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## METHODS FOR IMPROVING ACCOUNTING AND ANALYTICAL SUPPORT OF ENTERPRISES IN ORDER TO PROTECT THE ENVIRONMENT

**Purpose.** Analysis and identification of peculiarities of man-made pollution (MMP) that are not reflected in the reporting. Development of mathematical methods for their calculation. Classification of environmental costs (EC) in accounting. Development of proposals for improvement of tax reporting tools and norms, enhancement of the impact of tax instruments on the introduction of environmental protection technologies and stimulating enterprise management to use the “environmental obligations” tools.

**Methodology.** Special and general methods of scientific knowledge were used: induction and deduction – to identify the peculiarities of technogenic pollution which are not taken into consideration in the accounting reporting; analytical method – for proposals to improve accounting and analytical support; method of analysis and synthesis – for the development of EC classification; mathematical analysis – to develop the method for calculating the peculiarities of pollution that are not taken into account in the reporting.

**Findings.** It is proposed to strengthen the motivational value of environmental obligations. The need to take into account the synergistic and vector nature of the polluting effects on the environment is pointed out. It is proposed to introduce an information center for accounting of natural capital for analysis and consideration of environmental damage in real time. A classification of costs aimed at achieving environmental goals has been developed and purpose of each of their types is specified. This allows increasing the effectiveness of management accounting. The need to publish management reporting is substantiated to ensure public audit as well as to increase the effectiveness of the management of environmental tasks.

**Originality.** The peculiarities of MMP, which are not reflected in the accounting reports, are established, mathematical methods for their calculation and evaluation are developed. Improvement of tax reporting tools and norms, strengthening of the impact of tax instruments, effective stimulation of enterprise management to use “environmental obligations” tools are proposed.

**Practical value.** Methods for calculating the peculiarities of MMP and proposals for improving accounting and analytical support to increase the efficiency of management and tax activities are introduced.

**Keywords:** *accounting and analytical support, man-made pollution, mathematical methods of calculation, improvement of accounting*

**Introduction.** Climate change increases the importance of improving accounting and analytical support for environmental protection. It is customary to consider the problems of improving ecologically oriented accounting from two points of view: global level, country level, and the level of threat to whole ecosystems; of the enterprise level – regarding the methodology of implementation of managerial and financial accounting. So, in particular, these problems are considered by the International Auditing and Assurance Standards Board (IAASB). The global level and the country level are necessary for assessing threats and future budget costs, planning measures to neutralize the negative consequences of pollution for the economy, ecology and society and prevention of irrational use of natural capital. It is important to have complete, relevant and timely information on environmental protection issues for the effective strategic and tactical activity of the company’s management. This information is necessary not only for the implementation of environmental protection activities. Without it, it is impossible to fully implement the effective management of the production, financial, and economic activities of the enterprise. Timely, complete and accurate information on the generation of harmful substances is also needed for the implementation of the management policy of proper management of natural capital, development of relevant strategies for environmental protection. For this purpose, the regulatory and legal framework for accounting and reporting of enterprises regarding emissions (discharges) of harmful substances is being improved. Unfortunately, the current legal acts do not provide an opportunity to fully assess environmental damage on the basis of accounting information. For example, they do not take into account the dynamic nature of the impact, the possibility of the formation of dangerous compounds after the release (discharge) by a group of enterprises

of polluting substances that can enter into chemical reactions. This reduces the stimulating role of legal norms and the possibility of implementing effective strategic and tactical activities by both enterprises and state institutions.

**Literature review.** A significant number of works by domestic and foreign scientists are devoted to the problems of accounting and analytical support of enterprises in the conditions of climate change and the need to strengthen the protection of the natural environment. Detailed systematic reviews of the literature on this issue, in particular, were presented by Kelsall [1] and Tettamanzi, et al. [2]. The main attention in these studies is given to external reporting and accounting, and the issues of audit, management, development of a management strategy remained, mostly, out of the attention of scientists. Malikov, et al. [3] evaluated the “impact of greening production on enterprise activity”, which is considered in the presented article. Svyynous, et al. [4] studied the theoretical principles of the development of environmental accounting. In [4], it is indicated that there is a need to assess the dynamics of costs related to environmental protection. But for this, it is proposed only to allocate the basic means of environmental purpose in a separate section of accounting reporting, despite the provision of this reporting only once a year, which reduces the relevance of the assessment of dynamic impacts. Clyvka [5] indicates the need to present accounting information on environmental issues in such a way that it is possible to take into account both the environmental consequences of pollution and the economic and social consequences, which is taken into account in the presented article. Kolisnyk and Tomsha [6] studied accounting as a tool for managing the environmental activities of enterprises and indicated the effectiveness of this tool only if its implementation is systematic. Koval, et al. [7] provided an assessment of environmental taxation of clean technologies for the implementation of cost-effective emission reduction. The need to adjust the regulatory framework to en-

