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ASSESSMENT OF THE EFFICIENCY OF FUNCTIONING OF THE ENVIRONMENTAL MANAGEMENT SYSTEM OF ENTERPRISES

Purpose. A multifactor model is developed to assess the efficiency level of an enterprise's environmental management system, depending on the effectiveness of organizational environmental measures.

Methodology. The authors' method for determining a comprehensive criterion for monitoring the effectiveness of the environmental management system, which characterizes the efficiency of operation and determines the level of environmental safety of enterprises, is proposed and used. To solve the tasks, a complex research method was also used, which included the analysis and generalization of literary and patent sources, and analytical, experimental research using computer and mathematical modeling methods.

Findings. According to the studies and calculations of the generalized environmental quality indicator – 0.64, 0.66 and 0.66, the largest negative impact on the environment is caused by the activities of enterprises in the Pecherskyi, Podilskyi, and Solomianskyi districts of Kyiv, respectively. The obtained data testify to the relationship between the effectiveness of the implemented environmental measures (saving and rational use of resources, application of environmental technologies, advanced training, and environmental competence of employees) and the level of efficiency of the environmental management system of enterprises.

Originality. As a result of the studies conducted using actual data, a system of indicators of the generalized environmental quality indicator has been proposed for the first time, which allows determining the environmental efficiency and effectiveness of the implemented environmental measures to assess the effectiveness of the functioning of the implemented environmental management system of the enterprise.

Practical value. Based on the research results, a technique is proposed to assess the effectiveness of the environmental management system of enterprises by determining a generalized environmental quality indicator in terms of reducing the negative impact of the enterprise's activities on the environment. Such an assessment system will help the management of the enterprise to promptly introduce corrective actions to improve the efficiency of the environmental management system and increase the level of environmental safety.

Keywords: *environmental management system, environmental quality, environmental protection measures, environmental safety, enterprise*

Introduction. The complexity of the problems, the dynamism of situations occurring in the enterprise-environment system lead to the need to study technical, economic, environmental, social, psychological, managerial and other aspects inside and outside this system. Changes in the parameters of ecosystems, increased human intervention in the management of natural objects and territories require a systematic approach to changes in the organization of enterprises. In today's world, which strives for ecological, social and economic development, there is a need to develop and implement environmental management systems (EMS) for enterprises operating in various sectors of the economy in accordance with the requirements of DSTU ISO 14001:2015. The main task in developing and implementing an EMS is, among other things, to ensure its continuous monitoring to achieve efficient operation. Therefore, conducting monitoring studies to determine the viability of the enterprise-environment system will allow one to control the functioning of the EMS, paying special attention to determining changes in the impact of the enterprise on the environment [1]. The selection of criteria and indicators, the application of environmental protection measures, and raising awareness of employees in the field of balanced environmental management are considered as changes in the organization of the Enterprise-Environment system. In order to control the implemented EMS, it is advisable to determine the implementation of environmental initiatives in the dynamics by clear criteria and indicators. Thus, the application of criteria, for example, before and after the EMS implementation or after the first audit and before the next audit, helps the company's management and the EMS working group to formulate a plan of further actions and adjust environmental measures to continuously improve environmental performance. Therefore, it was decided to propose individual factors that together form the values of the generalized criteria – environmental quality and biosystems. Based on the values of these generalizing criteria, the company's management can immediately assess the effectiveness of the EMS in terms of measures aimed at reducing environmental impact. Mathematical modeling methods should be used to calculate and structure these indicators [2, 3]. Thus, the formation of a mathematical apparatus for developing models that will allow assessing the efficiency of the EMS of enterprises depending on the effectiveness of their organizational environmental measures is an urgent scientific problem.

Literature review. The issue of developing criteria for assessing the effectiveness of the EMS and environmental activities of enterprises is extremely relevant. Criteria and indicators are necessary to assess the impact of enterprises' activities on the environment. The information obtained will help the company's management to promptly implement corrective actions to improve the EMS efficiency and increase the level of environmental safety of the enterprise. The use of mathematical models that analyze the state of biosystems and environmental quality depending on the environmental and organizational changes in the Entity-Environment system before and after the implementation of the EMS makes it possible to predict the level of environmental safety of cities and regions [4]. The creation of criteria for assessing chemical risk and identifying toxic compounds based on ECOTOX monitoring data allows classifying the effects of chemicals in the environment. The data obtained from in vitro and in silico approaches are used for chemical testing and to provide information to authorities,

