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APPROACHES TO ASSESSING THE ENVIRONMENTAL RESPONSIBILITY OF ENTERPRISES IN THE INDUSTRIAL REGION

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Abstract

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The purpose of the study is the identification and forecasting of socioecological effects from the implementation of environmental responsibility by industrial enterprises at the local level. The development of methodical approaches and practical recommendations for the organizational and economic support of environmental responsibility to improve social tension in the industrial region is explored. The process of the assessment of the level of environmental responsibility of an industrial enterprise is improved based on the factors of its environmental obligation and environmental initiative. It is proposed to assess the level of environmental responsibility of enterprises not only on the basis of widely used coefficients characterizing the level of pollution, but also taking into account the level of environmental initiative of the enterprises under study, which is expressed mainly through social investments.

Key words: environmental responsibility, organizational and economic support, assessment, taxonomic indicator, environmental obligation, environmental initiative.

Introduction

The Environmental Action Program "European Green Deal" has chosen to achieve full climate neutrality in the context of the transition to a carbon-neutral economy. To achieve this goal, the concept of the «New European Bauhaus» was developed, which includes a combination of several financing instruments with additional volumes and reflects the necessary changes in the field of environmental taxation.

The tax system should be the basis for a green transition, using the right incentives, incl. for technogenic sources of pollution, using the following options: a) establish high rates of environmental taxes, incl. progressive depending on the volumes and types of pollutants, which will encourage enterprises to implement measures aimed at greening production to reduce the amount of environmental taxation and b) use the received amounts of environmental taxes for the development and implementation of projects for the eco-modernization of production and/or the creation of environmentally safe production. In the first option, environmental taxation performs a controlling function and is aimed exclusively at replenishing local budgets. In the second variant, taxation is not only of a fiscal and controlling nature, but also performs a regulatory function.

Identifying the importance of environmental responsibility of industrial enterprises, which are the main polluters of the natural environment and, accordingly, one of the stimulators of increasing social pressure in the places of their presence, is one of the most significant problems of managing and conducting modern industrial business in the regions. This issue remains relevant both for stakeholders, in particular, the local community, and for industrial enterprises themselves, including metallurgical enterprises. Thus, today, an important task is the development of a number of motivational mechanisms that would make it possible to achieve positive socioecological changes while preserving the economic capacity of industrial enterprises.

The works by Caroll et al. (2014), Myroshnychenko et al. (2019), and Prokopenko (2010) are devoted to researching the relationship between theoretical and methodological approaches to the development of socioeconomic systems from the standpoint of corporate social and environmental responsibility and sustainable development. Economic mechanisms of stimulating and accounting for social and environmental responsibility at the local and regional level were considered by scientists like Kuznietsova et al. (2016), Morf et al. (2013), and Nickols (2020). The relationship between the concepts of social responsibility and the theory of stakeholders was explored in the articles by Aguinis et al. (2020), Farooq et al. (2017), and Jones et al. (1999). The method of economic and mathematical modeling of social responsibility at

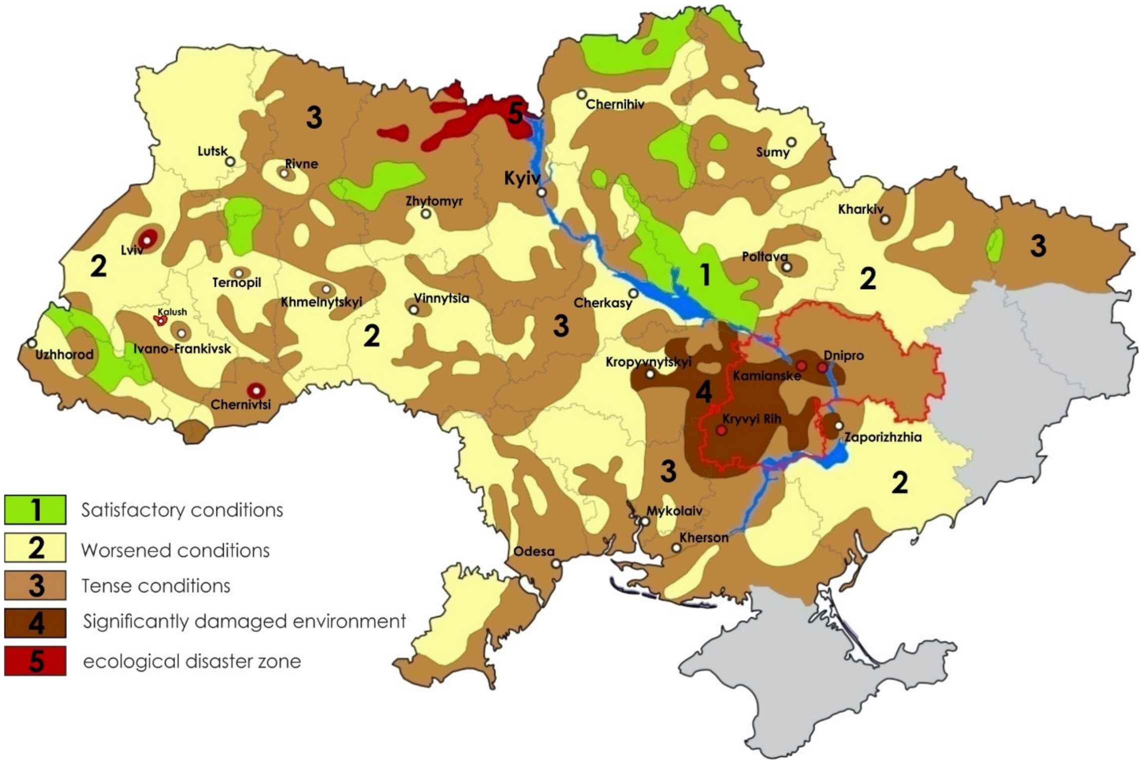

Fig. 1. Zoning of the regions of Ukraine according to the ecological conditions of the population's residence. Note: Formed by authors based on Koshkalda et al. (2022).

Fig. 2. Location of the studied enterprises in accordance with the ecological conditions of the population's residence. Note: Formed by authors based on Koshkalda et al. (2022).

different levels was considered in the works by Horoshkova et al. (2020), Kubatko et al. (2010), and Yankovy (2011).