sure the specified economic efficiency is pointed out. The article by Kolisnyk and Gordienko [8] points out the importance of systematization of costs when the enterprise maintains ecologically oriented accounting of environmental costs in the management system, which is also taken into account in this article. Storozhuk and Druzhynska [9] indicated that accounting should provide data for structures of different levels: state, region, branch and enterprise level, which requires the introduction of a new information system. Unfortunately, this system and methods of its implementation are not specified in article [9]. Hrechyn, et al. [10] developed a mathematical approach to the economic-ecological assessment of a specific technological process and indicated that the proposed model should be supplemented by the development of software and a database, i.e. a comprehensive approach to IT support of environmental accounting reporting was proposed. The approach of complex information support of economic and ecological problems proposed by Hrechyn, et al. [10] is used in the presented study. D'Adamo, et al. [11] analyze a mathematical indicative approach to the accounting and analytical provision of economic and environmental reporting. Unfortunately, this approach, despite its convenience, does not allow one to fully present the data required for analysis.

Wang, et al. [12] studied the role of institutional influence on the implementation of effective management accounting as to environmental issues. This is considered in the presented work.

The works by Tran, et al. [13], Ghasemi, et al. [14], Tilt [15] are devoted to issues of accounting for environmental costs in developing countries. These scientific works on the improvement of accounting of enterprises on environmental issues are useful in view of the significant similarity of the situation with Ukraine in almost all aspects and the presence of social, economic, political and environmental crises. The study by Burrit, et al. [16] indicates an increase in the effectiveness of the implementation of environmental aspects of accounting when additional levers appear – a separate additional profit due to the release of environmentally friendly products. The article also points out the insufficiency of tax incentives for the implementation of environmental obligations of enterprise management.

Mikhno, et al. [17] and Zayed, et al. [18] pointed out the importance of an integrated approach to the formation of a legal framework that will ensure an increase in the efficiency of resource use. For this, Spilnyk and Palukh [19] suggest increasing the level of digital integration of accounting resources. This approach is also used in the presented work.

**Unsolved aspects of the problem.** Despite the above-mentioned studies, there is a need to analyze the accounting and analytical support of enterprises for the protection of the natural environment, to improve the accounting of pollution volumes and types and directions of environmental damage, to develop methods for their calculation, to introduce proposals for changes in the management policy of environmental protection activities both at the level of enterprise management and national level.

**Purpose of the article.** Analysis and identification of peculiarities of man-made pollution that are not reflected in the reporting. Development of mathematical methods for their calculation. Classification of environmental costs in accounting.

Development of proposals for improving tax reporting tools and norms, increasing the effectiveness of tax tools on the implementation of environmental protection technologies, and encouraging enterprise management to use the “environmental obligations” tool.

**Methods.** In the process of research, the results of which are presented in the article, special and general methods of cognition were applied.

Thus, the method of induction and deduction was used to identify the peculiarities of man-made pollution which, according to current regulations, are not taken into consideration in accounting reporting, the analytical method was used to

implement recommendations for changing approaches to the formation of accounting and analytical support for industrial enterprises in the conditions of climate change and the growing need for protection of the natural environment, the method of analysis and synthesis – for the development of the classification of environmental costs of the enterprise.

The specified peculiarities of man-made pollution are primarily of the cumulative and synergistic nature of environmental damage, which is not reflected in the reporting documents under the current legal framework for accounting and analytical support of industrial enterprises for environmental protection. And the data presented by the managers of the enterprises in the reporting documents do not give an opportunity to assess the damage to the environment according to the specified peculiarities.

The cumulative nature of man-made pollution is that the level of pollution, even from a single source, tends to increase over time due to accumulation in the surrounding environment. Moreover, this growth can harm large areas, not only certain locations close to the source of pollution.

The synergistic effect is that the damage to the environment can increase both due to different pollutants from one source, and due to a significant increase in the total negative impact due to the superposition and interaction of environmental pollution from different sources that generate pollutants and different components of emissions (discharges). In particular, the synergistic effect can lead to the formation of dangerous compounds after the release (discharge) of pollutants that can enter into chemical reactions.

The following peculiarities are, in most cases, a clearly expressed vector of the spread of harmful substances (for example, by prevailing winds or currents) and the dynamic nature of pollution. The presence of such a vector causes uneven damage to the environment. This means that for a relatively acceptable level of the average annual emission (discharge) of polluting substances in accordance with the existing norms, damage to certain territories due to a local increase in the concentration of harmful substances in a relatively short time may have unacceptable consequences. Therefore, it is advisable to calculate the vector of the spread of harmful substances both by geographical direction and by the time of generation.

All the mentioned peculiarities can lead over time to a sudden deterioration of the ecological situation – a catastrophe, in the mathematical and literal sense of the word. Therefore, the task of implementing such accounting support, analysis of available data, which would allow predicting such consequences of pollution, arises. The absence of such data in the reports creates a distorted view of the level of consequences for management, investors and owners of enterprises, complicates the planning of production activities and financial policy of enterprises. This does not allow management to correctly calculate environmental costs and carry out the necessary financial transactions. The consequence of this will be not only losses for the business entity, administrative and legal liability, but also damage in the national plan due to the depreciation of natural capital and environmental degradation.

