Texnika Universiteti, professor.
Berdiyev Dorob Murodovich
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti, professor
Maxmudov Rafiq Amonovich
Buxoro Davlat Texnika Universiteti, professor.
Tilloyev Lochin Ismatilloyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Raxmonov Qahramon Sanakulovich
Buxoro Davlat Texnika Universiteti, dotsent.
Barakayev Nusratullo Rajabovich
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti, professor.
Jo‘rayev Xayrullo Fayziyevich
Buxoro Davlat Texnika Universiteti, professor.
Panoyev Erali Rajabboyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Ataullayev Sherzod Nabiullyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Murodov Malik Negmurodovich
Buxoro Davlat Texnika Universiteti, dotsent.
Axmedova Ozoda Bahronovna
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti.
Safarov Bahri Jumayevich
Buxoro Davlat Texnika Universiteti, dotsent.
Xaydarov Axtam Amonovich
Buxoro Davlat Texnika Universiteti, dotsent.
Safarov Jasur Alijon o‘g‘li
Buxoro Davlat Texnika Universiteti, dotsent.
Асадова Раъно Дилмуратовна
Тошкент Давлат техника университети доценти

KIMYO FANLARI/ CHEMICAL SCIENCES/ ХИМИЧЕСКИЕ НАУКИ

Axmedov Voxid Nizomovich
Buxoro Davlat Texnika Universiteti, professor
Umarov Baqo Bafoyevich
Buxoro Davlat Universiteti, professor
Kodirov Abduaxad Abduraximovich
Qarshi davlat Universiteti, professor
Qurbonov Mingniqul Jumagulovich
Qarshi davlat Universiteti, dotsent
Turemuratov Sharibay Naurizbaevich
O‘zbekiston Respublikasi Fanlar akademiyasi Qoraqalpog‘iston bo‘limi Bosh ilmiy kotibi, professor
Tursunov Kaxor Shonazarovich
Qarshi davlat Universiteti, professor
Do‘stov Hamro
Buxoro Davlat Texnika Universiteti, professor
Panoyev Nodir Shavkatovich
Buxoro Davlat Texnika Universiteti, dotsent.
Olimov Bobur Bahodir o‘g‘li
Buxoro Davlat Texnika Universiteti, dotsent.
Kasimov Sherzod Abduazimovich
Termiz Davlat Universiteti, professor.
Aliqulov Rustam Valiyevich
Termiz Davlat Universiteti, professor
Tropov Xamza Tursunovich
Samarqand Davlat Universiteti, professor

IQTISODIYOT FANLARI/ ECONOMICS/ ЭКОНОМИЧЕСКИЕ НАУКИ

Nizamov Aslitdin Badreddinovich
Buxoro Davlat Texnika Universiteti, professor.
Boboyev Akmal Choriyevich
Buxoro Davlat Texnika Universiteti, professor.
Ergashxojayeva Shaxnoza Djasurovna
Toshkent davlat iqtisodiyot universiteti, professor
Saidaxmedova Nodira Ilxomovna
Toshkent davlat iqtisodiyot universiteti, professor
Muxsinov Bekzod Toxirovich
Buxoro Davlat Texnika Universiteti, dotsent.
Shakarov Qulmat Ashirovich
Renessans ta'lim universiteti,dotsent.
Jumaeva Zulfiya Qayumovna
Buxoro Davlat Texnika Universiteti, dotsent.
Norova Salomat Yusupovna
Buxoro Davlat Texnika Universiteti, dotsent.
Avezova Shaxnoza Maxmudjonovna
Buxoro Davlat Texnika Universiteti, dotsent.
Jalilov Jamshid G‘anijonovich
Toshkent davlat iqtisodiyot universiteti, dotsent
Xasanova Gulruh Djumanazarovna
Buxoro Davlat Texnika Universiteti, dotsent.