The problem of identifying socioeconomic effects from the implementation of the strategy of environmental responsibility at the local level remains poorly developed in the scientific literature. It is also worth emphasizing that an extended and a comprehensive assessment of the effectiveness of the environmental responsibility of an industry, a group of enterprises, or a specific enterprise cannot be independently implemented exclusively by stakeholders, given the lack of sufficient resources, primarily information and time. The purpose of the study, the results of which are presented in this article, is the identification of the level of environmental responsibility of enterprises in an industrial region and determining the balance of initiatives and obligations in the environmental sphere to achieve socioecological effects at the local level.

In the study by Koshkalda et al. (2022), the ecological situation in the regions of Ukraine according to the indicators of territorial concentration of production, economic development of land, population density, pollution of the natural environment, and the degree of damage was analyzed. Generalized cartographic data are shown in Figure 1.

Table 1. Emissions of polluting substances into the air per square kilometer, tons.

Region	Period (in years)						
	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Ukraine	11,6	11,4	9,3	7,8	5,3	4,5	4,4
Chain growth rate, %	-	*-1.72*	*-18.42*	*-16.13*	*-32.05*	*-15.09*	*-2.22*
Dnipropetrovs´ka oblasť	36,8	35,9	32,5	27,5	26,1	20,6	19,2
Chain growth rate, %	-	*-2.45*	*-9.47*	*-15.38*	*-5.09*	*-21.07*	*-6.80*

Note: Complied by authors based on Ukrstat.

Table 2. Gross regional product per capita (in actual prices, UAH).

Region	Period (in years)						
	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Ukraine	32002	33473	36904	46413	55899	70233	84235
Chain growth rate, %	-	4.60	10.25	25.77	20.44	25.64	19.94
Dnipropetrovs´ka oblasť	44650	46333	53749	65897	75396	97137	114784
Chain growth rate, %	-	3.77	16.01	22.60	14.41	28.84	18.17

Note: Complied by authors based on Ukrstat.

Taking into account the given data, all regions of Ukraine were divided into five types according to the degree of favorable living conditions of the population, namely:

1. satisfactory conditions (separate districts of Zakarpattia, Ivano-Frankivsk, Chernivtsi, Ternopil, Rivne, Zhytomyr, Sumy regions);
2. worsened conditions (Vinnytsia, Kirovohrad, partly Mykolaiv, Odesa, Zaporizhzhia regions);
3. tense conditions (Chernihiv, Kyiv, partially Donetsk region, Polissia, partly Dnipro region);
4. significantly damaged environment (partly Dnipro region, Lviv and Chernivtsi agglomerations); and
5. ecological disaster zone (30 km zone of the Chernobyl nuclear plant, Kalush).

Dnipropetrovs'ka oblast', where the investigated industrial enterprises are located (Fig. 2), is included in the territories with deteriorated environmental conditions of the population, which only emphasizes the need for research in the field of strengthening environmental responsibility in production.

Dnipropetrovs'ka oblast' is traditionally considered industry oriented, which is confirmed by statistical data for 2021, in which the volume of sold industrial products (goods, services) amounted to UAH 671.2 billion or 18.7% of the national turnover from industrial activity (the highest indicator among the regions of Ukraine). Such a result indicates not only the prospects for the further development of this industry, but also the urgent need and readiness of the population of the region to perceive more balanced forms of socioeconomic relations.

The data and dynamics of the gross regional product of Dnipropetrovs'ka oblast' and emissions of pollutants into the air (Tables 1, 2) show that the level of economic development achieved in the region can create prerequisites for strengthening the environmental requirements of the population. Consumers pay more and more attention to goods and services that position themselves as environmentally friendly ones, so the processes of greening all spheres of the economy are being intensified in the region.

Dnipropetrovsk Oblast ranks last in the level of environmental quality among the regions of Ukraine throughout the period studied in the article. For example, according to the Fokus rating (2022), formed using the official data published by the State Statistics Service, the State Water Agency, and the National Cancer Institute, Dnipropetrovsk Oblast ranks 24th and holds the last place.

The main territorial centers of pollution in the Dnipropetrovsk region are the regional center of Dnipro (PJSC "Evraz-Dnipro Metallurgical Plant"), Kryvyi Rih (PJSC "Arcelor Mittal"), and Kamianske (PJSC "Dniprovsky Metallurgical Plant"). Kryvyi Rih deserves a special mention. It produces approximately half of the region's harmful atmospheric emissions. Emissions contain a lot of carbon monoxide and methane, and nitrogen compounds are also present. The city is home to the second largest source of harmful gaseous emissions in Ukraine – the PJSC Arcelor Mittal plant. According to the environmental protection public organization "Stop poisoning Kryvyi Rih," it is this plant that produces 80% of harmful atmospheric emissions (Department of Ecology and Natural Resources under Dnipropetrovsk Regional State Administration, 2020).

As for the discharge of dirt into water, ecologists consider PJSC Dniprovsky Metallurgical Plant to be its main source. Approximately 75% of the volume of waste water does not meet the standards of environmental safety (Kamianske City Council, 2018).

According to the data for 2020, in the composition of pollutants in the region, carbon oxides make up 274,719 thousand tons, dioxides and other sulfur compounds contribute 60,857 thousand tons, substances in the form of suspended solid particles make up 52,22 thousand tons, methane contributes 115,967 thousand tons, nitrogen compounds contribute 28,298 thousand tons, and metals and their compounds make up 0,619 thousand tons.

Table 3. Indicators for assessing the level of environmental responsibility of industrial enterprises – block of environmental responsibility.

Indicator name, stimulator/destimulator	**Calculation procedure**	**Legend**
The coefficient of waste capacity according to the category "air emissions" (*x1*); stimulator	$C_A = 1 - \frac{E_A}{VP},\ C_A \to 1$	E_A – total volume of emissions into the atmosphere, thousand tons; *VP* – volume of manufactured products, thousand tons
The coefficient of waste capacity according to the category "water emissions" (*x2*); stimulator	$C_{WB} = 1 - \frac{V_{WB}}{VP}, C_{WB} \to 1$	V_{WB} – total volume of emissions into water bodies, thousand tons
The coefficient of waste capacity according to the category "waste" (*x3*); stimulator	$C_W = 1 - \frac{W}{VP}, C_W \to 1$	*W* – total amount of waste, thousand tons
The coefficient of waste utilization (*x4*); stimulator	$C_{UW} = \frac{V_{UW}}{W}, C_{UW} \to 1$	V_{UW} – volume of used waste, thousand tons; *W* – total amount of waste, thousand tons
The coefficient of energy intensity of products (*x5*); stimulator	$C_{\mathrm{E}} = 1 - \frac{E}{C}, C_{\mathrm{E}} \to 1$	E – energy costs for manufacturing products, thousand UAH; C - cost of manufactured products, thousand UAH.