The absence of such data in accounting reports and the absence of relevant norms in legislation also reduces the effectiveness of tax instruments as a mechanism for promoting the introduction of environmentally friendly technologies in production.

To avoid such a situation, an approach using methods of mathematical analysis was developed, which makes it possible to assess the cumulative, synergistic and uneven impact of emissions (discharges) on the environment.

In particular, it is proposed to calculate the dynamics of the current impact on the environment using the following method

$$r_{c,i} = f \left( \int_{t_1}^{t_2} \frac{\partial c_i}{\partial t} dt \right),$$

where  $r_{c,i,c_i}$  is the specific pollution effect;  $t$  is the time during which the calculation is carried out ( $t \in t_1, \dots, t_2$ );  $c_i$  is the concentration of the  $i^{th}$  harmful component in emissions (discharges) of the enterprise.

The following equation was used to estimate the integral dynamic cumulative effect based on its dynamic nature of the  $i^{th}$  component of emissions (discharges) for the period ( $\Delta t = t_2 - t_1$ )

$$R_{c,i} = f \left( \int_{t_1}^{t_2} \frac{\partial m c_i}{\partial t} dt + M_i \right),$$

where  $M_i$  is the mass of the accumulated harmful component of emissions (discharges) until the moment  $t_1$ .

At the same time, it should be noted that the total cumulative effect should not exceed the dangerous limit  $R_{c,i} \leq R_{c,i}^{\max}$ , where  $R_{c,i}$  is the integral cumulative effect of pollution,  $R_{c,i}^{\max}$  is the maximum (unacceptable) level of cumulative effect.

To assess the synergistic effect of harmful effects on the environment, it is necessary to take into account the effect of overlapping harmful effects of individual pollution components

$$R_{s,n} = \bigcup_1^n \left( \int_{t_1}^{t_2} \frac{\partial m c_i}{\partial t} dt + \sum_1^n M_i \right) \leq R_{s,n}^{\max},$$

where  $R_{s,n}$  is the synergistic effect of pollution from  $n$  harmful substances,  $R_{s,n}^{\max}$  is the maximum (unacceptable) level of synergistic effect.

If the emissions (discharges) are uneven over time and in separate territories, then this can be taken into account using the following mathematical formulation

$$\begin{cases} R_{c,i} = f \left[ \Delta t^* \text{grad} c_i + M_i \right] \leq R_{c,i}^{\max} \\ R_{s,n} = \bigcap_1^n \left( \Delta t^* \text{grad} c_i + M_i \right) \leq R_{s,n}^{\max} \end{cases}$$

To take into account the superimposition of gradients of concentrations of harmful substances from  $h$  enterprises

$$\begin{cases} R_{c,i}^h = \bigcap_1^h R_{c,i,j} \\ R_{s,n}^h = \bigcap_1^h R_{s,n,j} \end{cases},$$

where  $R_{c,i}^h$  is the total cumulative effect of environmental pollution by the  $i^{th}$  component of emissions (discharges) from a group of enterprises;  $R_{s,n}^h$  is the total synergistic effect of harmful influence from a group of enterprises;  $j = 1, \dots, h$  is the enterprise index;  $h$  is the total number of enterprises.

The following approach is proposed for calculating the relevant amounts of costs

$$\text{grad} S_{cap} | S_{opr} | S_{inv} | S_{env} \sim \begin{cases} \text{grad} R_{c,i} \\ \text{grad} R_{s,m} \\ \sim k_{depr. eq.}, k_{obsoles} \end{cases},$$

where  $S_{cap}$ ,  $S_{opr}$ ,  $S_{inv}$ ,  $S_{env}$  accordingly, are the volume of capital and operating costs for reducing the man-made impact of the enterprise on the environment, investments, environmental protection costs;  $k_{depr. eq.}$  is the coefficient of wear and tear of equipment,  $k_{obsoles}$  is the coefficient of moral aging of equipment.

The maximum (unacceptable) level of pollutants is currently regulated by DSP-201-97 [21]. Unfortunately, it does not list enough harmful compounds. More extensive assessments of unacceptable levels of contamination by chemical compounds are provided in documents from the World Health Organization, the US National Environmental Quality Standards, the Integrated Risk Information System, the Agency for Toxic Substances and Disease Registry, the U.S.EPA Health Effects Assessment Tables, etc.

Therefore, Table 1 [22] provides data on hazardous compounds, in particular those that may not be taken into account by domestic regulatory documents, but the formation of which may be dangerous as a result of the vector nature of emissions from individual enterprises and the interaction of these emissions. The necessary accuracy of calculations on the basis of the given values of dangerous concentrations of compounds is also indicated.

Here, Chemical Abstracts Service (CAS) is the registration number of a chemical compound and in the registration service. RFC is the standard abbreviation for Reference Exposure Concentration – the concentration of a compound sufficient to cause harm.

