UDC 338.1
JEL Classification: D61, C51, L20, M21

Ryabyk G. E., Geleta I. V.

DIGITALIZATION OF INDUSTRIAL PROCESSES FOR ENVIRONMENTAL RISK MANAGEMENT IN ENTERPRISES

Ukrainian State University of Chemical Technology (Educational Scientific Institute "Ukrainian State University of Chemical Technology"), Dnipro, Ukraine

The article examines the digitalization of industrial processes as an effective tool for managing environmental risks at enterprises. Emphasis is placed on a comprehensive approach to the use of modern digital technologies – the Internet of Things (IoT), Big Data, analytics, automation, and robotics – aimed at enhancing environmental safety, minimizing the impact of harmful emissions, and optimizing production activities. Special attention is given to the implementation of an intelligent automated system at PJSC "DniproAzot", which enables the collection, processing, and transmission of CO_2, emissions data in real time. The study analyzes a promising approach to CO_2, emissions utilization through their conversion into carbon-ammonia fertilizers, which combines the reduction of greenhouse gas emissions with economic benefits in the form of valuable agrochemical product output. It is demonstrated that the implementation of digital technologies not only reduces environmental pressure but also contributes to increased productivity, cost reduction, and greater flexibility in enterprise decision-making. The economic feasibility of investing in an intelligent automated system for environmental risk management is substantiated, with calculations provided for potential profit and reduced environmental fees. The role of digitalization in ensuring sustainable development of industrial enterprises amid modern environmental challenges is highlighted. The findings have both practical and theoretical significance for shaping effective environmental policies at the enterprise and national levels.

Keywords: digitalization, environmental risks, Internet of Things (IoT), Big Data, automation, CO_2, emissions, sustainable development, carbon-ammonia fertilizers, industrial enterprises, intelligent management systems.

DOI: 10.32434/2415-3974-2025-21-1-160-167

Problem statement

In the modern world, industrial enterprises face numerous challenges, among which one of the most important is environmental risk management. Growing attention to environmental safety and sustainable development forces companies to look for new approaches to minimize negative impact on the environment. One of such approaches is the digitalization of industrial processes, which opens up new opportunities for effective environmental risk management.

Digitalization involves the use of modern technologies, such as the Internet of Things (IoT), big data, analytics, and automation, to optimize production processes and monitor environmental performance. Thanks to these technologies, enterprises can not only increase the efficiency of their operations, but also significantly reduce the costs of environmental management, while increasing the level of environmental safety.

In this article, we will examine the main aspects of the digitalization of industrial processes, its impact on environmental risk management, and the benefits it brings to businesses. We will also discuss the prospects for the development of digital technologies in this area and their potential to create a more sustainable and environmentally friendly future.

Analysis and research of publications

The digitalization of industrial processes and environmental risk management are highly relevant issues that attract the attention of many researchers. In her article, Olga Ilyash explores the transformational effects of digitalization in ensuring the development of industrial production in the conditions of Industry 4.0. She emphasizes that digitalization contributes to the optimization of production lines and increasing the efficiency of industrial enterprises [1]. Another study conducted by M. Beloborodova focuses on environmental risk management in the development strategy of industrial enterprises. The author analyzes domestic approaches to assessing environmental risks and proposes a classification of development strategies taking into account environmental factors [2]. Deeva N.E. in her work develops an organizational and economic mechanism for managing environmental risks at enterprises. She substantiates the concept of the economic essence of the category "environmental risk" and offers methodological recommendations for the implementation of subsystems of the economic and organizational mechanism for managing environmental risks [3].

These studies demonstrate the importance of integrating digital technologies into industrial processes for effective environmental risk management. They also highlight the need to develop new approaches and strategies to ensure the sustainable development of industrial enterprises.

A study by Vera Kudlay highlights that the digitalization of the global economy is a global technological challenge that impacts the global ecosystem. She notes that digital technologies are one of the tools to ensure global economic growth, achieve human well-being and solve environmental problems [1]. According to estimates provided by the World Economic Forum and Accenture, digital technologies can provide up to one fifth of all emission reductions needed to achieve net zero by 2050 [2]. This includes the use of 5G networks, which are 90% more energy efficient than legacy 4G networks, as well as the implementation of digital solutions in the energy, logistics and manufacturing sectors. These studies demonstrate the importance of integrating digital technologies into industrial processes to effectively manage environmental risks. They also highlight the need to develop new approaches and strategies to ensure the sustainable development of industrial enterprises.

