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RESEARCH ARTICLE

Integration of Environmental Technologies into Industrial Management as a Tool for Ensuring Sustainable Development

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ABSTRACT

The article aims to develop a conceptual framework for integrating environmental technologies into industrial process management to support the achievement of sustainable development goals. It focuses on analyzing how the adoption of innovative environmental solutions can enhance the environmental performance of industrial production, reduce ecological impact, optimize natural resource use, and contribute to global sustainability goals, particularly those related to climate change, ecosystem preservation, and responsible consumption and production. The article seeks to highlight the key advantages, challenges, and risks involved in integrating environmental technologies into industrial management, emphasizing its role as a critical factor for achieving both environmental sustainability and enterprise competitiveness. Using risk-based approaches, system analysis, and modeling, the article explores the conditions necessary for improving the environmental efficiency of industrial operations, with a particular focus on the use of digital environmental technologies to meet sustainable development goals. Research Findings: The study examines the innovative approaches for integrating environmental protection technologies into industrial management as part of the sustainable development agenda. The benefits of this integration are identified as pivotal to achieving sustainability in industrial operations. The article further explores the convergence of digitalization and environmental strategies, offering new opportunities for sustainable development. This direction helps address the environmental challenges facing modern industries and underscores the importance of innovation in both environmental protection and the effective management of industrial processes. Theoretical Significance: The research contributes to the scientific discourse by developing an approach that incorporates environmental technologies into industrial management, positioning it as a fundamental component in achieving sustainable development. The study presents a new vision of industrial management that merges environmental technologies with contemporary management practices to enhance sustainability. Practical Significance: The study deepens the understanding of the impact of digital and environmental innovations on the economic, environmental, and social performance of industrial enterprises.

INTRODUCTION

The relevance of integrating environmental protection technologies into industrial management is driven by several key factors. In the face of growing environmental threats such as global warming, environmental pollution and the depletion of natural resources, the introduction of environmental protection technologies is becoming a necessity for industrial enterprises. Reducing greenhouse gas emissions and minimising harmful environmental impacts are important steps towards achieving sustainable development goals. National and international regulations require industrial companies to strictly comply with environmental responsibility standards. This encourages companies to implement technologies that meet the requirements of environmental legislation. The integration of environmental technologies can help to improve the economic efficiency of enterprises by reducing resource consumption, optimising production processes and cutting energy costs. Growing consumer demand for environmentally responsible products and services is forcing companies to adapt their production processes to meet the requirements of sustainable development. This opens up new business opportunities in the context of competition. Companies are increasingly recognising the need not only for economic growth but also for social and environmental sustainability. The use of environmentally friendly technologies is becoming part of corporate responsibility, which improves the reputation of brands. The integration of environmental technologies into industrial management is not only a requirement of the times, but also a strategic necessity to ensure sustainable development of both enterprises and society as a whole. The integration of environmental technologies into industrial management means rethinking and transforming traditional production processes based on the use of non-renewable resources and a linear production model into environmentally sustainable and efficient management systems that take into account the environmental impact at all stages of the product life cycle. Approaches to sustainable development in industrial management may include: 1) Implementation of environmental management and ISO 14001; 2) Use of energy efficient technologies and renewable energy sources; 3) Application of the circular economy concept, which focuses on reuse of resources and minimisation of waste; 4) Use of digital tools to monitor environmental impact and optimise resources.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Analysing recent articles and studies on the integration of environmental technologies into industrial management to ensure sustainable development shows that scientists are increasingly paying attention to this topic, in particular to the combination of greening and digitalisation in industrial processes.

Many studies by V. Voronkova, V. Nikitenko, N. Metelenko, and R. Oleksenko confirm the importance of introducing environmentally friendly technologies into production processes to achieve environmental sustainability. The scientists emphasise that reducing harmful emissions, optimising resource use and reducing energy consumption have a direct impact on achieving sustainable development goals. The articles analyse specific case studies of companies that have implemented environmental solutions (e.g., using renewable energy sources or minimising production waste) and achieved significant improvements in their environmental performance.

Digitalisation is presented as a catalyst for environmental change in the works of Klopov Ivan, Shapurov Alexander, Voronkova Valentyna, Nikitenko Vitalina, Oleksenko Roman, Khavina Irina, Chebakova Yuliia. According to recent studies, digital technologies play a key role in improving industrial management. In particular, articles highlight the importance of using automation, big data, artificial intelligence and the Internet of Things (IoT) to monitor environmental performance, optimise processes and adapt quickly to changes. Analytical platforms help to collect and analyse data on energy consumption and emissions, allowing businesses to make more informed decisions.