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regulators, and scientists [5]. Alongside the development of criteria for assessing the environmental performance of enterprises, scientists are studying plant species within the urban area. Using remote sensing, 3,755 points of tree leaf blades were scanned. The obtained digital data allowed us to identify the effects of urbanization and climate change in Munich [6]. To reduce carbon emissions, the Chinese government closely monitors the environmental activities of enterprises through environmental regulations and green financing. The use of such tools leads to a reduction in carbon emissions by enterprises and has a positive impact on the surrounding areas [7]. The application of the Green Lean Six Sigma (GLSS) integrated approach by industrial managers leads to a reduction in emissions and waste from the activities of small and medium-sized enterprises. The application of GLSS has led to an improvement in the state of the environment within the scope of the enterprises' activities and to positive changes in achieving economic and environmental aspects of sustainable development of enterprises and in increasing their level of environmental safety [8]. Many governments emphasize the need for changes in the long-term environmental policy of the state. However, most environmental initiatives, especially in the agricultural sector, have not yielded the desired results. The transformation of environmental policy is associated with a new view of governments on the use of long-term environmental agreements between countries [9]. The combination of natural ecosystems with urbanized areas in the coastal zone of Yancheng (China) shows how management can accelerate the sustainable development of a territory or region. The application of criteria for assessing anthropogenic pressure on six typical local ecosystems allowed us to analyze energy flow and sustainability based on the emergency theory. The data obtained make it possible to consider the level of environmental hazard of the territories, as well as to develop corrective environmental measures to ensure that ecosystems achieve sustainable development [10]. Increasing the level of environmental efficiency of the production activities of enterprises will contribute to the transition to sustainable development. The implemented measures will have a positive impact on the processes of investment flows to producers. The application of integrated management ideas and infrastructure monitoring will allow replacing traditional management processes with environmental ones [11]. Efficient chemical processing technologies, in particular r-PET technologies with melt pretreatment, were compared with conventional chemical processing technologies. It was found that r-PET technologies can turn PET bottle waste into valuable raw materials. Therefore, the use of such innovative technologies is an important environmental task for small and medium-sized businesses [12]. The introduction of green technologies has a positive impact on the environmental management system and its environmental performance [13, 14]. To study the impact of enterprises' activities on environmental quality through "substitution effects" and "additional effects", a theoretical model was developed to assess the relative benefits of Big Data. The data obtained on the sustainable development of the enterprise allowed improving its reputation, productivity and commercial attractiveness. Environmental monitoring data – resource depletion, waste management, air and water pollution – determine the level of sustainable development of an enterprise [15]. By analyzing the data obtained, it becomes possible to forecast and make decisions by the company's management aimed at developing more sound and effective environmental practices and strategies, in particular when implementing the EMS [16, 17]. To implement an effective and efficient EMS, it is necessary to cooperate with external stakeholders (investor network). A striking example of the application of low-carbon innovations in the activities of small and medium-sized enterprises is the experience of Chinese family firms. The data obtained on the activities of 9,249 firms for the period 2007–2019 allowed one to develop a methodology for measuring ESG activities among cluster institutional investors to accelerate the implementation of low-carbon innovations [18]. The correct choice of management approaches at all stages of implementation and operation of the enterprise's EMS ensures an increase in its efficiency. Controlling the indicators of environmental and organizational changes and the criteria for the EMS effectiveness allows the enterprise management to form a set of management approaches. Based on the data on the implemented environmental and organizational changes at the enterprise, the QFD methodology (Quality Function Deployment) was applied, which determines the vector of orientation of approaches, considering their complexity and significance for the implementation of an effective EMS [19]. The COP26 conference emphasized the role of increasing climate investment. They play an important role in mitigating climate change through environmental management and the spread of green innovations [20]. Using data from 30 regions of China and a spatial model to investigate the relationship between green innovations, environmental regulations (ER) and green investments, it was found that ER potentially enhances the impact of green investments on the promotion of green innovations [21].

Unsolved aspects of the problem. It is established that the issues of introducing environmental innovations at enterprises to improve the condition of territories and regions are relevant and are covered in many literary sources. Sustainable development of enterprises is an essential aspect of many scientific studies. As a result of the study of modern research, it was found that most authors do not consider the issue of implementing the EMS comprehensively. Almost no consideration is given to the formation of criteria by which it will be possible to assess the effectiveness and efficiency of the EMS operating at the enterprise. The formation and calculation of such criteria will allow assessing the effectiveness of the implemented environmental protection measures, which are indicators of the effectiveness of the EMS of the enterprise. Therefore, studies aimed at assessing the efficiency of the EMS of enterprises depending on the effectiveness of their organizational environmental protection measures are relevant and necessary for the formation of a long-term strategy for sustainable development of enterprises.

Purpose. The purpose of this work is to develop a multifactorial model for assessing the efficiency of the EMS of enterprises from the effectiveness of their organizational environmental measures. To achieve this goal, it was necessary to:

- to select ten companies operating in ten administrative districts of Kyiv that have implemented an EMS in accordance with the requirements of the DSTU ISO 14001:2015 standard;
- to review the environmental protection measures implemented at the enterprises;
- to develop criteria for the environmental performance of the EMS, considering the weighting of individual factors and group indicators;
- to calculate a generalized environmental quality indicator that includes data on pollutant emissions, water use, waste generation, and soil conditions in areas adjacent to the enterprises;
- based on the data obtained and the calculation of a generalized environmental quality indicator using computer modeling, to assess the effectiveness of the EMS of enterprises depending on the implemented environmental protection measures that have a certain impact on the state of natural components of the environment.

Research methodology (structure, sequence). The article proposes and uses for research the authors' method for determining a comprehensive criterion for monitoring the environmental performance of the EMS with taking into account the weighting factors of individual factors and group indicators to establish the environmental effectiveness of the implemented EMS, which characterizes its efficiency and determines the level of environmental safety of enterprises.

Modern environmental research focuses on a comprehensive analysis of the impact of industrial activity on the environment using statistical analysis and big data processing methods.

One of the main elements of the analysis using experimental research is a generalized indicator of environmental quality, which includes data on pollutant emissions, water use, waste generation, and soil conditions in areas adjacent to enterprises.