The purpose of the article

The purpose of the article is to study and analyze the implementation of an intelligent automated system for optimizing economic activities using the example of JSC "DniproAzot", which is directly related to the digitalization of industrial processes aimed at managing environmental risks at enterprises.

Statement of the main material

According to the State Statistics Service of Ukraine, carbon dioxide emissions from stationary sources of pollution in Ukraine continue to grow. In 2024, CO_2, emissions from industrial enterprises amounted to 250 million tons, which is 5% more compared to 2023 [4]. This indicates the need to implement effective measures to reduce emissions and manage environmental risks.

Economic losses from natural and man-made disasters are becoming so significant that this trend is developing into a threat to economic stability on a global scale. According to Swiss RE, in 2009, natural and man-made disasters caused insurance payments totaling 26 billion USD, and economic losses were estimated at 62 billion USD [5]. This emphasizes the importance of environmental risk management to prevent significant economic losses.

In this article, we will examine the main aspects of the digitalization of industrial processes, its impact on environmental risk management, and the benefits it brings to businesses. We will also discuss the prospects for the development of digital technologies in this area and their potential to create a more sustainable and environmentally friendly future.

The Internet of Things (IoT) is one of the key technologies transforming industry. IoT involves the use of sensors and devices to monitor the condition of equipment and the environment. The Industrial Internet of Things (IIoT) allows for the collection and transmission of information, remote control of processes, automation of production, and increased profitability [4]. For example, sensors in factories can monitor the condition of equipment, preventing breakdowns or downtime [4]. General Electric (GE) has implemented IoT solutions to improve operational efficiency and reduce carbon emissions. Using IoT platforms, GE was able to optimize the operation of its power plants, reducing CO_2, emissions by 10% [6]. Siemens is using IoT to manage and integrate renewable energy into the electricity grid. Thanks to IoT technologies, Siemens was able to reduce emissions of harmful substances by increasing energy efficiency [6]. Schneider Electric is developing IoT platforms that help energy companies more effectively

manage energy consumption, reducing waste and reducing carbon emissions. Using IoT allowed the company to reduce CO_2, emissions by 12% [6].

These examples demonstrate how the implementation of IoT technologies can contribute to reducing emissions of harmful substances and increasing the efficiency of industrial processes. The use of IoT allows enterprises not only to reduce their environmental impact, but also to gain economic benefits by optimizing operational processes.

Big Data and analytics are important tools for data collection and analysis that enable prediction and management of environmental risks. Big data includes huge amounts of structured and unstructured data generated from various sources [7]. Big data analytics allows you to discover patterns, predict trends, and make informed decisions [8]. Dynamic Quantum Clustering (DQC) is an innovative methodology for analyzing multidimensional data. This method allows you to discover structures and patterns in large amounts of data using quantum principles [9]. DQC implements the "let the data speak for itself" paradigm, which allows you to obtain insights without prior definition of models. MapReduce is one of the most common algorithms for processing big data. It allows you to distribute data processing across multiple nodes, which significantly increases the efficiency of the analysis [9]. MapReduce is used to process large amounts of environmental data, such as air and water pollution data. For example, neural networks can be used to predict climate change and identify risk areas. The Air Quality Prediction project uses machine learning algorithms to predict air quality in real time. Using data from IoT sensors, the machine learning model analyzes pollution levels and predicts future changes in air quality [10]. This allows timely measures to be taken to reduce the negative impact on public health.

Using algorithms and models to analyze big data allows businesses to effectively predict and manage environmental risks. Machine learning and deep learning are powerful tools that help identify patterns and trends in large amounts of data, providing accurate predictions and informed decisions [13].