Note: Developed by authors on the basis of Makarenko et al. (2019, p. 23), Guthrie et al. (1989, p. 346), and Serdiuk et al. (2019).

In addition, during the study period, 20.5 million tons of carbon dioxide – the main greenhouse gas that affects climate change – entered the atmosphere. In 2020, the state of atmospheric air pollution in the city of Dnipro was monitored at six stationary monitoring stations, in the city of Kamianske at four stationary stations, and in the city of Kryvyi Rih at five stationary stations.

According to the comprehensive index of air pollution by priority substances (AQI), calculated on the basis of observation data of 2020, the level of atmospheric air pollution in the cities of the Dnipropetrovsk region is above average. The comprehensive AQI in 2020 is as follows: Dnipro 14.6, Kamianske 14.9, and Kryvyi Rih 13.8. If the value of AQI is ≤ 5, the level of air pollution in the city is considered below average, if $5 < \text{AQI} \leq 8$, the level is approximately equal to the average, if $8 < \text{AQI} \leq 15$, the level is above average, and if AQI is >15, the level is significantly above average.

Material and methods

The analysis used data from the official state statistics of Ukraine, Department of Environmental Policy under Dnipro City Administration, Kamianske City Council, Kryvyi Rih City Council, Medical Statistics Center under the Health Ministry of Ukraine, and the Stock Market Infrastructure Development Agency of Ukraine. Official data regarding the state of the natural environment in the Dnipropetrovsk region, environmental passports, and health condition of population of different cities in the region, and official health reports of Ukraine and the world were examined. We also used official data taken from open access regarding large metallurgical plants in the Dnipropetrovsk region.

The production activity of the metallurgical complex enterprises causes a significant load on the state of the atmospheric air and water resources, which are used by these enterprises. Nevertheless, the metallurgical complex of Ukraine is an industry-forming unit and has a significant impact on the process of transition of the national economy to the principles of sustainable development (Ukrstat 2020a; Main Department of Statistics in Dnipropetrovsk Region, 2020a). The metallurgical complex is one of the most exportable branches of the economy and plays a crucial role in the generation of foreign exchange earnings and budget revenues. The main direction of the implementation of the environmental obligation for industrial enterprises is to adhere to the strategy of cleaner production, which is expressed in waste management as well as reduction of emissions into atmospheric air and water. It should be emphasized that in recent years, it has become a characteristic feature of industry enterprises to show a high interest in implementing measures the energy efficiency increasing. The growth of this interest is caused by high prices for fuel and energy resources (Graafland, 2018). This has led to the inclusion of waste capacity coefficients for emissions into the environment by the categories of atmospheric air, water, waste, the coefficient of waste utilization, and the energy intensity coefficient of products in the indicator system of the environmental obligation block (Table 3).

Nevertheless, indicators of the effectiveness of the environmental management system should be included in the indicators of the environmental initiative block, since it is the presence of environmental management at the enterprise that allows us to talk about the existing sufficient level of environmental responsibility (Faivre, 2017). For example, such indicators include indexes of the structure of environmental costs, namely, capital investments, current costs for environmental protection, and the coefficient of ecological loss capacity as an indicator of compliance with the requirements of environmental legislation, which is also a consequence of the implementation of the environmental management system (Table 4).

Summarizing the above, it is worth noting that all criteria for the level of environmental responsibility of industrial enterprises are proposed to be divided into two groups – those that belong to the sphere of compliance with environmental obligations, in other words, to environmental responsibility, and those that relate to the enterprise's own environmental initiative and are defined as voluntary. The scope of environmental obligations of an industrial enterprise can include responsibility for the environmental damage caused by production activities, compliance with environmental regulations, and limits of emissions (Didukh et al., 2023).

It is proposed that the process of assessing the level of environmental responsibility of an industrial enterprise should be carried out according to the following algorithm. At the first stage, in the course of qualitative and quantitative analyses of indicators, a point assessment of the level of environmental ini-

Table 4. Indicators for assessing the level of environmental responsibility of industrial enterprises – block of environmental initiative.

Indicator name, * (stimulator/destimulator)	**Calculation procedure**	**Legend/conventions**
Share of capital investments in environmental protection measures in the total amount of expenses for the protection of SNE (surrounding natural environment) → (*x6*); stimulator	These indicators will allow the management to assess the functioning of the environmental management system, the level of performance of the company's environmentalization tasks, monitor costs for the protection of SNE, and analyse the relationship between environmental characteristics and financial and economic indicators of the company's activity.	
Share of current SNE protection costs in total SNE protection costs → (*x7*); destimulator		
Share of unreimbursed environmental costs paid out of profit → (*x8*); destimulator		
Coefficient of ecological loss capacity of products (*x9*); stimulator	$C_L = 1 - \frac{T + FS}{C}$ $C_L \to 1$	*T* – amount of assessed environmental tax, thousand UAH; *FS* – sanctions for violation of environmental protection legislation, thousand UAH.
Integral indicator of ecological initiative → 1 (*x10*); stimulator	Reflects the enterprise's activities towards the implementation of self-initiated environmental protection measures. Includes expert assessments of measures to compensate the community for damages from SNE pollution, optimization of waste management directions, the state of the surrounding territory in the sanitary zone of the enterprise, etc.	

Note: Developed by the authors on the basis of Makarenko et al. (2019) and Taraniuk et al. (2017).

tiative of an enterprise is conducted, coefficients of indicators of environmental responsibility and environmental initiative are calculated, and the nature of their influence on the resulting indicator as stimulators or destimulators is determined.