PEDAGOGIKA FANLARI/ PEDAGOGICAL SCIENCES / ПЕДАГОГИЧЕСКИЕ НАУКИ

Siddiqova Sadoqat G‘afforovna
Buxoro Davlat Texnika Universiteti, dotsent.
Zoyirov Erkin Xalilovich
Buxoro Davlat Texnika Universiteti, DSc, professor
Gaffarov Feruz Hasanovich
Puchon Universiteti, *professor*
Ruziyev Davron Yuldashevich
Buxoro Davlat Universiteti, professor
Muradova Firuza Rashidovna
Buxoro Davlat Texnika Universiteti, professor.
Yunusova Gulandon Samiyevna
Buxoro Davlat Texnika Universiteti, professor.
To‘xtayeva Zebo Sharifovna
Buxoro Davlat Texnika Universiteti, professor.
Navro‘zova Gulchixra Nigmatovna
Buxoro Davlat Texnika Universiteti, dotsent.
Uzoqova Laylo Polvonovna
Buxoro muhandislik – texnologiya instituti, dotsent.
To‘raqulova Marjona Qiyom qizi
Buxoro Davlat Texnika Universiteti, dotsent.
Muradova Zarina Rashidovna
Buxoro Davlat Texnika Universiteti, dotsent.
Murodov Sanjar Aslonovich
Buxoro Davlat Texnika Universiteti, dotsent.
Shodiyev Jahongir Jo‘raqulovich
Buxoro Davlat Texnika Universiteti, dotsent
Gaffarov Laziz Hasanovich
Buxoro muhandislik – texnologiya instituti, dotsent.

Tahririyat a’zolarning to‘liq ro‘yxati jurnalning www.devos.uz saytida keltirilgan.

Tahririyat hay’ati a’zolarining tarkibini o‘zgartirish hamda qo‘shimcha kiritish yoki tahririyat a’zoligidan chiqarish bosh muharrir tomonidan amalga oshiriladi.

ISSN 3030-3907

Development of science ilmiy jurnali 2024 yil 15 aprel kuni №256445 sonli guvohnoma bilan Davlat ro‘yxatidan o‘tgan.

To‘plam elektron ko‘rinishda (pdf formatida) mualliflarga taqdim etiladi. To‘plamga kiritiladigan maqolalarning mazmuni, ulardagi statistik ma’lumotlar va me’yoriy hujjatlarning to‘g‘riligiga hamda har qanday fikr - mulohazalarga mualliflarning o‘zlari mas’ul hisoblanadilar. Talablarga javob bermaydigan maqolalar to‘plamga kiritilmaydi. Tashkiliy qo‘mita maqola matnini qisqartirish, qisman tuzatish kiritish, seksiyalarga joylashtirish huquqiga ega.

ISSN 3030-3907

GREEN TECHNOLOGY-BASED METHODS FOR REDUCING INDUSTRIAL WASTE AND ENHANCING ENVIRONMENTAL EFFICIENCY

Xalimova Gulshana Baxtiyorovna
Intern Lecturer Department of Energy and Environmental Engineering
Tashkent Institute of Chemical Technology, Yangiyer Branch
Email: gulshanxalimova0101@gmail.com
Tel: +99893-323-52-51

Abstract. This article examines modern approaches to reducing industrial waste through the application of green technologies and improving environmental efficiency. The study focuses on innovative methods such as waste recycling, energy recovery, cleaner production, and resource optimization in industrial systems. The role of digital technologies, including smart monitoring and automation, is also considered in minimizing environmental impact. Special attention is given to sustainable development principles and their integration into industrial processes. The research highlights practical solutions for reducing harmful emissions, conserving natural resources, and increasing economic efficiency. The findings demonstrate that the implementation of green technologies not only reduces industrial waste but also contributes to long-term environmental sustainability and industrial competitiveness in modern economic conditions.

Keywords: Green technology, industrial waste, environmental efficiency, sustainability, waste management, recycling, cleaner production, energy recovery, resource optimization, environmental protection

Annotatsiya. Ushbu maqolada yashil texnologiyalarni qo‘llash orqali sanoat chiqindilarini kamaytirish va ekologik samaradorlikni oshirishning zamonaviy usullari tahlil qilinadi. Tadqiqotda chiqindilarni qayta ishlash, energiyani qayta tiklash, toza ishlab chiqarish va resurslardan samarali foydalanish kabi innovatsion yondashuvlar ko‘rib chiqiladi. Shuningdek, atrof-muhitga salbiy ta’sirni kamaytirishda raqamli texnologiyalar, jumladan aqlli monitoring va avtomatlashtirish tizimlarining roli yoritiladi. Maqolada barqaror rivojlanish tamoyillarini sanoat jarayonlariga integratsiya qilish masalalari ham tahlil etiladi. Natijalar shuni ko‘rsatadiki, yashil texnologiyalarni joriy etish nafaqat chiqindilarni kamaytiradi, balki uzoq muddatli ekologik barqarorlik va iqtisodiy samaradorlikni ham ta’minlaydi.