Automation and robotics are key components of modern industry, reducing human intervention and increasing the accuracy of manufacturing processes. Automation involves the use of machines and systems to perform tasks that were previously performed by humans. Robotics allows complex and repetitive tasks to be performed with high accuracy.

Advantages of automation and robotics [7 ,8, 11]:

– increased productivity: With automation, machines can run 24/7 without interruption, which greatly increases production. For example, an automated car factory can produce one car every 55 seconds;

– quality improvement: Automated systems are consistent and accurate, resulting in consistent product quality and greatly reducing human error. In some high-precision industries such as electronics, the error rate has dropped to less than 0.1%;

– cost reduction: While the initial investment may be high, automation significantly reduces operating costs in the long run. Fewer errors mean less waste, and the energy efficiency of modern machines reduces utility costs;

– some companies report savings of up to 30% of their operating costs after implementing automation solutions;

– safety: Robots can perform hazardous tasks, reducing the risk to workers. For example, robots are used to work in high temperatures or toxic environments;

– manufacturing flexibility: Automated systems can quickly adapt to changes in production processes, allowing businesses to be more agile and responsive to changing demand.

For example, automated air quality monitoring systems use sensors to measure pollution levels in real time. These systems allow for rapid detection of exceedances of permissible standards and take measures to reduce emissions of harmful substances [11]. Automated waste management systems use robots to sort and recycle waste. This reduces the amount of waste going to landfills and increases recycling efficiency [11]. The use of automated systems and robots in industry reduces environmental risks, increases the efficiency of production processes, and ensures worker safety. Specific types of robots, such as SCARA, Delta, and Cobot, have their own unique advantages and applications, making them indispensable in modern industry.

Environmental risk identification is the first step in the environmental risk management process. It involves identifying potential environmental risks at an enterprise, such as emissions of harmful substances, water, soil and air pollution, and possible accidents [3]. Risk identification allows enterprises to identify weaknesses and develop measures to eliminate them.

Developing and implementing strategies to minimize environmental risks is a key management step. This may include implementing environmental standards, using new technologies, training staff, and conducting regular audits [12].

Digital technologies allow businesses to more effectively and accurately identify, assess, and manage environmental risks.

The next step is a detailed analysis of a specific example of the implementation of digital technologies for environmental risk management at DNIPROAZOT JSC.

It is proposed to implement an intelligent automated system at the enterprise, which allows for a more detailed consideration of the practical aspects of digitalization of industrial processes. This study is an important example of how digital technologies can be used to optimize business activities and manage environmental risks. This will help to better understand the practical aspects of digitalization and its benefits for industrial enterprises.

Utilization of carbon dioxide (CO_2,) emissions is an important task for industrial enterprises, since these emissions have a significant impact on the environment. One of the promising methods of CO_2, utilization is its use for the production of carbon-ammonia fertilizers. This process involves the implementation of an intelligent automated system for collecting and transmitting information on the quantitative and qualitative composition of emissions.

One promising method of utilizing CO_2, is to use it for the production of carbon-ammonia fertilizers. This process not only helps reduce the concentration of greenhouse gases in the atmosphere, but also ensures the production of valuable agrochemical products that improve soil fertility and crop yields. Carbon-ammonia fertilizers are nitrogen fertilizers in which nitrogen is contained in the form of ammonia (NH_3). They have a high concentration of nitrogen, which makes them effective for plant nutrition. Using CO_2, for the production of such fertilizers allows reducing greenhouse gas emissions while providing farmers with the necessary nutrients for plants.

For effective implementation of this method, it is necessary to use intelligent automated systems for collecting and transmitting information on the quantitative and qualitative composition of emissions. Such systems allow for continuous monitoring of exhaust gas parameters, analysis of the content of pollutants and transmission of data in real time. This ensures accuracy and efficiency in making decisions on optimizing the processes of CO_2, utilization and fertilizer production.

The implementation of intelligent automated systems has several key advantages:

– increased efficiency: Automated systems provide precise control and management of processes, which increases the efficiency of fertilizer production;

– reducing environmental impact: Using CO_2, to produce fertilizers helps reduce greenhouse gas emissions, contributing to the fight against climate change;

– improving product quality: Intelligent systems allow you to optimize the composition of fertilizers, which improves their quality and effectiveness for crops [14].