The use of the proposed mathematical approach can lead not only to the improvement of the general environmental situation, but also to improve the financial condition of the enterprises themselves, since the deterioration of the environmental condition is, in particular, a consequence of the use of outdated equipment. Manufacturing products on such equipment causes its low quality, that is, low sales, leads to an increase in production waste, and creates the problem of their disposal. This, in turn, results in a decrease in labor productivity and an increase in the level of resource and energy consumption. That is why the coefficients of wear and moral aging of the equipment are introduced into the system of equations.

Failure to take into account the mentioned peculiarities opens the way not only to underestimating the level of damage to the environment, but also to evading the payment of environmental tax by unscrupulous management of polluting enterprises.

**Results.** According to the current regulations, the calculation of the environmental tax depends on the following factors: the tax rate (which, in turn, is affected by the volumes and types of pollution; which depends on the sources of pollution); the period for which the calculation is carried out; the content of harmful components in the emission (discharge); the emission coefficient of each of the harmful components in the emission (discharge), the heat of combustion of the fuel and its total costs by the polluting enterprise. At the same time, the amount of the environmental tax is also directly or indirectly affected by the reported accounting data regarding the assets of economic entities and the economic operations realized by this entity during the reporting period.

This provides grounds for declaring tax policy as a tool for stimulating polluting enterprises to invest in technologies that lead to a reduction in the level of technogenic burden on the environment, and the specified accounting data form the basis for the implementation of management decisions to reduce pollution both at the level of enterprises and at the state level. But if the method of accounting for emissions (discharges) of harmful substances and, accordingly, the method for calculat-

Table 1

Comparative scales for evaluating the results of calculations of the dangerous level of concentrations of chemical compounds

The name of the compound	CAS	RFC, $\frac{\text{mg}}{\text{m}^3}$	Boundary relative error for component calculation $R_{c,i}$ , $R_{s,n}$
Styrene oxide	96-09-3	0.0060	3E-4
Polychlorinated biphenyls	1136-36-3	0.0012	6E-4
Carbon disulfide	75-15-0	0.7000	4E-2
Phosgene	75-44-5	0.0003	2E-5
Carbon disulfide	75-15-0	0.7000	4E-2
Propylene oxide	75-56-9	0.0300	2E-3
Hydrogen fluoride	7664-39-3	0.0300	2E-3

ing the environmental tax leave certain areas of damage to the environment out of consideration, the tax instruments for stimulating polluting enterprises to invest in clean technologies do not work to the full extent.

This is confirmed by the analysis of the data given in Table 2 [21]. The analysis indicates that even with the existing tendency to reduce the level of the country's total final energy consumption year by year, the energy intensity indicator remains at an unacceptably high level and the rate of its reduction is low.

This indicates that the rate of technological renewal of enterprises is inadequate, which, in particular, indicates an inadequate level of stimulation of polluting enterprises to invest in clean technologies.

Inadequate attitude of the management of enterprises to the introduction of measures that reduce the man-made impact on the environment can lead to: a decrease in demand for the enterprise's products; additional costs (in particular, fines) that may affect the selling prices of products; legal responsibility; increase in socio-economic risks (in particular, labor force problems due to population migration from areas close to harmful industries); depreciation of capital; reduction of investments; increase in loan rates (credit risk), etc. This should be helped by improving accounting reporting on environmental impacts.

The organization of accounting and analytical procedures, which is based on the informational, analytical and control function of accounting, should also be aimed at forming an effective general accounting and management policy of the enterprise. This is possible only with appropriate methodical support of accounting and analytical procedures, conducting environmental audits, environmental controlling and introducing appropriate forms of accounting. This will require, first of all, amendments to the "Report on costs for environmental protection", "Report on emissions of pollutants and greenhouse gases into atmospheric air from stationary sources of emissions", "Logs for recording the quality of waste and return water discharged". It is also appropriate to amend the "Statement of Financial Results (Statement of Comprehensive Income)". For this, first of all, the Law of Ukraine "On Accounting and Financial Reporting" and the Order of the Ministry of Finance "General requirements for preparing financial statements" will require changes. Management reporting on the accounting of environmental costs and revenues and the analysis of their impact on the costs and revenues of the enterprise and the obligations of the management of enterprises on environmental policy are offered.

The organization of accounting and analytical procedures, which is based on the informational, analytical and control function of accounting, should also be aimed at forming an effective general accounting and management policy of the enterprise.

This is possible only with appropriate methodical support of accounting and analytical procedures, conducting environmental audits, environmental controlling and introducing appropriate forms of accounting.

To some extent, the characteristic of the current state of the company's management policy is the result of a compari-

Table 2

Dynamics of final energy consumption and energy intensity in Ukraine

Parameter	Years				
	2017	2018	2019	2020	2021
Final energy consumption, thousand toe	49,911	51,408	49,665	47,773	45,973
Energy intensity, toe/thousand international dollars	0.099	0.099	0.092	0.092	0.092

son of the average annual share of current costs and capital investments by types of environmental protection measures (Table 3) [21]. The analysis of the data given in Table 3 shows the inverse correlation between the indicated values – a decrease in the share of capital investments leads to an increase in the share of current costs by types of environmental protection measures.