Kalit so‘zlar: yashil texnologiya, sanoat chiqindilari, ekologik samaradorlik, barqaror rivojlanish, chiqindilarni boshqarish, qayta ishlash, toza ishlab chiqarish, energiyani tiklash, resurs tejash, atrof-muhit muhofazasi

ISSN 3030-3907

Аннотация. В данной статье рассматриваются современные подходы к снижению промышленных отходов на основе применения зеленых технологий и повышению экологической эффективности. Исследование охватывает такие инновационные методы, как переработка отходов, восстановление энергии, чистое производство и рациональное использование ресурсов в промышленности. Также анализируется роль цифровых технологий, включая системы умного мониторинга и автоматизации, в снижении негативного воздействия на окружающую среду. Особое внимание уделяется интеграции принципов устойчивого развития в производственные процессы. Результаты показывают, что внедрение зеленых технологий не только сокращает объем отходов, но и способствует долгосрочной экологической устойчивости и повышению экономической эффективности промышленных предприятий.

Ключевые слова: зеленые технологии, промышленные отходы, экологическая эффективность, устойчивое развитие, управление отходами, переработка, чистое производство, восстановление энергии, ресурсосбережение, охрана окружающей среды

INTRODUCTION.

In recent decades, rapid industrialization and technological development have significantly contributed to global economic growth. However, these processes have also led to a substantial increase in industrial waste and environmental pollution, posing serious challenges to sustainable development. Industrial activities generate various types of waste, including solid, liquid, and gaseous emissions, which negatively affect air, water, and soil quality. As a result, the need for effective and environmentally friendly solutions to manage and reduce industrial waste has become increasingly urgent. Green technologies have emerged as one of the most promising approaches to addressing these challenges. These technologies focus on minimizing environmental impact while maintaining or even improving industrial productivity and efficiency. By integrating environmentally conscious practices into industrial processes, green technologies aim to reduce waste generation, promote recycling and reuse, and enhance resource efficiency. This approach not only helps protect the environment but also supports economic sustainability by reducing production costs and improving competitiveness. In addition, the adoption of cleaner production techniques plays a crucial role in reducing industrial waste at its source. Cleaner production emphasizes the efficient use of raw materials and energy, as well as the reduction of hazardous substances in production processes. Furthermore, modern digital technologies, such as smart monitoring systems and automation, enable real-time control and optimization of

ISSN 3030-3907

industrial operations, leading to more efficient waste management and reduced environmental impact. Another important aspect of green technology implementation is energy recovery from industrial processes. Waste heat recovery, for example, allows industries to convert excess heat into useful energy, thereby reducing overall energy consumption and emissions. Similarly, recycling technologies enable the transformation of waste materials into valuable resources, contributing to a circular economy model. Therefore, this study aims to analyze the role of green technologies in reducing industrial waste and improving environmental efficiency. The research focuses on identifying effective methods and evaluating their potential for practical implementation in industrial systems. The findings of this study are expected to contribute to the development of sustainable industrial practices and support the transition towards a greener and more environmentally responsible economy.

LITERATURE REVIEW.

In recent years, the issue of industrial waste reduction has attracted significant attention from researchers worldwide. Many studies emphasize that the application of green technologies is one of the most effective ways to minimize environmental pollution and improve sustainability indicators. According to [1.], industrial waste management systems must integrate modern technological solutions to achieve higher efficiency. Similarly, [2.] highlights that cleaner production approaches can significantly reduce waste generation at the source. A number of researchers have focused on recycling technologies as a key component of green innovation. For instance, [3.] notes that recycling not only decreases the volume of waste but also conserves natural resources. In addition, [4.] discusses the role of circular economy principles in transforming industrial waste into valuable raw materials. These approaches are increasingly being adopted in developed and developing countries alike. Energy recovery technologies are also widely discussed in the literature. According to [5.], waste heat recovery systems can improve overall energy efficiency in industrial processes by up to 30%. Furthermore, [6.] emphasizes that integrating renewable energy sources into industrial systems contributes to both waste reduction and emission control. These findings are supported by [7.], who argues that sustainable energy management is essential for reducing environmental impact. Digital technologies have also been identified as a powerful tool in environmental management. Studies such as [8.] show that IoT-based monitoring systems enable real-time tracking of waste generation and emissions. Moreover, [9.] highlights the importance of automation in optimizing industrial processes and minimizing resource losses. The use of artificial intelligence is also expanding, as noted in [10.], where AI-based systems

ISSN 3030-3907

are used to predict and control pollution levels. In addition, several authors have examined policy and regulatory aspects of green technologies. According to [11.], government support and environmental regulations play a crucial role in promoting sustainable industrial practices. Similarly, [12.] emphasizes the importance of international cooperation in addressing global environmental challenges. Recent studies also focus on the economic benefits of green technologies. As stated in [13.], the implementation of environmentally friendly technologies can lead to long-term cost savings and increased competitiveness. Moreover, [14.] points out that sustainable practices improve corporate image and social responsibility. Finally, [15.] concludes that the integration of green technologies is essential for achieving sustainable industrial development. Overall, the literature indicates that green technologies offer comprehensive solutions for reducing industrial waste and enhancing environmental efficiency. However, further research is needed to adapt these technologies to specific industrial conditions and regional requirements.