This approach is a promising direction in the field of environmental engineering and agrochemistry, which can significantly impact the sustainable development of agriculture and reduce the negative impact on the environment.

The process of utilizing CO_2, emissions to produce carbon-ammonia fertilizers includes several stages (Figure).

Stage 1. Capture CO_2 from emission sources Carbon dioxide emissions are captured from industrial sources using specialized systems (absorption columns, membrane filters, etc.).
Stage 2. Carrying out the chemical reaction to form fertilizers CO_2 reacts with ammonia (NH_3) in a high-pressure reactor to form carbon-ammonia fertilizers. The product is used as a nitrogen fertilizer.
Stage 3. Intelligent process monitoring Intelligent sensors constantly collect data on the quantitative and qualitative composition of gases, as well as reaction parameters (pressure, temperature, concentrations).
Stage 4. Real-time data transmission and analysis The collected information is transmitted to a central system for analysis, control and optimization of the disposal process.

Stages of the process of utilizing CO_2, emissions to obtain carbon-ammonia fertilizers

This approach combines environmental impact reduction with innovative resource conservation, allowing the transformation of harmful emissions into valuable products – fertilizers with a high nitrogen content. In addition, process automation provides reliable monitoring and control, which is in line with the principles of Industry 4.0 and sustainable development.

The implementation of an intelligent automated system for collecting and transmitting information on CO_2, emissions is a significant investment project. For example, for JSC "DniproAzot" the costs of purchasing new equipment are 3,500 thousand UAH, intelligent sensors – 230.5 thousand UAH, and a personal computer – 96.25 thousand UAH (Table 1).

The proposed economic cost analysis in Table 1 for the implementation of an intelligent automated environmental risk management system demonstrates its feasibility from both an environmental and economic point of view. The calculations demonstrate significant potential for reducing environmental fees and generating profits from the utilization of CO_2, emissions through the production of carbon-ammonia fertilizers.

The assessment of the effectiveness of the implementation of an intelligent automated system includes an analysis of economic and environmental indicators. The implementation of the system allows you to reduce CO_2, and ammonia emissions, which contributes to reducing environmental pollution fees

Table 1

Economic costs of system implementation

Indicator	Expenses (thousand UAH)	Share in total costs (%)	Service life (years)	Comment / Purpose
Equipment cost	3500.00	91.5	10	Main technological system
Cost of smart sensors	230.50	6.0	5	CO_2 sensors for real-time
Cost of a personal computer	96.25	2.5	3	Data processing, monitoring, reporting
Total costs	3826.75	100	–	–

(Table 2). For example, in 2022, JSC "DniproAzot" paid 65.157 thousand UAH of pollution fees.

Table 2

Return on investment assessment

Indicator	Expenses (thousand UAH)	Savings on environmental fees (thousand UAH/year)	Payback period (years)
Total costs	3826.75	65.16	~5.9

An extended analysis of the economic efficiency of implementing an intelligent automated environmental risk management system in Table 3 confirms its significant potential as a source of profit and a means of reducing environmental costs. Most of the economic effect (over 97%) is provided by the annual profit from the production of carbon-ammonia fertilizers, which indicates the feasibility of processing CO_2, emissions into agrochemical products. At the same time, reducing environmental fees, although it constitutes a smaller share of the total profit, plays an important role in increasing the environmental responsibility of the enterprise. The net additional profit of over 2 million UAH is a convincing argument in favor of further implementation of digital solutions in the field of environmental management.

Thus, the system demonstrates not only environmental, but also high economic efficiency, combining an innovative approach to sustainable development with practical benefits for an industrial enterprise.