Taking into account the cumulative and synergistic nature of pollution, the dynamic nature of the effects on the environment will allow the management of the enterprise, state structures to correctly assess the difference between the forecasted ecological and economic indicators of the subjects of economic activity and the possibilities of natural restoration of the environment, which, from the point of view of corporate interests and strategic planning, can be considered as available resources or natural assets.

The introduction of data flow diagrams (DFD) can be a formalized approach to take into account the cumulative, synergistic nature of pollution, dynamic effects on the environment and take into account the specified difference. The DFD itself is an effective type of analysis of enterprise activity, in particular, dynamic flows of raw materials and emissions (discharges) according to the "cost-output" principle.

Article 2.2 of the Paris Climate Agreement declares the principle of "common but differentiated responsibility" in compliance with climate change policies. That is, compliance with this principle should take into account different regional conditions. Therefore, it is proposed to implement this principle of "general but differentiated responsibility" to implement the obligations of the management of Ukrainian enterprises in terms of environmental policy. This will make it possible to fully take into account the balance of interests of local authorities, regional administrations, business owners and the public, while at the same time simplifying for the management of enterprises the transition to technologies that do not harm the environment.

In order to prevent improper interpretation of this principle by unscrupulous management of enterprises that generate emissions, it is proposed to involve the public in monitoring its compliance.

It is also proposed to introduce an information center for natural capital accounting under the Ministry of Transformation of Ukraine and the Ministry of Environmental Protection and Natural Resources of Ukraine. In view of this, there is a need for the development of appropriate software (Table 4) and the introduction of databases (knowledge) of ecological and economic activities of enterprises and their integration into the national database (knowledge).

The implementation of automatic formation of digital reporting in real time (which will be facilitated by information technologies shown in Table 4) will allow one, with the implementation of appropriate data processing methods, to assess the dynamic effects of individual polluting enterprises and their groups on the environment.

Table 3

Analysis of the average annual share of the type of environmental protection measures in the total costs for environmental protection, %

Type of expenses	Type of environmental domain			
	protection of atmospheric air and climate change problems	wastewater management	waste management	protection and remediation of soil, groundwater and surface water
Current expenditures	11.296	45.799	38.938	6.2769
Capital investments	34.622	14.936	18.588	10.367

Table 4

Types of proposed information technologies for improving the accounting and analytical activities of enterprises in environmental, financial and management accounting

No	Types of information technologies	Purpose
1	Software and hardware for environmental monitoring and audit of the enterprise	The comprehensive and permanent process of recording and documenting the company's activities to ensure effective management and the formation of transparent reporting in compliance with laws and regulations on environmental protection
2	Databases (knowledge bases) of the enterprise's environmental and economic activities and their integration into the national database (knowledge bases)	For retrospective analysis and real-time analysis of dynamic changes in the production, financial and environmental activities of the enterprise to assess their dynamic cumulative, and synergistic character by impact vectors
3	Software blocks for the implementation of accounting and analytical procedures for environmental, financial and management accounting	Current formation of interim and final reports of the enterprise on environmental issues, financial and management accounting

To date, the problem of metrological support of tools and devices for unified automatic measurement of the content of harmful substances (point 1 Table 4), even, for example, the most common type of emissions – carbon oxides, and software capable of interpreting these data as accounting information is not regulated in a normative manner.

Current norms and rules regarding management accounting for environmental tasks at present do not provide an opportunity to assess the impact on the environment by emission vectors, especially in real time, which is important for a relevant assessment of the dynamic cumulative and synergistic effects on the environment of different enterprises at the same time. Existing or planned databases of environmental direction are based on the existing accounting information of enterprises, which does not provide an opportunity to fully assess the damage to the environment. The damage that these databases record is based on the information provided in the accounting reports, and it is recorded after the fact. The same happens with damage while conducting research by relevant institutions, it is also fixed after the fact. The planned introduction of an integrated permit, which is mainly a document that will contain systematized information only about a specific enterprise on the basis of its reports according to existing norms, will not solve these problems.

Therefore, it is proposed to introduce databases that are permanently replenished during the formation of reports automatically. In addition, the databases of individual enterprises do not provide an opportunity to assess not the additive contribution of each enterprise, but the complex damage of a group of enterprises due to the possible overlap of emission vectors and their interaction. Therefore, it is proposed to integrate accounting data of individual enterprises into the national database (knowledge).

The introduction of the natural capital accounting information center will allow automatic data analysis and selection of information for various organizations and state institutions using not raster, but vector tools. For example, information for decision-making related to agriculture, improvement of the

quality of life of the population of certain locations, development of regions, use of resources, tourism, etc. could be selected and automatically presented.