The assessment of atmospheric pollution from industrial emissions to develop recommendations for the organization of control measures was based on the methodology of inventorying the pollutants of enterprises. This methodology includes a collection of systematized information on the locations and nature of emissions on the territory of enterprises, as well as quantitative and qualitative characteristics of pollutants and their compliance with hazard classes. During the inventory, both calculation methods and instrumental and laboratory studies were used to analyze the composition of pollutant emissions. The choice of methods depended on various factors, such as sampling conditions, availability of design data, type of pollution sources and a list of acceptable methods for assessing the impact of these sources.

The assessment of the state of biosystems was based on methods that allow detecting toxic effects on living organisms. An important aspect is to determine the chemical composition of atmospheric emissions that can accumulate in water and soil bodies, posing a potential risk to public health.

The American risk assessment model (*U.S. Environmental Protection Agency (EPA) 1997. The benefits and costs of the Clean Air. Act 1970 to 1990. Office of Air and radiation EPA 410-R-97-002. October*) is recommended by scientific organizations. It includes identification of potential hazards, determination of dose-effect relationships, assessment of the impact of regulatory measures, and description of risks based on scientifically justified uncertainties. Well-known methodologies, such as the exponential model, allow calculating the potential risk to public health from chronic exposure to pollution.

Risk levels for public health are determined on the basis of values that range from minimal to extremely dangerous and are assessed through average daily concentrations, maximum permissible levels, and the duration of exposure to pollutants.

Assessment of potential risks is important for understanding the interaction between pollution and public health, in particular when exposure to different pollutants is combined. Such an analysis requires the use of additional scientific methods, such as bioassays and biotesting, to assess the degree of toxic impact on natural environmental components.

In addition, to assess the effectiveness of environmental management systems at enterprises, it is necessary to analyze not only the current concentrations of pollutants, but also to integrate inventory data with the results of experimental studies. The use of bioindication and biotesting methods allows for a more detailed assessment of the state of the environment and the effectiveness of environmental protection measures.

Results. To continuously improve the environmental management system of an enterprise, to assess the effectiveness of the implemented environmental protection measures, to control the state of natural components of the environment, it is proposed to calculate a group indicator of environmental efficiency of the *EMS* (*EE*).

$$EE = \begin{cases} EEb \\ EEq \end{cases} = \begin{cases} EEb(ND) \cap EEb(RA) \cap EEb(GT) \cap EEb(QW) \cap EEb(SD) \\ EEq(Air) \cap EEq(pH) \cap EEq(W) \cap EEq(Was) \end{cases},$$

where *EEb(ND)* is an integrating indicator that covers factors that characterize the level of necrosis and chlorosis of tree leaves; *EEb(RA*) is an integrating indicator that covers factors that show the level of dust pollution of trees and morphological changes that occur in their vegetative organs; *EEb(GT)* is an integrating indicator that covers data on the phytotoxic effect of precipitation and soil; *EEb(QW*) is an integrating indicator that covers data on the degree of toxicity of surface water; *EEb(SD*) is an integrating indicator that covers indicators of tree development stability; *EEq(Air*) is an aggregate indicator that covers factors that characterize the emission rate of POPs and potential risks to public health under the combined effect of several POPs released into the air; *EEq(pH)* is an aggregate indicator that covers factors that help determine the pH of soil cover and precipitation; *EEq(W)* is an aggregate indicator that covers factors that determine the level of total risk from the impact of all impurities that end up in the water environment after the implementation of EMS measures, such as water consumption and pH of water resources and objects; *EEq(Was)* is an aggregate indicator that covers factors that shape the level of waste generation as a result of the enterprises' activities.

To study the individual factors of the generalized environmental quality indicator (*EEq*), calculations were made, taking into account the intake of POPs into the air, water, soil, etc.

An inventory of pollutant emissions into the air was conducted for ten enterprises in Kyiv. The studied enterprises have an implemented and operating EMS, as well as operate in various sectors of the economy and are located in different administrative-territorial districts of Kyiv (Table 1, Fig. 1).

Based on statistical information from environmental reports of enterprises and using the methodology for calculating concentrations of AR in the air, the total potential risk to public health was determined.

The potential risk to public health from prolonged exposure to air pollution was calculated using the following formula

$$Risk = 1 - \exp\left(\ln(0.84) \cdot \left(\frac{C}{MPC_{sd}} \right)^b \Big/ K_z \right), \quad (1)$$

where *Risk* is the probability of developing uncharacteristic toxic effects due to chronic intoxication under certain conditions; MPC_{sd} is the average daily maximum permissible concentration, mg/dm^3; *C* is the concentration of chemical compounds that affect human health in a certain time period, mg/dm^3*;* *b* is a value that allows assessing the isoeffective effects of impurities according to their classes; K_z is a stock indicator that depends on the class of the PP.

To determine the public health risk associated with contamination of drinking water with toxic substances generated

Table 1

Activities and location of the research enterprises

Company number*	District of m. Kyiv	Field of activity
1	Holosiivskyi	Construction of roads and highways
2	Obolonskyi	Production of meat products
3	Shevchenkivskyi	Leasing and operation of own or leased real estate
4	Darnytskyi	Manufacture of perfumes and cosmetics
5	Dniprovskyi	Production of tools and equipment for measurement, research and navigation
6	Desnianskyi	Passenger land transport of urban and suburban traffic
7	Pecherskyi	Operation of restaurants, provision of mobile catering services
8	Sviatoshinsky	Fuel retailing
9	Podilskyi	Comprehensive maintenance of facilities (heat supply)
10	Solomianskyi	A chain of food outlets

*Note: * further in the text of the article, references to companies will correspond to their serial number in the table*