Table 3

Cost-effectiveness of system implementation

Indicator	Value (thousand UAH)	Share in total profit (%)	Comment
Reduction of pollution charges	65.157	2.49	Savings on environmental costs
Annual profit from fertilizer production	2554.307	97.51	Income from the sale of agricultural products
Total profit growth	2619.464	100	Total revenue from system implementation
Net additional profit	2043.182	–	Profit after deducting system costs

Conclusions

The implementation of an intelligent automated system for collecting and transmitting information on CO_2, emissions is an effective solution for industrial enterprises. Given the high level of environmental burden on industrial enterprises, the digitalization of production processes using IoT, Big Data, analytics and automation allows not only to reduce the harmful impact on the environment, but also to increase the overall efficiency of the enterprise. Thus, the integration of digital technologies into the environmental management system is a justified strategic step towards sustainable development of industry. This allows not only to reduce the environmental impact, but also to obtain economic benefits through the production of carbon-ammonia fertilizers. The use of modern digital technologies provides accurate monitoring, analysis and management of emission utilization processes.

REFERENCES

1. Smoliar, L. H., Iliash, O. I., & Trofymenko, O. O. (2021). Transformatsiini efekty tsyfrovizatsii u zabezpechenni rozvytku promyslovoho vyrobnytstva v umovakh Industrii 4.0 [Transformational effects of digitalization in ensuring the development of industrial production under Industry 4.0]. *Pidpryiemnytstvo ta innovatsii – Entrepreneurship and Innovation*, *21,* 24–30. DOI: https://doi.org/10.37320/2415-3583/21.4 [in Ukrainian].

2. Bieloborodova, M. V. (2020). Upravlinnia ekolohichnymy ryzykamy v stratehii rozvytku promyslovykh pidpryiemstv [Management of environmental risks in the strategy of industrial enterprises development]. *Ekonomika i orhanizatsiia upravlinnia – Economics and Management Organization*, *1(37),* 37–48. DOI: https://doi.org/10.31558/2307-2318.2020.1.4 [in Ukrainian].

3. Bukanov, H. M. (2020). *Derzhavne upravlinnia u sferi formuvannia ta realizatsii derzhavnoi ekolohichnoi polityky na rehionalnomu rivni: teoretychnyi i praktychnyi aspekty: monohrafiia [Public administration in the field of formation and implementation of state environmental policy at the regional level: theoretical and practical aspects: monograph].* Dnipro: Hrani [in Ukrainian].

4. Derzhavna sluzhba statystyky Ukrainy. Vykydy zabrudniuiuchykh rechovyn i parnykovykh haziv v atmosferne povitria [Emissions of pollutants and greenhouse gases into the atmospheric air]. (n.d.). *stat.gov.ua*. Retrieved from https://stat.gov.ua/uk/datasets/vykydy-zabrudnyuyuchykh-rechovyn-i-parnykovykh-haziv-v-atmosferne-povitrya [in Ukrainian].

5. Natsionalnyi instytut stratehichnykh doslidzhen. Otsinka tendentsii ekoloho-tekhnohennoi sytuatsii u sviti: analitychna dopovid [Assessment of trends in the ecological and technogenic situation in the world: analytical report]. (n.d.). *niss.gov.ua*. Retrieved from https://niss.gov.ua/doslidzhennya/nacionalna-bezpeka/ocinka-tendenciy-ekologo-tekhnogennoi-situacii-u-sviti-analitichna [in Ukrainian].

6. Didych, Z. (2018). "Internet rechei": mozhlyvosti ta perspektyvy yikh vykorystannia u silskomu hospodarstvi Ukrainy ["Internet of Things": opportunities and prospects for their use in agriculture of Ukraine]. *Ahrarna ekonomika – Agrarian Economics*, *11(1–2),* 88–93. DOI: https://doi.org/10.31734/agrarecon2018.01.088 [in Ukrainian].

7. Honcharenko, B. M., Osadchyi, S. I., Vikhrova, L. H., Kalich, V. M., & Didyk, O. K. (2016). *Avtomatyzatsiia vyrobnychykh protsesiv [Automation of production processes].* Kirovohrad: Vydavets-Lysenko V. F. [in Ukrainian].

8. Chankvetadze, D., & Feshanych, L. (2023). Perspektyvy rozvytku system promyslovoi avtomatyzatsii v konteksti Industrii 4.0 [Prospects for the development of industrial automation systems in the context of Industry 4.0]. *Vymiriuvalna ta obchysliuvalna tekhnika v tekhnolohichnykh protsesakh – Measuring and Computing Devices in Technological Processes, 4,* 234–239. DOI: https://doi.org/10.31891/2219-9365-2023-76-31 [in Ukrainian].