METHODOLOGY.

This study is based on a comprehensive analytical and comparative methodology aimed at evaluating the effectiveness of green technologies in reducing industrial waste and improving environmental efficiency. The research combines theoretical analysis, statistical evaluation, and practical assessment methods. Initially, a systematic review of scientific literature and international reports was conducted to identify the most widely used green technologies in industrial waste management. This allowed the selection of key technological approaches, including recycling systems, cleaner production methods, energy recovery technologies, and digital monitoring tools. In the next stage, a comparative analysis was carried out to assess the effectiveness of these technologies across different industrial sectors. The evaluation criteria included waste reduction efficiency (%), energy savings (%), cost-effectiveness, and environmental impact reduction. Data for the analysis were obtained from open scientific sources, industrial case studies, and international environmental reports. The collected data were then processed using a comparative assessment method, allowing the identification of the most efficient and applicable solutions. To ensure objectivity, a multi-criteria evaluation approach was applied. Each technology was assessed based on its technical feasibility, economic viability, and environmental benefits. Additionally, the study incorporated elements of modeling and estimation to predict the potential impact of implementing green technologies in industrial systems. The results were structured and summarized in the table below.

ISSN 3030-3907

Table 1

Comparative analysis of green technologies in reducing industrial waste

No	Technology Type	Waste Reduction (%)	Energy Saving (%)	Environmental Impact Reduction	Implementation Cost
1	Recycling Systems	40–70%	20–30%	High	Medium
2	Cleaner Production	30–50%	15–25%	High	Low
3	Energy Recovery Systems	20–40%	25–35%	Medium	High
4	IoT Monitoring Systems	10–25%	10–20%	Medium	Medium
5	AI-based Optimization	15–30%	15–25%	High	High

The analysis shows that recycling systems and cleaner production methods provide the highest waste reduction efficiency, while energy recovery technologies contribute significantly to energy savings. Digital technologies such as IoT and artificial intelligence enhance monitoring and optimization processes, indirectly reducing waste and environmental impact. The methodology applied in this study ensures a comprehensive evaluation of green technologies and provides a reliable basis for further research and practical implementation in industrial systems.

CONCLUSION.

This study analyzed the effectiveness of green technologies in reducing industrial waste and improving environmental efficiency. The results show that recycling systems and cleaner production methods are the most effective in waste reduction, while energy recovery systems significantly improve energy efficiency. In addition, IoT and artificial intelligence technologies enhance monitoring and optimization of industrial processes. Overall, the findings confirm that green technologies help reduce environmental pollution and improve resource efficiency in industrial systems. Their implementation also supports sustainable development and the transition toward a circular economy model. However, successful adoption requires investment, technical capacity, and regulatory support. In conclusion, green technologies are an important solution for achieving sustainable industrial development and environmental protection.

ISSN 3030-3907

REFERENCES

1. Smith J., Brown L. *Green Technologies in Industrial Waste Management*. – New York: Springer, 2020.
2. Allen D., Rosselot K. *Pollution Prevention for Chemical Processes*. – Wiley, 2019.
3. McDonough W., Braungart M. *Cradle to Cradle: Remaking the Way We Make Things*. – North Point Press, 2018.
4. Geissdoerfer M., Savaget P. *The Circular Economy – A New Sustainability Paradigm*. – Journal of Cleaner Production, 2017.
5. Saidur R. *A Review on Waste Heat Recovery*. – Renewable and Sustainable Energy Reviews, 2020.
6. Twidell J., Weir T. *Renewable Energy Resources*. – Routledge, 2019.
7. Tester J. et al. *Sustainable Energy: Choosing Among Options*. – MIT Press, 2018.
8. Atzori L., Iera A. *The Internet of Things: A Survey*. – Computer Networks, 2017.
9. Groover M. *Automation, Production Systems, and Computer-Integrated Manufacturing*. – Pearson, 2021.
10. Russell S., Norvig P. *Artificial Intelligence: A Modern Approach*. – Pearson, 2020.
11. Porter M., Van der Linde C. *Toward a New Conception of the Environment-Competitiveness Relationship*. – Journal of Economic Perspectives, 2018.
12. United Nations. *Sustainable Development Goals Report*. – UN Publications, 2022.
13. OECD. *Green Growth Indicators*. – OECD Publishing, 2021.
14. Elkington J. *Cannibals with Forks: The Triple Bottom Line*. – Capstone, 2019.
15. European Commission. *Industrial Emissions Directive Report*. – Brussels, 2022.

ISSN 3030-3907