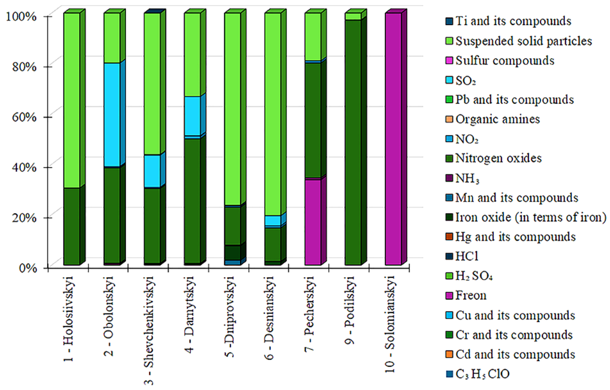

Fig. 1. Analysis of the inventory of emissions of PP into the air

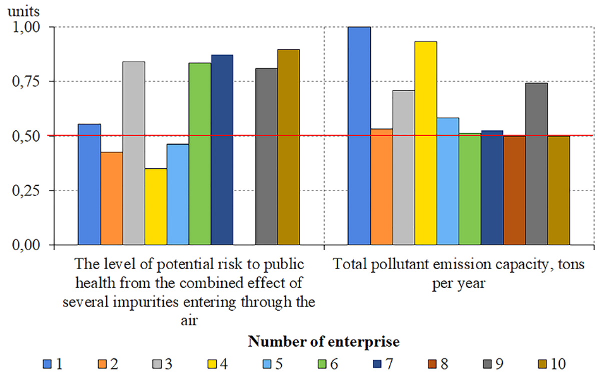

Fig. 2. Comparative analysis of individual factors of the "Atmospheric air – EEq(Air)" aggregate indicator (Decoding of symbols is shown in Table 1)

by the activities of enterprises, we applied the formula of a threshold-free model for assessing the potential non-carcinogenic risk to public health, considering the level and duration of exposure (dose-time-effect relationship)

$$Risk = 1 - \exp\left(\left(\frac{\ln(0.84)}{MPC \cdot K_z}\right) \cdot C\right), \quad (2)$$

where *Risk* is the probability of uncharacteristic toxic effects during prolonged intoxication (from 0 to 1); *C* is the concentration of impurities in drinking water, calculated as the average daily concentration of a substance that is ingested during prolonged human consumption of drinking water; *MPC* is the regulatory indicator, the maximum permissible concentration of a substance; K_z is the value of the margin, which in most cases is 10.

In the course of enterprises' operations, a combined effect occurs that causes a negative impact of several pollutants coming through one of the environmental components.

The cumulative impact of environmental pollution forms a potential risk to human health and is calculated using the formula

$$Risk_{sum} = 1 - \prod_{i=1}^{n}(1 - Risk_i),$$

where $Risk_{sum}$ is the potential risk of cumulative exposure to impurities; $Risk_i$ is the potential risk of exposure to the i^{th} impurity; *n* is the total number of impurities.

When interpreting the obtained values of the potential risk to public health, a ranking scale from 0 (minimal risk) to 1 (fatal effects) is used.

An analysis of the inventory of industrial pollutants showed that a large number of compounds that adversely affect public health are released into the air.

The generalized results of the studies of environmental indicators of enterprises were presented in the form of a normalized value of the unifying indicator "Atmospheric air – *EEq(Air)*" (Figs. 2, 3).

Analyzing the graphical interpretation of the calculations, we determined that the largest amount of pollutants released into the air as a result of its activities is emitted by the enterprise for the construction of roads and highways in Holosiivskyi district.

As can be seen from the diagram presented in Fig. 3, enterprises operating in the Holosiivskyi, Podilskyi, and Shevchenkivskyi districts of Kyiv have the highest value of the aggregate indicator "Atmospheric air – *EEq(Air)*", which indicates a negative impact of their activities on the environment.

In the course of its operations, the company emits 13 different impurities, 4 of which are classified as hazardous. The total potential risk to public health is 0.57, and continuous exposure to pollution causes severe chronic effects. As can be seen from the diagram presented in Fig. 4, in terms of the total

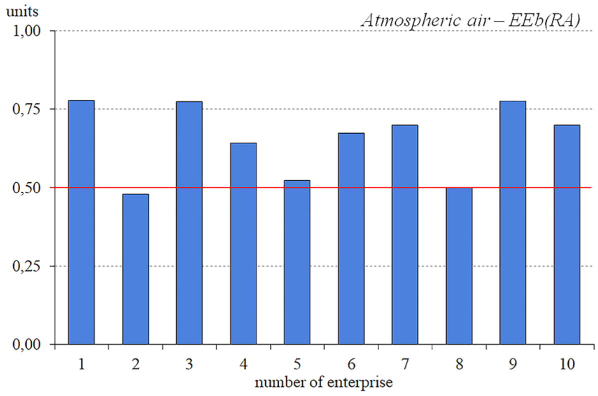

Fig. 3. Analysis of the aggregate indicator "Atmospheric air – EEq(Air)" by enterprises (Decoding of symbols is shown in Table 1)

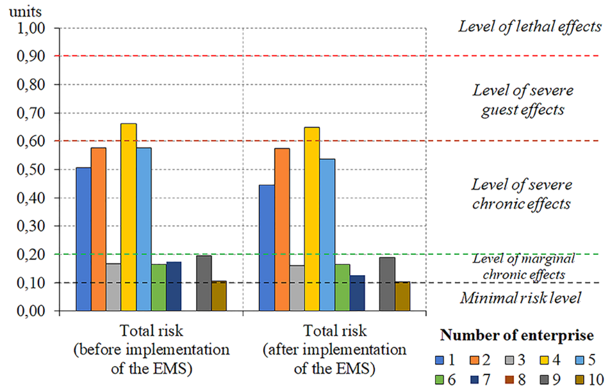

Fig. 4. Analysis of the level of potential risk to public health under the combined effect of several airborne impurities before and after the introduction of EMS (Decoding of symbols is shown in Table 1)

potential risk (0.65, which causes severe chronic effects in the population with chronic exposure to air pollution), the perfume and cosmetics production facility has the greatest negative impact on public health.