The introduction of automatic notification of the natural capital accounting center about the cumulative, synergistic effect of emissions (discharges), the dynamics of the spread of pollution and the transparency of these data for investors and the public will lead to the spread of such a tool as “environmental obligations”. Environmental obligations are the result of the management and owners of enterprises realizing the fact that the ecological orientation of production activities and, accordingly, the accounting and analytical support of enterprises is a factor in increasing the competitiveness of products at foreign markets and, accordingly, an incentive for foreign and domestic investments [23].

Currently, environmental obligations are not widely used in the management activities of Ukrainian enterprises. This leads to both the insufficiency of the regulatory and legal development of accounting standards on this issue, and the fact that the management of enterprises mostly does not have full information about the consequences of emissions (discharges) of harmful substances and the possibility to avoid them through the introduction of innovative technologies, and about the costs and profits of environmental protection activities of enterprises. This is also facilitated by the fact that environmental obligations are currently reflected in the reporting of enterprises at the end of the reporting period. Given the very essence of environmental obligations, it should be done at the time of their occurrence. And this can be facilitated by legal acts regarding the digital form of enterprise reporting and real-time reporting.

In order to implement the appropriate level of the control function of accounting, it is proposed that management accounting for environmental tasks be open for electronic audits, and that reports on these issues be open to the public. This will require certain changes in accounting and management reporting on environmental issues (Table 5).

The aforementioned changes in accounting and management reporting on environmental issues will require a clear classification of expenses aimed at achieving environmental goals, both for legislators and for enterprise management. The proposed classification of costs and specification of the purpose of each of their types is presented in the figure.

The classification of costs allows for the clear identification of costs for environmental purposes, which, in turn, allows one: to avoid their implicit presentation in accounting reports; identifying the share of costs for environmental purposes in the cost of products; unambiguous determination of income from expenses for environmental purposes; consideration of non-financial information related to environmental protection and preservation of natural capital in management activities.

The peculiarity of the management of the enterprise's environmental activities so far consisted only in the fact that managers had to allocate environmental costs to those necessary for the implementation of the production process and those necessary for environmental protection. However, climatic changes and social changes lead to the need to ensure not only the preservation of natural capital but also the appropriate level of people's quality of life when implementing production activities.

This determines the emergence of new users of accounting and reporting information – public organizations and individual citizens. This affects the need to improve both accounting forms, their presentation, and methods of their analytical processing and publication (Figure and Table 4).

Also, a new form of effective permanent audit of the activities of enterprises and ensuring the implementation of new technologies of environmental protection of the appropriate level by the management of economic entities is actually being formed – constant public control and the appearance of feedback on management measures.

Types, objects and purposes of accounting and management reporting on environmental issues

Type of report	Subject	Users
Report on environmental protection costs	1. Capital investments for environmental protection 2. Current expenses for environmental protection 3. Specialized environmental services	Owners, investors, creditors, tax and statistical institutions. The information center for natural capital accounting, local authorities, the public are proposed
Report on emissions of pollutants and greenhouse gases into atmospheric air from stationary sources of emissions	1. Total emissions of pollutants and greenhouse gases into atmospheric air 2. Distribution of pollutant emissions into atmospheric air by categories of emission sources	Owners, investors, creditors, tax and statistical institutions. The information center for natural capital accounting, the Ministry of Environmental Protection and Natural Resources of Ukraine, local authorities, the public are proposed
Journals of accounting for the quality of waste and return water discharged	Annual emissions of pollutants into the aquatic environment It is proposed – a dynamic distribution of emissions of pollutants into the atmospheric air by categories of sources of emissions	Owners, investors, creditors, tax and statistical institutions. The information center for natural capital accounting, the Ministry of Environmental Protection and Natural Resources of Ukraine, local authorities, the public are proposed
Management reporting is offered	1. Accounting for environmental costs and revenues and analysis of their impact on the costs and revenues of the enterprise (proposed) 2. Obligations of enterprise management on environmental policy (proposed)	Ministry of Environmental Protection and Natural Resources of Ukraine, owners, management, public are proposed