9. Veres, O. M., & Olyvko, R. M. (2017). Klasyfikatsiia metodiv analizu velykykh danykh [Classification of big data analysis methods]. *Visnyk Natsionalnoho universytetu "Lvivska politekhnika": informatsiini systemy ta merezhi – Bulletin of Lviv Polytechnic National University: information systems and networks, 872,* 84-92. Retrieved from http://nbuv.gov.ua/UJRN/VNULPICM_2017_872_12 [in Ukrainian].

10. Cherep, A., Voronkova, V., Cherep, O., & Nikitenko, V. (2024). Shtuchnyi intelekt yak instrument zabezpechennia ekolohichnoi bezpeky ta staloho rozvytku [Artificial intelligence as a tool for ensuring environmental safety and sustainable development]. In Tabachnikov, S. (Ed.), *Ukrainian science and education in the conditions of European integration: collective monograph* (pp. 39–54). California: GS Publishing Services. DOI: https://doi.org/10.51587/9798-9895-14670-2024-020-39-54 [in Ukrainian].

11. Khorolskyi, V. P., & Korenets, Yu. M. (2022). *Avtomatyzatsiia vyrobnychykh protsesiv: pidruchnyk [Automation of production processes: textbook].* Kryvyi Rih: [DonNUET] [in Ukrainian].

12. Upravlinnia ekolohichnymy ryzykamy za ISO 14001 [Environmental risk management under ISO 14001]. (n.d.). *tms.ua*. Retrieved from https://tms.ua/blog/upravlinnia-ekolohichnymy-ryzykamy-za-iso-14001/ [in Ukrainian].

13. Tang, J., Huang, K., & Xiong, A. (2025). Impact of digital transformation on corporate sustainability: evidence from China's carbon emissions. *Energy Informatics, 8*(20), 1–27. DOI: https://doi.org/10.1186/s42162-025-00479-8 [in English].

14. Ahmed, N., & Shakoor, N. (2025). Advancing agriculture through IoT, Big Data, and AI: A review of smart technologies enabling sustainability. *Smart Agricultural Technology, 10*, 100648. DOI: https://doi.org/10.1016/j.atech.2025.100848 [in English].

Received 10.03.2025.
Revised 20.03.2025.
Accepted 22.05.2025.
Published 25.06.2025.

ЦИФРОВІЗАЦІЯ ПРОМИСЛОВИХ ПРОЦЕСІВ ДЛЯ УПРАВЛІННЯ ЕКОЛОГІЧНИМИ РИЗИКАМИ НА ПІДПРИЄМСТВАХ

Рябик Г. Є., Гелета І. В.

У статті розглядається цифровізація промислових процесів як ефективний інструмент управління екологічними ризиками на підприємствах. Акцент зроблено на комплексному підході до використання сучасних цифрових технологій – Інтернету речей (IoT), великих даних (Big Data), аналітики, автоматизації та роботизації – з метою підвищення рівня екологічної безпеки, мінімізації впливу шкідливих викидів та оптимізації виробничої діяльності. Особливу увагу приділено впровадженню інтелектуальної автоматизованої системи на прикладі АТ «ДніпроАзот», яка дозволяє збирати, обробляти та передавати дані про викиди CO_2, у режимі реального часу. У дослідженні проаналізовано перспективний підхід до утилізації викидів CO_2, шляхом їх перетворення у вуглеамічні добрива, що дозволяє поєднати зменшення викидів парникових газів з отриманням економічної вигоди у вигляді виробництва цінної агрохімічної продукції. Показано, що впровадження цифрових технологій дозволяє не лише зменшити екологічне навантаження, але й сприяє підвищенню продуктивності, зниженню витрат і підвищенню гнучкості управлінських рішень на підприємстві. Обґрунтовано економічну доцільність інвестицій у впровадження інтелектуальної автоматизованої системи управління екологічними ризиками, надано розрахунки потенційного прибутку та зменшення екологічних зборів. Висвітлено значення цифровізації у забезпеченні сталого розвитку промислових підприємств в умовах сучасних екологічних викликів. Отримані результати мають як практичне, так і теоретичне значення для формування ефективної екологічної політики на рівні підприємства та держави загалом.