The analysis of the level of total potential risk to public health allows us to identify a group of three enterprises whose chronic exposure to air pollution causes severe chronic effects. Therefore, the EMS working group of these enterprises needs to adjust the goals and objectives of the environmental program to achieve the intentions set out in the environmental policy of these enterprises.

It should be noted that regarding a number of enterprises, although they emit a significant amount of pollutants in the course of their production activities, their total risk to public health causes boundary chronic effects.

Thus, the lowest total potential risk to public health is caused by the activities of a retailer in non-specialized stores, mainly selling food, beverages, and tobacco products in Solomianskyi district of Kyiv. The value of the total risk is 0.1 and, in case of chronic exposure to air pollution, corresponds to the level of minimal risk.

After the implementation of the EMS, there has been a positive trend towards reducing the emissions of various impurities into the air in the course of the enterprises' operations.

The condition of water bodies within the area of influence of the research facilities is determined by the aggregate indicator "Water bodies – *EEq(W)*".

The complex chronic impact on public health of the release of radionuclides into the aquatic environment leads to a potential risk and damage to the environment, in particular the aquatic environment. The total potential risk was determined based on the concentration of the OPs in surface water bodies located at almost the same distance from the source of exposure and using formulas 1 and 2 (Table 2).

The analysis of the five research enterprises showed that the total potential risk of chronic exposure to water pollution is satisfactory (Fig. 5) and does not lead to irreversible water degradation.

Separate indicators of the aggregate indicator "Water bodies – *EEq(W)*": acidity and hardness of water bodies are determined by the compliance of experimental values with the

Table 2

The results of the study on the unifying indicator "Water bodies – *EEq(W)*" – "The level of potential risk to public health under the complex effect of several impurities entering through the water environment $EEb(W)_1$"

No. of the enterprise	Pollutant	*MPCs.e.* mg/dm³	Stock factor *Kz*	Before the implementation of the EMS			After the implementation of the EMS			Direction of change	$EEb(W)_1$
				Concentration, mg/l	Potential risk	Total risk	Concentration, mg/l	Potential risk	Total risk		
1	–	–	–	–	–	–	–	–	–	–	–
2	Fe	0.1	10	0.13	0.0224	0.055	0.13	0.0224	0.045	–	0.955
	Zn	0.01		0.003	0.0052		0.003	0.0052			
	NO_2	0.05		0.08	0.0275		0.05	0.0173			
	NO_{3-}	2		0.08	0.0007		0.07	0.0006			
3	–	–	–	–	–	–	–	–	–	–	–
4	Fe	0.1	10	0.12	0.0207	0.073	0.12	0.0207	0.054	–	0.946
	Zn	0.01		0.003	0.0052		0.003	0.0052			
	NO_2	0.05		0.09	0.0309		0.06	0.0207			
	NO_{3-}	2		2.1	0.0181		1.01	0.0088			
5	Fe	0.1	10	0.1	0.0173	0.045	0.1	0.0173	0.045	–	0.955
	Zn	0.01		0.004	0.0069		0.004	0.0069			
	NO_2	0.05		0.06	0.0207		0.06	0.0207			
	NO_{3-}	2		0.08	0.0007		0.09	0.0008			
6	Fe	0.1	10	0.09	0.0156	0.048	0.09	0.0156	0.045	–	0.955
	Zn	0.01		0.003	0.0052		0.003	0.0052			
	NO_2	0.05		0.08	0.0275		0.07	0.0241			
	NO_{3-}	2		0.09	0.0008		0.08	0.0007			
7	–	–	–	–	–	–	–	–	–	–	–
8	Fe	0.1	10	0.1	0.0173	0.058	0.1	0.0173	0.050	–	0.950
	Zn	0.01		0.004	0.0069		0.004	0.0069			
	NO_2	0.05		0.05	0.0173		0.05	0.0173			
	NO_{3-}	2		2	0.0173		1.08	0.0094			
9	–	–	–	–	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	–	–	–

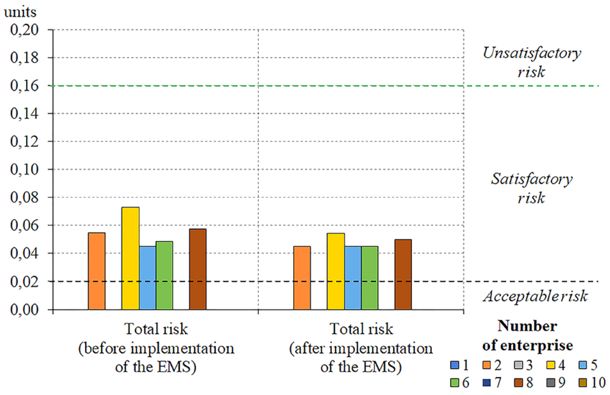

Fig. 5. Analysis of the level of potential risk to public health under the complex impact of several pollutants entering the aquatic environment before and after the EMS implementation (Decoding of symbols is shown in Table 1)

norm. Based on the results of the calculations, the analysis shows that the company, whose activities are related to the production of perfumes and cosmetics, has the least negative impact on the state of water bodies, since the pH (0.96) and water hardness (1) are within the normal range (Fig. 6).