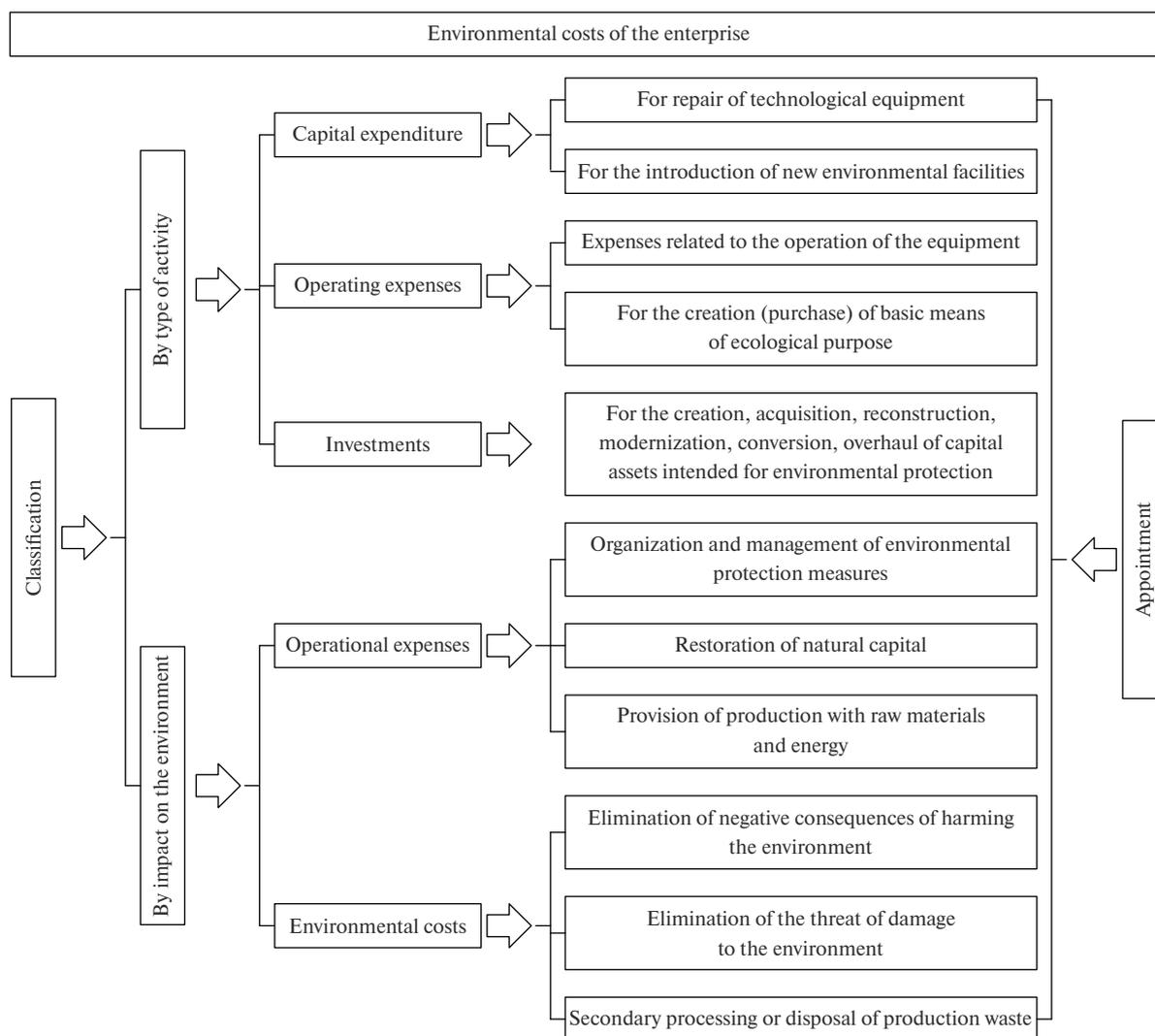


Fig. Classification of environmental costs of the enterprise

In the accounting and analytical activities of enterprises, not only the column “expenses for environmental activities” appears, but also profits from it. This requires a change in the ideology of enterprise managers, improvement of management accounting, implementation of the management skills of business entities in such a way as to direct expenses for environmental protection in order to obtain an appropriate level of profit from them.

The management’s awareness of the full necessary amount of expenses according to their directions also provides an opportunity to realistically assess the potential environmental consequences of production activities when planning the production of new types of products and the need to implement measures to prevent environmental damage, a real, not a formal approach to avoiding environmental threats.

In general, this approach to the formation of accounting and analytical support allows ensuring the proper efficiency of management activities and, accordingly, the sustainable development of individual enterprises and the country’s economy as a whole.

**Conclusions.** The research established the presence of such peculiarities of man-made pollution which, according to current regulations, are not taken into consideration in accounting reports. The specified peculiarity of man-made pollution is, in particular, its synergistic nature, the presence of a vector for the spread of harmful substances (for example, by prevailing winds or currents) and the dynamic nature of pollution. In the regulatory documentation, the concept of “pollution zone” is used, which is not equivalent to the proposed concept of “pollution vector”, which is dynamic in nature and changes over time. The proposed normalization of pollution vectors will make it possible to assess the concentrated dynamic effects and, because of this, increase the risk of the formation of dangerous chemical compounds already after the emission.

This means that with an acceptable level of average annual emission (discharge) of polluting substances in accordance with the existing standards, damage to certain directions in a relatively short time may be unacceptable. Therefore, the task of implementing accounting support, the analysis of available data, which would allow predicting such consequences of pollution, arose. The absence of such data in the reports distorts the management’s presentation of the necessary management measures, complicates the planning of production activities and the financial policy of enterprises. The absence of such data in accounting reports and the absence of relevant norms in legislation also reduces the effectiveness of tax instruments as a mechanism for promoting the introduction of environmental protection technologies in production, which to some extent devalues tax environmental policy.

Therefore, a mathematical approach, which makes it possible to estimate the dynamic cumulative, synergistic and uneven technogenic impact on the environment, was developed.