Ключові слова: цифровізація, екологічні ризики, Інтернет речей (IoT), великі дані, автоматизація, викиди CO_2, сталий розвиток, вуглеамічні добрива, промислові підприємства, інтелектуальні системи управління.

DIGITALIZATION OF INDUSTRIAL PROCESSES FOR ENVIRONMENTAL RISK MANAGEMENT AT ENTERPRISES

Ryabik* G. E., Geleta I. V.

Ukrainian State University of Chemical Technology (Educational Scientific Institute "Ukrainian State University of Chemical Technology"), Dnipro, Ukraine

***e-mail: anna.ryabik77@gmail.com**

Ryabik G.E. ORCID: **0000-0002-2194-3054**

Geleta I.V. ORCID: **0009-0008-7743-2350**

The article examines the digitalization of industrial processes as an effective tool for managing environmental risks at enterprises. Emphasis is placed on a comprehensive approach to the use of modern digital technologies – the Internet of Things (IoT), Big Data, analytics, automation, and robotics – aimed at enhancing environmental safety, minimizing the impact of harmful emissions, and optimizing production activities. Special attention is given to the implementation of an intelligent automated system at PJSC "DniproAzot", which enables the collection, processing, and transmission of CO_2, emissions data in real time. The study analyzes a promising approach to CO_2, emissions utilization through their conversion into carbon-ammonia fertilizers, which combines the reduction of greenhouse gas emissions with economic benefits in the form of valuable agrochemical product output. It is demonstrated that the implementation of digital technologies not only reduces environmental pressure but also contributes to increased productivity, cost reduction, and greater flexibility in enterprise decision-making. The economic feasibility of investing in an intelligent automated system for environmental risk management is substantiated, with calculations provided for potential profit and reduced environmental fees. The role of digitalization in ensuring sustainable development of industrial enterprises amid modern environmental challenges is highlighted. The findings have both practical and theoretical significance for shaping effective environmental policies at the enterprise and national levels.

Keywords: digitalization, environmental risks, Internet of Things (IoT), Big Data, automation, CO_2, emissions, sustainable development, carbon-ammonia fertilizers, industrial enterprises, intelligent management systems.

REFERENCES

1. Smoliar, L. H., Iliash, O. I., & Trofymenko, O. O. (2021). Transformatsiini efekty tsyfrovizatsii u zabezpechenni rozvytku promyslovoho vyrobnytstva v umovakh Industrii 4.0 [Transformational effects of digitalization in ensuring the development of industrial production under Industry 4.0]. *Pidpryiemnytstvo ta innovatsii – Entrepreneurship and Innovation*, *21,* 24–30. DOI: https://doi.org/10.37320/2415-3583/21.4 [in Ukrainian].

2. Bieloborodova, M. V. (2020). Upravlinnia ekolohichnymy ryzykamy v stratehii rozvytku promyslovykh pidpryiemstv [Management of environmental risks in the strategy of industrial enterprises development]. *Ekonomika i orhanizatsiia upravlinnia – Economics and Management Organization*, *1(37),* 37–48. DOI: https://doi.org/10.31558/2307-2318.2020.1.4 [in Ukrainian].

3. Bukanov, H. M. (2020). *Derzhavne upravlinnia u sferi formuvannia ta realizatsii derzhavnoi ekolohichnoi polityky na rehionalnomu rivni: teoretychnyi i praktychnyi aspekty: monohrafiia [Public administration in the field of formation and implementation of state environmental policy at the regional level: theoretical and practical aspects: monograph].* Dnipro: Hrani [in Ukrainian].

4. Derzhavna sluzhba statystyky Ukrainy. Vykydy zabrudniuiuchykh rechovyn i parnykovykh haziv v atmosferne povitria [Emissions of pollutants and greenhouse gases into the atmospheric air]. (n.d.). *stat.gov.ua*. Retrieved from https://stat.gov.ua/uk/datasets/vykydy-zabrudnyuyuchykh-rechovyn-i-parnykovykh-haziv-v-atmosferne-povitrya [in Ukrainian].