The graphical interpretation of the analysis of individual factors of the aggregate indicator "Water bodies – *EEq(W)*", shown in Fig. 6, shows that the pH and water hardness are almost within the norm, and the multiplicity value is close to 1.

Fig. 7 shows a comparison of enterprises based on the results of calculations of the aggregate indicator "Water bodies – *EEq(W)*".

The highest value of the normalized aggregate indicator "Water bodies – *EEq(W)*" was recorded for the enterprises of Desnianskyi and Obolonskyi districts. This indicates the effectiveness of the implemented environmental technologies aimed at saving water resources.

All of the studied enterprises are committed to saving water resources in the course of their production activities. The most significant volume of water use (4.45 thousand m^3/year) was recorded at a fuel retailer in Solomianskyi district.

The results of calculations of the aggregate indicator "Acidity of the environment – *EEq(pH)*" of Kyiv enterprises are visualized in Fig. 8.

The analysis of the results of the study of individual factors of the unifying indicator "Environmental acidity – *EEq(pH)*" showed the direction of change in the acidity of precipitation and soil within the sanitary protection zone of the research enterprises. The information obtained will influence the adop-

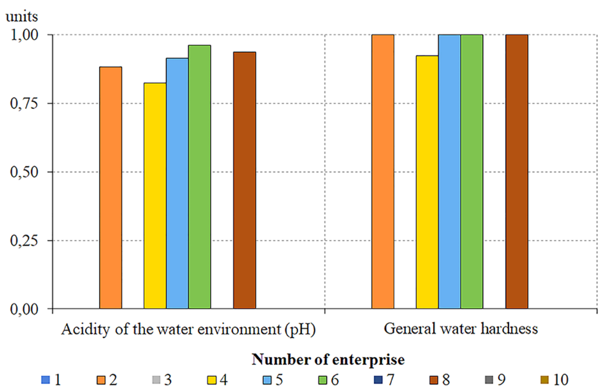

Fig. 6. Comparative analysis of individual factors of the aggregate indicator "Water bodies – EEq(W)": "Acidity of water bodies pH" and "Total water hardness" (Decoding of symbols is shown in Table 1)

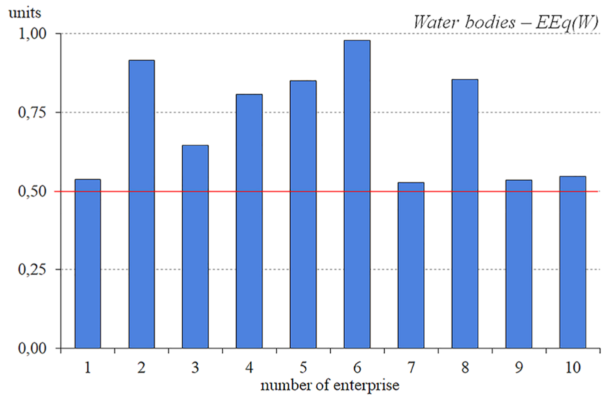

Fig. 7. Analysis of the aggregate indicator "Water bodies – EEq(W)" by enterprises (Decoding of symbols is shown in Table 1)

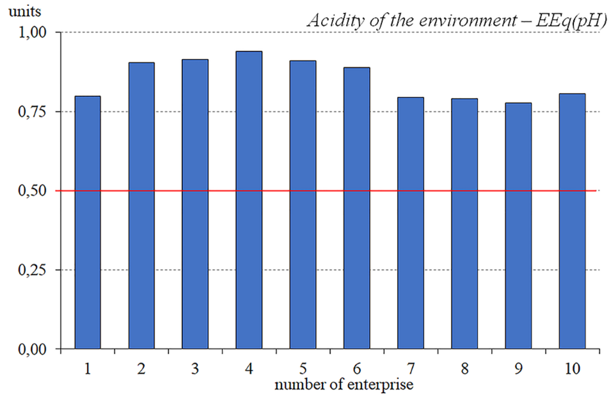

Fig. 8. Analysis of the aggregate indicator "Acidity of the environment – EEq(pH)" by enterprises (Decoding of symbols is shown in Table 1)

tion of further environmental decisions by the management of the enterprises.

The negative direction of changes in the indicators was observed at enterprises operating in Obolonskyi, Shevchenkivskyi, Dniprovskyi, and Desnianskyi districts. According to the observations, a slight negative impact was detected, since almost all the studied enterprises have values close to 1. It should be noted that most of the studied enterprises have a high (≥ 0.9) level of normalized values of the unifying indicator "Acidity of the environment – *EEq(pH)*".

Fig. 9 shows that the least destabilizing effect on the environment is caused by the perfume and cosmetics production enterprise (pH value is 0.98).

The graphical analysis of soil acidity shows a positive trend in changes in the level of indicators. Thus, the highest value of 0.95 (enterprises of Dniprovskyi district) causes insignificant changes in soil pH (Fig. 9).

The lowest value of the acidity multiplicity of atmospheric precipitation was determined for the enterprise for complex maintenance of facilities (boiler house) (Podilskyi district of Kyiv), whose production activities are a source of technogenic impact, and is equal to 0.76.