The recent article by Nikitenko, Vitalina, Voronkova, Valentyna, Oleksenko Roman, Matviienko, Halyna, Butkevych, Oksana (2023) highlights the role of innovation in solving environmental problems. The researchers emphasise that investments in green technologies, such as circular economy technologies, can achieve environmental sustainability and increase the profitability of enterprises at the same time. Innovations in industrial management also include new materials, production processes, and management models focused on sustainability.

A separate study by Voronkova, Valentyna, Nikitenko, Vitalina, Oleksenko, Roman, Andriukaitiene Regina, Kharchenko Julia Kliuienko Eduard (2023) highlights the economic benefits of integrating environmental technologies into industrial management. In particular, the articles point out that reducing resource costs, increasing energy efficiency, and complying with environmental standards allow enterprises to reduce operating costs and at the same time improve their reputation among environmentally conscious consumers.

Recent research by Klein Naomi (2016) examines the challenges companies face when implementing environmental technologies. In particular, they include high initial investments in new technologies, the need to retrain staff, and technical and organisational difficulties in integrating environmental innovations into traditional production processes.

Current research clearly indicates that environmental technologies and digitalisation are important tools for industrial management seeking to achieve sustainable development goals. Despite certain challenges, the integration of these technologies is becoming an integral part of the strategy of future-oriented enterprises.

MATERIALS AND METHODS

The study used the methods of system analysis and synthesis, Agile methodology, axiological, synergistic, ecological methods and approaches, which allowed us to reveal new directions of innovative integration of environmental protection technologies into industrial management for sustainable development. With this approach, it is possible to combat environmental problems more effectively and develop sustainable approaches to the use of the planet's resources. The ecological research method is an interdisciplinary method developed in line with the development of environmental problems and the improvement of modern research methods. The methods of researching innovative integrations of environmental protection technologies into industrial management for sustainable development include the following: 1) the method of systemic analysis and synthesis, which allows all disparate environmental facts to be brought into a system of preserving ecological balance; 2) Agile methodology, which is about adapting the environment and bringing it into balance between digital technologies and their integration into environmental protection; 3) the axiological method, which is based on the values of natural resource management, reducing harmful effects on ecosystems and compliance with international environmental standards. The implementation of environmental management includes environmental risk audits, optimisation of water and energy consumption, and emissions control; 4) synergistic method, based on self-organising processes and the possibility of finding an attractor that can lead to synergy and overcome problems and achieve sustainable development goals; 5) general philosophical methods - analysis and synthesis, generalisation, comparison, which allowed to form the concept of 'ecological industrial production', based on the use of ecological digital technologies that are used in the production of goods and services. The methods and approaches used have proved that the integration of environmental technologies into industrial management is an effective tool for achieving the goals of sustainable development Reducing the negative impact on the environment: The introduction of environmental technologies can significantly reduce greenhouse gas emissions, reduce waste and optimise the use of natural resources in industrial processes. A comparative analysis of successful cases and practices in various industries has shown the integration of such technologies that help reduce energy and resource costs, which increases the economic sustainability of enterprises in the

long term. The method of system analysis allowed us to establish the relationship between environmental technologies, digital innovations and indicators of sustainable development and to improve the efficiency of integrating these technologies into industrial management. The modelling method allowed for the development of models to predict the impact of digitalisation and greening on environmental performance and economic benefits of the company, and the use of simulation models to assess the effectiveness of technology implementation in specific industrial processes. The method of expert assessments was used to determine the prospects for the development of the integration of greening and digitalisation, and risk analysis to assess the possible negative consequences of the introduction of new technologies. The integration of environmental and digital technologies allows enterprises to meet the requirements of international environmental standards and regulations, which increases their competitiveness in the global market. The combination of greening and digitalisation in industrial management is a powerful tool for achieving sustainable development goals such as climate change, efficient use of resources and responsible production. Thus, the integration of environmental and digital technologies into industrial management is a key factor in ensuring the environmental, economic and social sustainability of enterprises. These materials and methods will help to analyse and assess the impact of the integration of environmental and digital technologies on industrial management and their role in ensuring sustainable development.

The purpose of the article is to develop the concept of integration of environmental technologies into industrial management as a tool for ensuring sustainable development. Objectives: 1. To analyse the directions of innovative integration of environmental protection technologies into industrial management for sustainable development. 2. To identify the benefits of integrating environmental technologies into industrial management as a key to sustainable development. 3. To integrate digitalisation and greening in the context of identifying new opportunities for sustainable development.