5. Natsionalnyi instytut stratehichnykh doslidzhen. Otsinka tendentsii ekoloho-tekhnohennoi sytuatsii u sviti: analitychna dopovid [Assessment of trends in the ecological and technogenic situation in the world: analytical report]. (n.d.). *niss.gov.ua*. Retrieved from https://niss.gov.ua/doslidzhennya/nacionalna-bezpeka/ocinka-tendenciy-ekologo-tekhnogennoi-situacii-u-sviti-analitichna [in Ukrainian].

6. Didych, Z. (2018). "Internet rechei": mozhlyvosti ta perspektyvy yikh vykorystannia u silskomu hospodarstvi Ukrainy ["Internet of Things": opportunities and prospects for their use in agriculture of Ukraine]. *Ahrarna ekonomika – Agrarian Economics*, *11(1–2),* 88–93. DOI: https://doi.org/10.31734/agrarecon2018.01.088 [in Ukrainian].

7. Honcharenko, B. M., Osadchyi, S. I., Vikhrova, L. H., Kalich, V. M., & Didyk, O. K. (2016). *Avtomatyzatsiia vyrobnychykh protsesiv [Automation of production processes].* Kirovohrad: Vydavets-Lysenko V. F. [in Ukrainian].

8. Chankvetadze, D., & Feshanych, L. (2023). Perspektyvy rozvytku system promyslovoi avtomatyzatsii v konteksti Industrii 4.0 [Prospects for the development of industrial automation systems in the context of Industry 4.0]. *Vymiriuvalna ta obchysliuvalna tekhnika v tekhnolohichnykh protsesakh – Measuring and Computing Devices in Technological Processes, 4,* 234–239. DOI: https://doi.org/10.31891/2219-9365-2023-76-31 [in Ukrainian].

9. Veres, O. M., & Olyvko, R. M. (2017). Klasyfikatsiia metodiv analizu velykykh danykh [Classification of big data analysis methods]. *Visnyk Natsionalnoho universytetu "Lvivska politekhnika": informatsiini systemy ta merezhi – Bulletin of Lviv Polytechnic National University: information systems and networks, 872,* 84-92. Retrieved from http://nbuv.gov.ua/UJRN/VNULPICM_2017_872_12 [in Ukrainian].

10. Cherep, A., Voronkova, V., Cherep, O., & Nikitenko, V. (2024). Shtuchnyi intelekt yak instrument zabezpechennia ekolohichnoi bezpeky ta staloho rozvytku [Artificial intelligence as a tool for ensuring environmental safety and sustainable development]. In Tabachnikov, S. (Ed.), *Ukrainian science and education in the conditions of European integration: collective monograph* (pp. 39–54). California: GS Publishing Services. DOI: https://doi.org/10.51587/9798-9895-14670-2024-020-39-54 [in Ukrainian].

11. Khorolskyi, V. P., & Korenets, Yu. M. (2022). *Avtomatyzatsiia vyrobnychykh protsesiv: pidruchnyk [Automation of production processes: textbook].* Kryvyi Rih: [DonNUET] [in Ukrainian].

12. Upravlinnia ekolohichnymy ryzykamy za ISO 14001 [Environmental risk management under ISO 14001]. (n.d.). *tms.ua*. Retrieved from https://tms.ua/blog/upravlinnia-ekolohichnymy-ryzykamy-za-iso-14001/ [in Ukrainian].

13. Tang, J., Huang, K., & Xiong, A. (2025). Impact of digital transformation on corporate sustainability: evidence from China's carbon emissions. *Energy Informatics, 8*(20), 1–27. DOI: https://doi.org/10.1186/s42162-025-00479-8 [in English].

14. Ahmed, N., & Shakoor, N. (2025). Advancing agriculture through IoT, Big Data, and AI: A review of smart technologies enabling sustainability. *Smart Agricultural Technology, 10*, 100648. DOI: https://doi.org/10.1016/j.atech.2025.100848 [in English].