The last indicator included in the structure of the generalized environmental quality indicator is the effectiveness of the environmental program of enterprises in terms of the waste management system. Based on our research and mathematical data processing, we calculated the normalized value of the separate indicator "Waste – *EEq(Was)*" (Fig. 10).

The graphical interpretation of the separate indicator "Waste – *EEq(Was)*" shows that the enterprise for the production of tools and equipment for measurement, research and navigation (Dniprovskyi district of Kyiv) has a normal-

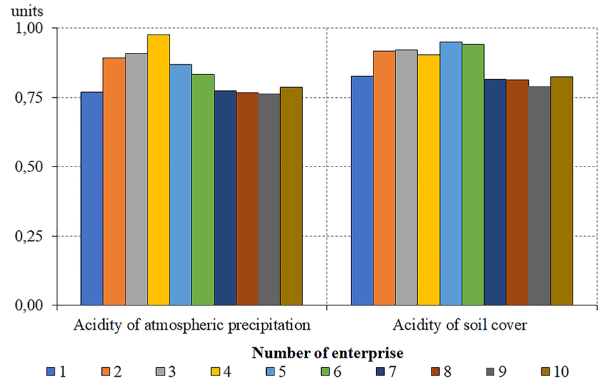

Fig. 9. Comparative analysis of individual factors of the unifying indicator EEq(pH) (Decoding of symbols is shown in Table 1)

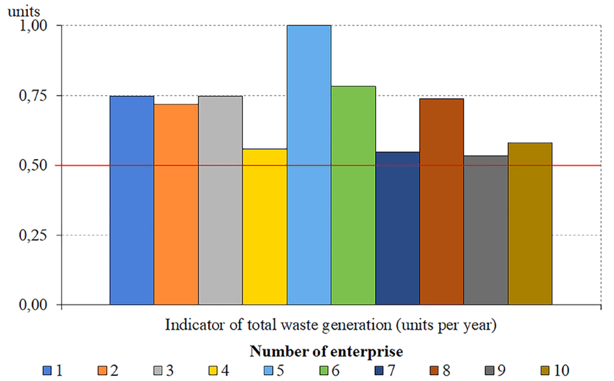

Fig. 10. Analysis of a separate indicator "Waste – EEq(Was)" (Decoding of symbols is shown in Table 1)

ized value of 1, which indicates the effectiveness of the new technologies being introduced in the waste management system. The enterprises operating in Podilskyi, Pecherskyi, Darnytskyi, and Solomianskyi districts of Kyiv are characterized by the value of the indicator "Waste – *EEq(Was)*" of less than 0.6.

Thus, the results of the above studies of the aggregate and individual indicators that make up the generalized environmental quality indicator (*EEq*) were combined and presented in Table 3 and Fig. 11.

According to the calculations of the aggregate indicator "Atmospheric air – *EEq(Air)*", it can be noted that the three studied enterprises have almost the same level of air quality control. The value of the aggregate indicator for the enterprises of Holosiivskyi, Obolonskyi and Podilskyi districts is 0.78, 0.77 and 0.78, respectively.

According to the normalized values of the aggregate indicator "Water bodies – *EEq(W)*", it was established that the environmental program of the enterprises of Desnianskyi and Obolonskyi districts is being implemented and is aimed at the effective implementation of its goals in a timely manner to reduce environmental impact. The minimum normalized values (below 0.53) of the aggregate indicator "Water bodies – *EEq(W)*" were found at the enterprises of Pecherskyi and Podilskyi districts of Kyiv.

To remedy the situation, it is necessary to review the EMS environmental program and adjust the tasks and measures, their timing, and consider opportunities to improve the production activities of enterprises through the introduction of innovative environmental and economic technologies.

Summarizing the research and calculations, the normalized value of the generalized environmental quality indicator

Table 3

Results of calculating the aggregate and individual indicators that make up the generalized environmental quality indicator (*EEq*)

No. of the enterprise	Atmospheric air – *EEb*(*Air*)	Water bodies – *EEq*(*W*)	Acidity of the medium – *EEq*(*pH*)	Waste – *EEq*(*Was*)
1	0.78	0.54	0.80	0.75
2	0.48	0.92	0.90	0.72
3	0.77	0.65	0.91	0.75
4	0.64	0.81	0.94	0.56
5	0.52	0.85	0.91	1.00
6	0.67	0.98	0.89	0.78
7	0.70	0.53	0.79	0.55
8	0.50	0.85	0.79	0.74
9	0.78	0.53	0.78	0.53
10	0.70	0.55	0.81	0.58

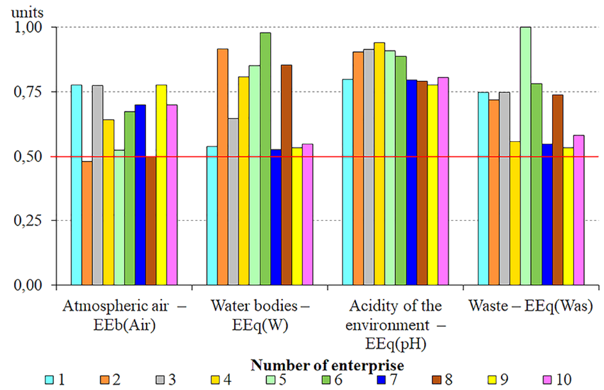

Fig. 11. Analysis of the study of the generalized environmental quality indicator (EEq) by aggregate and individual indicators (Decoding of symbols is shown in Table 1)

(*EEq*) of the studied enterprises was considered and visualized (Fig. 12).