RESULTS

1. Directions of innovative integration of environmental protection technologies into industrial management for sustainable development

Innovative integration of environmental protection technologies into industrial management for sustainable development means the process of introducing the latest environmental technologies and solutions into the industrial process management system in order to minimise the negative impact on the environment and ensure long-term environmental sustainability. This encompasses:

1. The use of innovative environmental technologies, such as purification systems, renewable energy sources, and waste management solutions;
2. Resource optimization aimed at reducing energy, water, and material consumption;
3. The implementation of environmentally-oriented management practices, including green audits and environmental certification of production facilities; and
4. The promotion of sustainable development, which integrates economic growth with the preservation of natural resources and a commitment to environmental responsibility.

The purpose of such integration is to improve the efficiency of industrial management and ensure a balance between economic, environmental and social aspects of development, which is the basis of the concept of sustainable development.

Table 1. Key aspects of integrating environmental technologies into industrial management

Key aspect of integration	Development direction
Environmental management	It is a systematic approach to managing natural resources, reducing the harmful impact on ecosystems and complying with international environmental standards. Implementing environmental management includes auditing environmental risks, optimising water and energy consumption, and controlling emissions. Companies that use environmental management standards such as ISO 14001 demonstrate their commitment to sustainable development.
Circular economy	The integration of the circular economy into industrial management allows for the creation of closed production cycles where resources are reused multiple times. This involves moving from a linear production-consumption-disposal model to a production-consumption-recycling model, which helps reduce waste, cut raw material consumption and minimise the company's environmental footprint.
Energy efficiency and emissions reduction	One of the central tasks of industrial management is to implement energy-efficient technologies that reduce energy consumption per unit of output. This can include the use of innovative production technologies with lower energy consumption, the use of renewable energy sources such as solar or wind power plants, and the transition to low-carbon or carbon-free technologies to reduce CO_2 emissions.
Implementation of green innovations	Environmental protection technologies contribute to the development of innovative solutions in industrial production. For example, green innovations may include the use of biomaterials, nanotechnology for water or air purification, environmentally friendly 3D printing, and the development of biodegradable or recyclable materials. These innovations reduce hazardous waste and reduce dependence on fossil resources.
Digital technologies for sustainable development	Modern digital technologies, such as the Internet of Things (IoT), artificial intelligence (AI) and big data, allow industrial enterprises to collect and analyse data on their environmental impact in real time. This allows them to respond quickly to any environmental issues and optimise resource use. For example, digital platforms can monitor emissions, energy efficiency, and automate recycling and disposal processes.
Social responsibility and corporate ethics	An essential aspect of integrating environmental technologies into industrial management is building a long-term corporate strategy based on the principles of social responsibility. This not only meets the expectations of consumers and investors, but also helps build transparent relations with society. Industrial companies that take measures to minimise their environmental impact can attract additional investment and create a positive image in the market.

2. Benefits of integrating environmental technologies into industrial management as a key to sustainable development

Integration of environmental technologies into industrial management has a number of important advantages that contribute to sustainable business development, reduce the negative impact on the environment and increase the competitiveness of enterprises. The benefits of integrating environmental technologies into industrial management as a key to sustainable development include the following. 1) Integration of environmental technologies helps to minimise pollution, emissions of harmful substances and reduce waste, which helps to preserve ecosystems and natural resources as a result of reduced environmental impact; 2) Modern environmental technologies promote the rational use of energy, water and raw materials, which reduces production costs and makes industrial processes more sustainable as a result of efficient use of resources; 3) Organisations that implement environmental technologies gain a positive image among businesses 7) Environmentally oriented enterprises contribute to the development of socially responsible business, which increases public trust and support among citizens and organisations based on social responsibility and public engagement. The integration of environmental technologies into industrial management not only improves environmental sustainability, but also contributes to economic and social benefits, which is a key element of sustainable development.

Table 2. Benefits of integrating environmental technologies in industrial management transformation for sustainable development and their characteristics