At the second stage, the obtained coefficients are standardized due to the different dimensions of the initial data, reference indicators are determined, and partial taxonomic indicators of the level of environmental responsibility and environmental initiative are calculated. At the third stage, a comprehensive assessment of the obtained indicators is carried out, the impact of each of the partial indicators on the overall level of environmental responsibility is calculated, and reserves for further development and improvement are determined (Trujillo-Gallego, 2021).

Results

The basis of the proposed method of assessing the level of environmental responsibility is the definition of the so-called taxonomic distance, that is, the distance between the points of a multidimensional space, the dimension of which is determined by the number of features that characterize the object of study. The undoubted advantage of the taxonomic method is the process of the so-called standardization of indicators, as a result of which the properties of the object, described by various qualitative and quantitative indicators, are transformed into a single standardized measurement system (Obelnytska, 2019). The algorithm for determining the taxonomic indicator of the development level includes a number of stages. At the first stage, the matrix of observations is formed, which contains the comprehensive characteristics of the studied set. The indicators that are included in the matrix are heterogeneous.

At the second stage, it is necessary to standardize the indicators according to equation (1):

$$z_{ik} = \frac{x_{ik} - \underline{x_k}}{S_k}, \tag{1}$$

where:

$$\underline{x_k} = \frac{1}{\omega}\sum_{i=1}^{\omega} x_{ik}; \tag{2}$$

$$S_k = \left[\frac{1}{\omega}\sum_{i=1}^{\omega} (x_{ik} - \underline{x_k})^2\right]^{\frac{1}{2}}, \tag{3}$$

where $k = 1, 2\ldots, n$; x_{ik} is the value of the indicator k for the unit i, $\underline{x_k}$ is the average arithmetic value of the k indicator, S_k is the standard deviation of the k indicator, and z_{ik} is the standardized value of indicator k for unit i.

After the standardization procedure, all selected indicators must be categorized according to the nature of the impact on the level of environmental responsibility as stimulators and destimulators. Stimulators are the indicators whose high values are desirable from the point of view of the chosen aspect of the study. The signs with opposite characteristics act as destimulators (Obelnytska 2019, p. 30). In other words, a feature is called a stimulator (has a monotonically increasing quality dependence) if the higher value of the feature corresponds to the better quality of the object. A feature is called a destimulator (has a monotonically decreasing quality dependence) if the lower value of the feature corresponds to a better quality of the object (Kubatko et al. 2010, p. 195).

At the fourth stage, the development reference vector with coordinates z_{0t} is constructed. The largest values of stimulators and the smallest values of destimulators form the coordinates of the sought standard of development:

$$z_{0t} = z_{ik}\text{, if the indicator } k \text{ is a stimulator;} \tag{4}$$

Table 5. Matrix of observations for evaluating the level of environmental responsibility – block of environmental obligation.

PJSC "ARCELOR MITTAL"	2014	2015	2016	2017	2018	2019	2020
Coefficient of waste capacity of emissions into the atmosphere *(X1)*	0,963	0,963	0,968	0,967	0,949	0,955	0,956
Coefficient of waste capacity of emissions into the water bodies *(X2)*	0,490	0,517	0,578	0,586	0,426	0,505	0,509
Coefficient of waste capacity *(X3)*	0,091	0,053	0,046	0,050	0,014	0,143	0,174
Coefficient of waste utilization *(X4)*	0,486	0,528	0,552	0,552	0,615	0,749	0,728
Coefficient of energy intensity of manufactured products *(X5)*	0,895	0,876	0,880	0,887	0,897	0,883	0,900
PJSC "DNIPROVSKY METALLURGICAL PLANT"	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Coefficient of waste capacity of emissions into the atmosphere *(X1)*	0,962	0,966	0,964	0,962	0,960	0,957	0,952
Coefficient of waste capacity of emissions into the water bodies *(X2)*	0,965	0,970	0,975	0,973	0,972	0,967	0,966
Coefficient of waste capacity *(X3)*	0,992	0,992	0,992	0,990	0,990	0,988	0,987
Coefficient of waste utilization *(X4)*	0,271	0,310	0,323	0,318	0,319	0,335	0,395
Coefficient of energy intensity of manufactured products *(X5)*	0,848	0,889	0,877	0,900	0,900	0,920	0,900
PJSC "EVRAZ-DNIPRO METALLURGICAL PLANT"	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Coefficient of waste capacity of emissions into the atmosphere *(X1)*	0,989	0,989	0,988	0,989	0,990	0,990	0,990
Coefficient of waste capacity of emissions into the water bodies *(X2)*	0,895	0,905	0,913	0,931	0,934	0,938	0,938
Coefficient of waste capacity *(X3)*	0,002	0,020	0,036	0,110	0,117	0,215	0,216
Coefficient of waste utilization *(X4)*	0,011	0,016	0,017	0,012	0,014	0,017	0,018
Coefficient of energy intensity of manufactured products *(X5)*	0,784	0,845	0,865	0,887	0,894	0,905	0,905

Notes: Summarized by the authors on the basis of SMIDA (2021a, 2021b, 2021c), Ukrstat (2020c), Ukrstat (2019), and Main Department of Statistics (2020b).

$z_{0t} = -z_{ik}$, if the indicator k is a destimulator. (5)

Therefore, the standard of development, will have the following coordinates:

$$P_o = (z_{01}, z_{02}, \dots, z_{0n}). \quad (6)$$

The taxonomic indicator of the development level is calculated according to the following equations, and according to the interpretation given in the work of Plyuta (1972), the higher the level of development, the closer its value is to one.

$$d_i = 1 - \frac{c_{i0}}{c_0}. \quad (7)$$

Moreover,

$$c_{i0} = \left[\sum_{S=1}^{n} (z_{is} - z_{0t})^2\right]^{\frac{1}{2}} (i=1,2,\dots,t); \quad (8)$$

$$c_0 = \underline{c_0} + 2S_0; \quad (9)$$

$$\underline{c_0} = \frac{1}{t}\sum_{i=1}^{t} c_{i0}; \quad (10)$$

$$S_0 = \left[\frac{1}{t}\sum_{i=1}^{t} (c_{i0} - \underline{c_0})^2\right]^{\frac{1}{2}}, \quad (11)$$

where c_{i0} is the distance between individual points–units and the point P_0, which is the standard of development.

The authors will determine the taxonomic indicator of the level of environmental responsibility for the studied enterprises for the period 2014–2020 and will form a matrix of observations (Tables 5, 6).