For enterprise management it is proposed to implement the “environmental obligations” tool based on the principle of “general but differentiated responsibility” to implement the obligations of Ukrainian enterprise management in terms of environmental policy. This will make it possible to fully take into account the balance of interests of local authorities, regional administrations, business owners and the public, while at the same time simplifying the transition to technologies that do not harm the environment for the management of enterprises.

In order to make the management of enterprises aware of the need for environmental expenses, to fully take into account the levels and directions of pollution, the relevance of their analysis, the integration of accounting data on environmental issues into the national database (knowledge) and its permanent automatic replenishment is proposed. For this purpose, it is proposed to introduce an information center for natural capital accounting under the Ministry of Transformation of Ukraine and the Ministry of Environmental Protection and

Natural Resources of Ukraine. The introduction of such an institution will enable centralized automatic data analysis and selection of information for various organizations and state institutions in real time, which will reduce the level of environmental threats and promote transparent payment of environmental taxes.

Information technologies for improving the accounting and analytical activities of enterprises in environmental, financial and management accounting are proposed. The implementation of automatic formation of digital accounting environmental reporting in real time will allow, with the implementation of appropriate data processing methods, assessing the dynamic effects on the environment of individual polluting enterprises and their groups.

In order to implement the appropriate level of the control function of accounting, it is proposed that management accounting for environmental tasks be open to electronic audits, and that environmental accounting information be open to the public. The proposed changes to accounting and management reporting on environmental issues will require both legislators and enterprise management to implement a unified classification of costs aimed at achieving environmental goals. Therefore, a classification of costs with specification of their purpose has been developed. Classification of expenses allows identification of expenses for environmental purposes, which, in turn, allows one: to avoid their implicit presentation in accounting reports; to identify the share of expenses for environmental purposes in the cost of products; to unambiguously determine income from expenses for environmental purposes; to take into account non-financial information related to environmental protection and preservation of natural capital in management activities.

This affects the need to improve both accounting forms, their presentation, and methods of their analytical processing and publication.

It is indicated that the online appearance of new users of accounting and reporting information – public organizations and individual citizens – creates a new form of effective permanent audit of the activities of enterprises and ensures the management of business entities to implement new technologies with an appropriate level of environmental protection – constant public control.

The implementation of appropriate forms of management accounting on environmental issues will allow realistic assessment of the consequences of production activities when planning new types of products and the need to implement measures to prevent environmental damage, a real, not a formal approach to avoiding environmental threats, and will simplify tax control.

In general, this approach to the formation of accounting and analytical support allows ensuring the proper efficiency of management activities.

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## Методи вдосконалення обліково-аналітичного забезпечення підприємств із метою захисту навколишнього середовища

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**Мета.** Аналіз і виявлення особливостей техногенного забруднення, що не відображені у звітності. Розроблення математичних методів їх розрахунку. Класифікація екологічних витрат в обліку. Розроблення пропозицій щодо вдосконалення інструментів і норм податкової звітності, посилення ефективності впливу податкових інструментів на впровадження технологій захисту довкілля та стимулювання менеджменту підприємств до використання інструменту «екологічних зобов'язань».

**Методика.** Використані спеціальні й загальні методи наукового пізнання: метод індукції та дедукції – для виявлення особливостей техногенного забруднення, що не враховуються в обліковій звітності; аналітичний метод – для пропозицій удосконалення обліково-аналітичного забезпечення; метод аналізу й синтезу – для розроблення класифікації екологічних витрат; метод математичного аналізу – для розрахунку особливостей забруднення, що не враховуються у звітності.

**Результати.** Запропоновано посилити мотиваційне значення екологічних зобов'язань. Вказано на необхідність урахування синергетичного й векторного характеру забруднюючих впливів на довкілля. Запропоноване запровадження інформаційного центру обліку природного капіталу для аналізу та урахування шкоди довкіллю в реальному часі. Розроблена класифікація витрат, спрямованих на досягнення екологічних цілей, і конкретизоване призначення кожного з їх виду. Це дозволяє збільшити ефективність управлінського обліку. Обґрунтована потреба оприлюднення управлінської звітності для забезпечення громадського аудиту й посилення ефективності менеджменту екологічних завдань.

**Наукова новизна.** Встановлені особливості техногенного забруднення, що сьогодні не враховуються в обліковій звітності, розроблені математичні методи їх розрахунку та оцінювання. Запропоновано вдосконалення інструментів і норм податкової звітності, посилення впливів податкових інструментів на впровадження технологій захисту довкілля, ефективного стимулювання менеджменту підприємств до використання інструменту «екологічних зобов'язань».

**Практична значимість.** Упроваджені методи розрахунку особливостей техногенного забруднення та пропозиції вдосконалення обліково-аналітичного забезпечення збільшать ефективність управлінської й податкової діяльності.

**Ключові слова:** облікове-аналітичне забезпечення, техногенне забруднення, математичні методи розрахунку, вдосконалення обліку

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