Advantages of integrating environmental technologies	Characteristics of the environmental technologies integration
Environmental impact reduction	The integration of environmental technologies helps to minimise the use of natural resources and reduce waste and emissions. This helps to preserve the environment and reduce the carbon footprint of enterprises.
Improving energy efficiency	The introduction of energy-saving technologies, such as renewable energy sources (solar, wind, biomass), helps to reduce energy costs and improve the overall energy efficiency of production processes.
Resource saving and cost optimisation	Environmental technologies promote the rational use of raw materials, which helps to reduce production costs. The use of recycled materials, waste recycling and the introduction of a circular economy ensure long-term resource savings.
Improving the company's reputation and image	Companies that implement environmental standards and technologies gain a positive image of responsible business in the eyes of society and customers. This helps to build trust, increase customer loyalty and attract investors focused on sustainable development.
Compliance with international standards and regulations	The integration of environmental technologies makes it possible for businesses to comply with international environmental standards (ISO 14001 and others), which provides access to international markets and reduces the risk of sanctions or fines for non-compliance with environmental regulations.
Reducing risks and improving business sustainability	Reducing dependence on non-renewable resources and adapting to climate change help to increase the company's resilience to future environmental challenges and risks associated with new regulations or market changes.
Innovative development and competitiveness	Environmental technologies stimulate innovation in production processes, products and services. This allows companies to be more competitive in a market focused on environmentally friendly solutions and meet the growing demand for green products.
Attracting skilled personnel	The implementation of environmental initiatives can attract talented and skilled workers who share the values of sustainable development and environmental responsibility. Thus, environmental technologies in industrial management not only contribute to the improvement of the environment, but also provide economic and strategic benefits for enterprises.
Increasing innovation potential and technological development	The integration of environmental technologies contributes to the development of new engineering solutions and improved production processes. Companies that focus on environmental innovations are able to develop their own know-how and use it to improve products and services, thereby creating an additional competitive advantage in the market.
Raising investment and financial resources	Investors are increasingly interested in businesses that comply with the principles of sustainable development. Integration of environmental technologies allows companies to access environmental funds, soft loans or grants aimed at supporting green technologies and solutions. Meeting the requirements of environmental investors increases the chances of attracting additional financial resources.
Economic stability in the long term	Environmental technologies enable more sustainable and flexible business models that are better able to adapt to changing market conditions. Businesses that implement sustainable development strategies reap long-term economic benefits by reducing costs of energy, materials, fines for environmental violations, and by mitigating financial risks associated with global climate change and regulatory requirements.
Addressing consumer demand for environmentally friendly products	Contemporary consumers increasingly prefer products that are environmentally friendly and produced with minimal impact on the environment. The introduction of environmental technologies helps companies meet the demands of eco-conscious customers, which helps to expand market opportunities and strengthen market positions.

Optimising supply chains	Environmental technologies allow us to review and optimise our supply chains, which leads to more efficient use of resources, reduced environmental impact and improved logistics processes. This helps not only to minimise costs but also to improve the quality of products and services.
Supporting sustainable development and corporate social responsibility	The integration of environmental technologies into industrial management emphasises a company's commitment to corporate social responsibility. This contributes to sustainable development and supports global efforts to protect the environment, which in turn helps companies meet the expectations of society and strengthen their positions in the international arena.
Improving employee health and safety	Environmental technologies also have a positive impact on the working conditions and health of employees. Reducing emissions of harmful substances, implementing safe waste management technologies and improving working conditions at production sites reduces health risks for employees, which helps to increase their productivity and reduce healthcare costs.
Increasing transparency and accountability	The use of environmental technologies and the implementation of environmental monitoring systems makes the company's operations more transparent to the public, government agencies and investors. This helps to build trust in the company and creates additional opportunities for public support.

Thus, the benefits of integrating environmental technologies into industrial management as a key to sustainable development are to create a more sustainable, responsible and innovative industrial ecosystem that will contribute to both economic growth and environmental protection. Green technologies not only bring significant environmental benefits, but also stimulate innovation, economic efficiency and social responsibility of enterprises. They form the basis for building a sustainable and successful business model that meets today's global challenges and market demands.

CONCLUSION

Integrating greening and digitalisation of technologies into industrial management as a tool for sustainable development means combining environmental practices and digital innovations to improve the efficiency of industrial process management and promote sustainable development. This includes: greening as a tool for implementing technologies and solutions that minimise negative environmental impact, reduce pollution and optimise the use of natural resources. Digitalisation as a tool for using modern digital tools and technologies (Internet of Things, artificial intelligence, big data) to automate, monitor and optimise industrial processes. The key aspects of integrating greening and digitalisation into industrial management as a tool for sustainable development are as follows: 1) Energy efficiency through digital control and management of resource use. 2) Reducing harmful emissions through automated systems for monitoring and managing production cycles. 3) Innovation and automation to reduce human error and increase the efficiency of environmental measures. 4) Economic and environmental benefits: long-term resource savings and compliance with environmental standards. This approach promotes sustainable development by balancing economic productivity with environmental protection. The theoretical significance of the study is that it is based on the development of models and concepts that explain the relationship between the integration of environmental technologies and the achievement of the global sustainable development goals (SDGs); analysis of the advantages and limitations of the introduction of environmental technologies to ensure sustainable development in the context of industrial sectors. The practical significance of the study lies in the need to introduce environmental and digital technologies to reduce energy consumption, emissions, waste and increase the efficiency of production processes; provide enterprises with specific solutions and tools for integrating sustainable practices into management, which will improve their environmental and economic sustainability; identify strategies to minimise the risks and costs associated with the introduction of environmental innovations in production.

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