Thus, it was found that the highest level of the normalized value is achieved by the enterprises of Dniprovskyi (0.82) and Desnianskyi (0.83) districts. This indicates that the environmental program and the goals and objectives specified in it are being carefully implemented on time, which leads to a

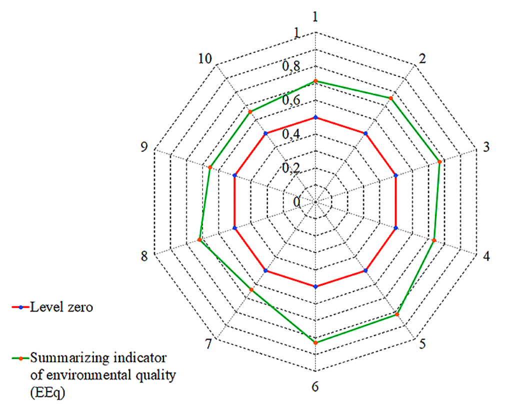

Fig. 12. Comparison of the values of the generalized environmental quality indicator (EEq) by enterprises with a zero level (Decoding of symbols is shown in Table 1)

reduction in the impact of enterprises' activities on the environment.

The greatest negative impact on the environment is caused by the activities of enterprises in Pecherskyi, Podilskyi and Solomianskyi districts. This information is confirmed by the normalized values of the generalized environmental quality indicator – 0.64, 0.66 and 0.66, respectively.

Conclusions and prospects for further development in this field. The conducted experimental studies of the generalized indicator of environmental quality allowed us to identify the factors that influence the effective implementation of environmental and organizational changes during the implementation of the EMS at enterprises engaged in various types of economic activity in ten administrative districts of Kyiv. The graphical interpretation of the results allowed visualizing the results of calculations of both individual factors and a generalized indicator of environmental quality using an experimental and statistical model. The analysis of the research results showed the dependence of the environmental quality indicator on the implemented environmental protection measures and the fulfillment of the goals and objectives of the environmental program of the enterprise.

It has been established that enterprises that have implemented EMS are constantly working to reduce air pollutant emissions, introduce new technologies into waste management systems, and develop and improve water treatment systems. Nevertheless, it was noted that most enterprises are rather slow in reducing air pollutant emissions, which leads to the lack of a tangible effect in reducing environmental impact.

Based on the analysis of the EMS documentation, the actual fulfillment of the goals and objectives of the environmental program of enterprises, based on the calculations of the experimental studies and their visualization, it was found that the effectiveness of the EMS functioning is related to the professionalism of the management and the working group in the development, implementation and operation of the EMS and depends, in particular, on:

1) quality of the preliminary environmental analysis of the company's activities;

2) professionalism in determining the environmental aspects of the company's activities and the impact of its activities on the environment;

3) clarity in the formulation of the company's environmental policy;

4) thorough training and education of employees in the basics of environmental management;

5) measurability of the goals, objectives and implementation of the company's environmental program.

Thus, assessing the effectiveness of the EMS of enterprises operating in various sectors of the economy and taking corrective measures can improve the level of environmental safety of cities and regions of Ukraine.

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Оцінювання ефективності функціонування системи екологічного менеджменту підприємств

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Мета. Розробка багатофакторної моделі для оцінювання рівня ефективності функціонування системи екологічного менеджменту підприємств у залежності від результативності проведених організаційних природоохоронних заходів.

Методика. Запропоновано й використано авторський метод визначення комплексного критерію контролю дієвості системи екологічного менеджменту, що характеризує ефективність функціонування та визначає рівень екологічної безпеки підприємств. Для вирішення поставлених завдань також застосовували комплексний метод дослідження, що включав аналіз та узагальнення літературних і патентних джерел, проведення аналітичних, експериментальних досліджень із використанням методів комп'ютерного й математичного моделювання.

Результати. Відповідно до проведених досліджень і розрахунків узагальнювального індикатора якості довкілля – 0,64; 0,66 та 0,66 найбільший негативний вплив на навколишнє середовище спричиняє діяльність підприємств Печерського, Подільського й Солом'янського районів м. Київ відповідно. Отримані дані свідчать про залежність між результативністю впроваджених природоохоронних заходів (економія й раціональне використання ресурсів, застосування природоохоронних технологій, підвищення кваліфікації та екологічної компетентності працівників) і рівнем ефективності функціонування системи екологічного менеджменту підприємств.

Наукова новизна. У результаті проведених досліджень із використанням фактичних даних уперше запропонована система показників узагальнювального індикатора якості довкілля, що дозволяє визначати екологічну дієвість і результативність упроваджених природоохоронних заходів для оцінювання ефективності функціонування системи екологічного менеджменту підприємства.

Практична значимість. За результатами досліджень запропоновано спосіб оцінювання ефективності функціонування системи екологічного менеджменту підприємств шляхом визначення узагальнювального індикатора якості довкілля в частині зменшення негативного впливу діяльності підприємства на навколишнє середовище. Така система оцінки допоможе керівництву підприємства оперативно запроваджувати коригувальні дії для покращення ефективності системи екологічного менеджменту й підвищення рівня екологічної безпеки.

Ключові слова: *система екологічного менеджменту, якість довкілля, природоохоронні заходи, екологічна безпека, підприємство*

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