To bring the matrix of observations to a dimensionless form, we standardize its elements according to equations (1–3) and obtain a new matrix. It is advisable to include two subgroups of indicators in the group of criteria of one's own environmental initiative – activities for the protection and restoration of the damaged natural environment, the presence of systems for monitoring the quality of the environment, management of the production ecology, and the effectiveness of communications with stakeholders.

Along with administrative and market instruments for regulating the environmental responsibility of industrial enterprises, tools and methods based on voluntary agreements between enterprises–nature users, state administration bodies, and the population in terms of the provision of environmental safety in the sphere of production and consumption of products and improvement of the environment are also gaining importance (Singer, 2014). As the global experience shows, a special role is assigned to implementation of the principles of environmental responsibility.

Table 6. Matrix of observations for evaluating the level of environmental responsibility – block of environmental initiative.

PJSC "ARCELOR MITTAL"	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Share of capital investments in environmental protection measures *(X6)*	0,710	0,748	0,719	0,812	0,863	0,673	0,676
Proportion of current costs for SNE protection *(X7)*	0,081	0,053	0,042	0,014	0,015	0,024	0,023
Share of unreimbursed environmental costs *(X8)*	0,274	0,276	0,340	0,305	0,501	0,000	0,000
Coefficient of ecological loss capacity of products *(X9)*	0,996	0,997	0,997	0,996	0,997	0,996	0,996
Integral indicator of environmental initiative *(X10)*	0,361	0,305	0,401	0,508	0,489	0,546	0,549
PJSC "DNIPROVSKY METALLURGICAL PLANT"	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Share of capital investments in environmental protection measures *(X6)*	0,013	0,072	0,216	0,123	0,020	0,668	0,016
Proportion of current costs for SNE protection *(X7)*	0,922	0,872	0,723	0,798	0,897	0,308	0,901
Share of unreimbursed environmental costs *(X8)*	0,030	0,125	0,002	0,001	0,001	0,001	0,001
Coefficient of ecological loss capacity of products *(X9)*	0,999	0,999	0,999	0,998	0,998	0,998	0,998
Integral indicator of environmental initiative *(X10)*	0,392	0,401	0,396	0,437	0,464	0,481	0,290
PJSC "EVRAZ - DNIPRO METALLURGICAL PLANT"	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Share of capital investments in environmental protection measures *(X6)*	0,477	0,498	0,493	0,594	0,363	0,650	0,616
Proportion of current costs for SNE protection *(X7)*	0,370	0,441	0,366	0,261	0,426	0,251	0,275
Share of unreimbursed environmental costs *(X8)*	0,117	0,017	0,028	0,016	0,018	0,000	0,000
Coefficient of ecological loss capacity of products *(X9)*	1,000	1,000	1,000	0,999	0,999	0,999	0,999
Integral indicator of environmental initiative *(X10)*	0,376	0,368	0,411	0,423	0,447	0,453	0,449

Notes: Summarized by the authors on the basis of SMIDA (2021a, 2021b, 2021c), Main Department of Statistics (2020b), Bieloborodova and Stroieva (2018), and Reese et al. (2015).

According to the results of categorizing the indicators as stimulators and destimulators using equations (4–6), we will form a standard vector for each of the studied enterprises with the corresponding coordinates:

1. PJSC "Arcelor Mittal:"
   P_o = (1.079; 1.292; 1.601; 1.458; 1.274; 1.689; −0.897; −1.328; 1.603; 1.018);
2. PJSC "Dniprovsky Metallurgical Plant:"
   P_o = (1.261; 1.516; 1.036; 1.908; 1.288; 2.154; −2.148; −0.478; 1.496; 1.151)
3. PJSC "Evraz-Dnipro Metallurgical Plant:"
   P_o = (1.289; 0.917; 1.281; 1.077; 0.821; 1.239; −1.145; −0.693; 1.509; 0.994)

Based on the calculated values, the distance between the elements of the standardized matrix and the elements of the reference vector has been determined according to equation 8. Further calculations of auxiliary coefficients and the taxonomic indicator, which characterizes the dynamics of the level of environmental responsibility of the studied enterprises in 2014–2020, are given in Table 7.

Discussion

According to the proposed methodology, partial taxonomic indicators of the level of environmental responsibility and environmental initiative of the studied enterprises, as well as the general taxonomic indicator of the level of environmental responsibility have been determined.

Since the taxonomic indicators of the level of environmental responsibility of the studied industrial enterprises have multidirectional dynamics, we consider it appropriate to use the method of economic and mathematical modeling to explain the influence of blocks of environmental responsibility and environmental initiative on the resulting indicator. Scientists like Yankovy (2011), Prokopenko (2010), and others emphasized the multiplicative nature of the impact of environmental factors. It was emphasized that the influence of these factors on the resulting indicator at each time interval can both increase and decrease, accumulating both positive and eco-destructive trends. The economic assessment of such accumulation can be multiplicative in nature. Multiplicative models, and the Cobb–Douglas function in particular, most objectively reflect the process of development of socioeconomic systems, avoiding the influence of subjective factors. This makes it possible to identify isolated factors of influence on the resulting indicator, which is the purpose of the study.

To construct the desired function, we will make a number of assumptions. Let the function of the dependence of environmental responsibility level (Y) on the blocks of environmental obligation ($X1$) and environmental initiative ($X2$) be twice continuously differentiable and continuous over the time interval $t \geq 0$. A change in the taxonomic indicator of the level of environmental responsibility of an industrial enterprise due to a change in one of the factors X_1, X_2 is mathematically expressed as a partial derivative of this factor. The function (Y) generally depends on two factors, X_1 and X_2.

The growth of the general taxonomic indicator of the level of environmental responsibility of an industrial enterprise increases more slowly than the growth of each of the partial taxonomic indicators of the block of environmental obligation and the block of environmental initiative. On the basis of the hypotheses put

Table 7. Taxonomic indicators of the level of environmental responsibility, environmental obligation of the environmental initiative for 2014–2020.

PJSC "ARCELOR MITTAL"	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
General taxonomic indicator of the level of environmental responsibility	0,110	0,138	0,217	0,236	0,095	0,299	0,423
Partial taxonomic indicator of the level of environmental obligation	0,318	0,191	0,298	0,385	0,038	0,414	0,579
Partial taxonomic indicator of the level of environmental initiative	0,050	0,187	0,219	0,164	0,317	0,255	0,331
PJSC "DNIPROVSKY METALLURGICAL PLANT"	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
General taxonomic indicator of the level of environmental responsibility	0,110	0,273	0,423	0,388	0,317	0,421	0,042
Partial taxonomic indicator of the level of environmental obligation	0,047	0,455	0,506	0,518	0,462	0,298	0,148
Partial taxonomic indicator of the level of environmental initiative	0,300	0,228	0,430	0,366	0,292	0,663	0,078
PJSC "EVRAZ - DNIPRO METALLURGICAL PLANT"	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
General taxonomic indicator of the level of environmental responsibility	0,046	0,274	0,294	0,440	0,387	0,614	0,650
Partial taxonomic indicator of the level of environmental obligation	0,118	0,403	0,304	0,488	0,678	0,868	0,885
Partial taxonomic indicator of the level of environmental initiative	0,068	0,190	0,384	0,445	0,153	0,432	0,483

Note: Calculated by authors.

forward above, we get the following production regression equation:

$$Y = a_o \,.\, X_1^{a1} \,.\, X_2^{a2}. \quad (12)$$

For the linearization of this model, we will logarithmize the equation:

$$ln\ ln\ Y = ln\ ln\ a_0 + a_1\ ln\ ln\ X_1 + a_2\ ln\ ln\ X_2\,. \quad (13)$$

We will replace the variables, which will result in a linear equation:

$$ln\ ln\ Y = Y_1;\ ln\ ln\ a_0 = a_{01};$$

where

$$ln\ ln\ X_1 = C_1;\ ln\ ln\ X_2 = C_2; \quad (14)$$

$$Y_1 = a_{01} + a_1\, C_1 + a_2\, C_{2.}\,. \quad (15)$$

To estimate the parameters of the regression line, we will use the built-in functions of MS Excel. We will present the production functions for the studied enterprises based on the results of the calculations. For greater clarity, the authors provide the geographic location of the enterprises under study on the map of Ukraine.

For PJSC "Arcelor Mittal":

$$a_o = 0.55;\ a_1 = 1.69;\ a_2 = 1.16;\ Y = 0.55\,.\,X_1^{1.69}\,X_2^{1.16} \quad (16)$$

The coefficient of determination of the R-squared model = 0.93. The found function is checked for adequacy using Fisher's test. Calculation value Fp = 124.95. Table value for the level of significance p = 0.95, degrees of freedom $f1 = m = 2; f2 = n–m-1 = 4$, Fm (0,05;2;4) = 6.94.

Since $Fp > Fm$, with the reliability of 95%, it can be assumed that the considered econometric model adequately describes the process considered in the study.

For this two-factor regression, the partial elasticity coefficient shows by what percent the taxonomic indicator of the level of environmental initiative will change if one of the factors changes by 1% while the other factor remains unchanged. In the case of the Cobb–Douglas production function, parameters a_1 and a_2 are the partial elasticity coefficients of factors X_1 and X_2, respectively.

For PJSC "Arcelor Mittal," the general taxonomic indicator of the level of environmental responsibility will change by 1.69% when the indicator of the block of environmental obligation changes by 1% and the indicator of environmental initiative block has a constant value. With a change in the indicator of the environmental initiative block by 1% and a constant value of the indicator of the environmental obligation block, the overall taxonomic indicator of the level of environmental responsibility will change by 1.16%. Thus, for PJSC "Arcelor Mittal," the influence of the blocks of environmental obligation and environmental initiative on the resulting indicator of the level of environmental responsibility is distributed relatively evenly with a slight predominance of the block of environmental obligation.

For PJSC "Dniprovsky Metallurgical Plant":

$$a_o = 1.34;\ a_1 = 1.62;\ a_2 = 2.54;\ Y = 1.34\,.\,X_1^{1.62}X_2^{2.54} \quad (17)$$

The coefficient of determination of the R-squared model = 0.98. The found function is checked for adequacy using Fisher's test. Calculation value Fp = 84.29. Table value for the level of significance p = 0.95, degrees of freedom $f1 = m = 2; f2 = n–m-1$ = 4, Fm (0.05;2;4) = 6.94.

Since $Fp > Fm$, with the reliability of 95%, it can be assumed that the considered econometric model adequately describes the process considered in the study.

Thus, for PJSC "Dniprovsky Metallurgical Plant," the total taxonomic indicator of the level of environmental responsibility will change by 1.62% with a change in the indicator of the block of environmental obligation by 1% and a constant value of the indicator of the environmental initiative block. With a change in the indicator of the environmental initiative block by 1% and a constant value of the indicator of the environmental obligation block, the overall taxonomic indicator of the level of environmental responsibility will change by 2.54%. Therefore, for PJSC "Dniprovsky Metallurgical Plant," at this stage of development of its environmental responsibility, it is more effective to implement measures to increase the environmental initiative block.

For PJSC "Evraz-Dnipro Metallurgical Plant:"

$$a_o = 1.15; a_1 = 2.39; a_2 = 1.58; Y = 1.15. X_1^{2.39} X_2^{1.58} \ . \qquad (18)$$

The coefficient of determination of the R-squared model = 0.98. The found function is checked for adequacy using Fisher's test. Calculation value Fp = 108.41. Table value for the level of significance p = 0.95 degrees of freedom $f1 = m = 2; f2 = n–m-1$ = 4, Fm (0.05;2;4) = 6.94.

Since $Fp > Fm$, with the reliability of 95%, it can be assumed that the considered econometric model adequately describes the process considered in the study.

Thus, for PJSC "Evraz-Dnipro Metallurgical Plant," the total taxonomic indicator of the level of environmental responsibility will change by 2.39% with a change in the indicator of the block of environmental obligation by 1% and a constant value of the indicator of environmental initiative block. With a change in the indicator of the environmental initiative block by 1% and a constant value of the indicator of the environmental obligation block, the overall taxonomic indicator of the level of environmental responsibility will change by 1.58%. Therefore, for PJSC "Evraz-Dnipro Metallurgical Plant," at this stage of development of its environmental responsibility, it is more effective to implement measures to increase the block of environmental obligation.

Therefore, the taxonomic indicator of the environmental responsibility level constructed from the blocks of environmental obligation and environmental initiative synthetically characterizes the changes in the value of the characteristics of the studied groups. Among the advantages of this indicator is the characterization of the direction and scale of changes in the processes described by the set of initial data (Zhong, 2022). The taxonomic method allows us to determine the level of environmental responsibility of industrial enterprises by determining the distance between the standardized values of the indicators and the coordinates of the reference point. The artificial standard is formed taking into account the differentiation of stimulating and destimulating effects of the features on the object of research. After a series of transformations, the calculated distance is transformed into an indicator with boundaries (0;1). Thus, it is proposed to assess the level of environmental responsibility of enterprises using the taxonomy method, which is used to reduce the factor space that is revealed in the aggregation of the information space, as a result of which a general indicator is formed Obelnytska (2019).

The methodology for assessing the level of environmental responsibility of industrial enterprises presented in the study makes it possible to identify directions for the correction of the environmental strategy and the level of its balance. Moreover, in further research, it creates a basis for comparing the current state of environmental responsibility at various enterprises of the metallurgical industry (Jiang, 2022; Taghipour, 2022). This makes it possible to identify leaders and outsiders in the field of environmental responsibility of industrial enterprises and provides a basis for building reference vectors for the development of enterprises, taking into account environmental factors.

However, environmental responsibility, by itself, without a justified impact on the society, acquires a philosophical rather than a practical character. Therefore, one of the tasks of this study was to determine and substantiate the impact of the level of environmental responsibility of industrial enterprises on local communities (Ociepa-Kubicka, 2017). As mentioned earlier, the studied enterprises have a significant negative impact on the state of the environment, especially on the quality of atmospheric air. However, in the process of implementing economic activities, they create the necessary prerequisites for the socioeconomic development of the population (Borghesi et al., 2014). Atmospheric air pollution significantly affects the health of the population because breathing is the basis of vital activity of any organism (Ukrstat, 2020b). As the public is constantly and repeatedly exposed to pollutants through air, industrial enterprises decrease the quality of life and the state of health of the population, even increasing the mortality rate, genetic disorders, the growth of oncological diseases, etc (OECD/European Union 2020; World Health Organisation et al. 2018).

It is also necessary to note the experience of Austria in the field of application of economic mechanisms for nature management. The relevant law was adopted by the Austrian parliament as part of the eco-social tax reform. According to the document (Austrian National Emissions Trading System, 2022), on July 1, 2022, the government had introduced a tax on CO_2 emissions for fuels used in the heating and transport sectors at the level of €30/t, with a gradual increase to €55/t by 2025. These are the areas that are not covered by the European market for greenhouse emissions trading (EU ETS). To reduce the financial burden on the population, each citizen will receive a climate bonus of up to 200 euros every year. The bonus rate depends on the ability to use public transport. For example, in Vienna, the rate is the lowest and reaches 100 euros, and the further into the countryside, the higher the compensation.

Overall, the law aims to encourage people to choose environmentally friendly modes of transport and heating by raising the prices of more expensive carbon-efficient options without increasing the overall tax burden. The plans include cutting income tax, some health insurance levies, and taxes on companies, especially in energy-intensive industries that will be hardest hit by the new CO_2 tax, from 25% to 23% by 2024. By 2025, the tax reform is expected to bring aid to individuals and legal entities in the amount of 18 billion euros.

In Ukraine, from January 1, 2022, tax rates on CO_2 emissions increased by 200% from UAH 10/t to UAH 30/t (EcoPolitic, 2022). Last time, the carbon tax was raised in 2019 from UAH 0.41/t to UAH 10/t, but it was not possible to achieve positive results; according to the results of the same year, greenhouse gas emissions decreased by 2%. The whole problem is that the funds from the payment of the eco-tax on CO_2 emissions in Ukraine have no intended use and are dissolved in the state budget.

Therefore, the decrease in the incidence of respiratory diseases in the cities where the studied industrial enterprises work can be an indicator of the success of their implementation of environmental responsibility. (Bars'ka et al. 2020). To carry out further research, it is necessary to establish the density and nature of such a relationship using the methods of economic and mathematical modeling.

The ability of an industrial enterprise to be ecologically transparent and open, its ability to establish a social dialog with stakeholders, is an important part of its strategy. Industrial activity always has a negative impact on the environment, and at the same time, it is this activity that creates the necessary conditions for sustainable development. The possibility of reaching a reasonable compromise here lies primarily in the enterprise conducting a dialog with all interested parties: investors and shareholders, public and the local population, local self-government and state environmental control bodies, mass media, scientific research organizations, educational institutions, cultural institutions, etc.

The process of introducing an environmental responsibility at an industrial enterprise is characterized by the need to agree on the goals, tasks, and directions of activity of the entire spectrum of its subsystems. Purposeful introduction of the principles of environmental responsibility into the development strategy of an industrial enterprise requires the development of a consistent, planned scheme for the implementation of this task (Savosko et al., 2022).

The process of introducing environmental responsibility is influenced by both external and internal factors. Thus, the requirements of local and regional authorities, the established limits on discharges into the natural environment, the activities of international environmental organizations, and the requirements of other stakeholders should be classified as factors external to the enterprise. The activities of trade union committees, the policy of shareholders, the availability of ISO 140001 series certificates, and the existing state of capital structures of environmental importance are the internal factors.

We propose to attribute the following to the main consequences of the introduction of the system of environmental responsibility:

- improvement of the state of natural environment;
- reduction in fines and payments for violation of limits on discounts in natural environment;
- improving communications with representatives of the company's external environment;
- formation of a positive environmentally conscious image of the enterprise;
- optimization of the investment policy in the sphere of protection of natural environment; and
- increasing the level of environmental friendliness of the enterprise's production system.

It is expedient to pay special attention to the process of implementation of the developed system of environmental responsibility in the general development strategy. Speaking of a large industrial enterprise, when formulating its strategy, basic directions of development are often determined, according to which separate mini-strategies are also formed, which are then integrated into the general one, thereby implementing a comprehensive approach to solving the task.

One of the most important factors when deciding on a development strategy for any industrial enterprise is increasing its competitiveness. For industrial enterprises, one of these factors is the environmental friendliness of production systems and the demonstration of acceptance of the concept of environmental responsibility. However, the main problem for the existing types of development strategies is the lack of a long-term vision of the environmental component. It is obvious that the formation of an organization's development strategy on the basis of compliance with the concept of environmental responsibility is its constituent part, without which the fulfillment of key business tasks is impossible.

As is well known, the concept of an environmentally responsible industrial enterprise implies the existence of a separate environmental strategy, which is part of the general strategy of its development. The decision to develop such a strategy is usually influenced by the following factors:

- consumer demand for open information on the environmental sustainability of product production is increasingly spreading throughout the world;
- banks and insurance organizations take into account the business reputation of organizations, which includes their environmental status, when making a decision to issue a loan and choose an insurance policy;
- state environmental control is becoming increasingly strict; and
- strengthening of international environmental management standards, etc.

Thus, the system of organizational and economic support of environmental responsibility of an industrial enterprise should become an organic part of its development strategy. When forming a strategy for the development of an industrial enterprise aimed at complying with the concept of environmental responsibility, it is not only necessary to take into account external factors that reflect state control, consumer opinion, and the environmental status of competitors, but also withstand the internal principles of eco-safety. Only in this case, the organization will be able to achieve a state of balanced environmental management and economic growth at the same time.

Therefore, the formation of the organization's strategy, taking into account the principles of environmental responsibility, is the integral part of its general economic strategy, without which it is impossible to fulfill the key tasks of the economic development of both an individual enterprise and the country as a whole.

At the same time, when choosing a strategy for the development of industrial enterprises, it is necessary to take into account regional ecological development strategies because it is the harmonious combination of environmentalization tasks at the local and regional level that allows achieving sustainable economic and social development. Thus, the adjustment of the development strategy of the industrial enterprise should take place in two directions – according to the level of environmental responsibility of the industrial enterprise and taking into account the ecological conditions of the population living in a specific region.

Accordingly, the requirements of the population of regions with different living conditions for the ecological development of their areas of residence and, accordingly, of the main industrial enterprises polluting the environment will be different. Thus, for the population of territories with deteriorated and stressful living conditions, the main requirements will be the introduction of a strategy for greening and improving the state of the environment, while local communities of territories with satisfactory living conditions can pay more attention to the presence of environmental initiatives at industrial enterprises and the introduction of new ecological methods of producing products.

Thus, it becomes obvious that the type of enterprise development strategy is related to the degree of its environmental responsibility and the ecological conditions of the population's residence, since the community acts as a full-fledged participant in the formation and implementation of an ecologically oriented strategy for the development of industrial enterprises. The choice of an industrial enterprise's development strategy should be adjusted taking into account the level of its environmental responsibility and the environmental conditions of the region.

Conclusion

In the literal sense, environmental responsibility should first of all be considered as a type of public good and environmental policy should be oriented on its creation. Therefore, environmental responsibility is a socially necessary level of environmental quality, at which there are no threats to human health and the vital activities of society, and it is also impossible to have negative changes in the functioning of natural ecosystems..

Environmental security has its spatially delineated boundaries, and its achievement depends both on the territorial specificity of placement and the level of development of productive forces and on the real capabilities of individual territories to solve environmental problems.

A comprehensive system for assessing the level of environmental responsibility of industrial enterprises has been proposed. The assessment is proposed to be carried out on the basis of calculation of a comprehensive indicator of the level of environmental responsibility, which, in turn, consists of two components: an integral indicator of the environmental friendliness of the production system and an integral indicator of the level of the enterprise's environmental initiative. These components are equivalent and have the same significance for determining the comprehensive indicator of environmental responsibility. Based on this evaluation system, the level of environmental responsibility of the investigated enterprises has been determined.

The relationship between the level of environmental responsibility of industrial enterprises, determined according to the authors' methodology, and the level of morbidity in the population with respiratory diseases determines the direction of the authors' further research. In particular, the obtained quantitative assessments of the environmental responsibility of enterprises in the industrial region make it possible to create their ratings and evaluate the relationship between pollution and the level of environmental obligation and environmental initiative of these enterprises.

References

Aguinis, H., Villamor, I. & Gabriel K.P. (2020). Understanding employee responses to COVID-19: A behavioral corporate social responsibility perspective. *Management Resources*, 18, 421–438. DOI: 10.1108/MRJIAM-06-2020-1053.

Austrian National Emissions Trading System (2022). *The International Carbon Action Partnership factsheet.* https://icapcarbonaction.com/system/files/ets_pdfs/icap-etsmap-factsheet-122.pdf

Bars´ka, Y., Zakhozha, V., Sakhno, Y., Semyhina, T., Stepurko, T. & Kharchenko N. (Eds.) (2020). *Health Index. Ukraine - 2019. Results of a national survey*, *Kyiv.* http://health-index.com.ua/HI_Report_2019_Preview.pdf

Bieloborodova, M. & Stroieva V. (2018). Modeling of the socio-economic effect of the implementation of environmental responsibility of an industrial enterprise. *Naukovyy Visnyk Khersons´koho Derzhavnoho Universytetu, ser. Ekonomichni Nauky*, 30(4), 53–56.

Borghesi, R., Houston, H. & Naranjo S. (2014). Corporate socially responsible investments: CEO altruism, reputation and shareholder interests. *Journal of Corporate Finance,* 26, 164–181. DOI: 10.2139/ssrn.2171916.

Carroll, A.B. & Buchholtz A.K. (2014). *Business and society: Ethics, sustainability, and stakeholder management.* Nelson Education.

Department of Ecology and Natural Resources under Dnipropetrovsk Regional State Administration (2020). *Regional report on the state of the natural environment in the Dnipropetrovsk region for 2019.* https://adm.dp.gov.ua/storage/app/uploads/public/605/06f/47b/60506f47bd3cb255698190.pdf

Department of Environmental Policy under Dnipro City Administration (2018). *Environmental Passport of the City of Dnipro for 2017.* https://t1p.de/kgsdz

Didukh, Y., Pashkevych, N., Kucher, O. & Chusova O. (2023). Impact of climate change on ruderal communities in the conditions of Ukraine. *Ekológia* (*Bratislava*), 42(1), 39–46. DOI: 10.2478/eko-2023-0005.

EcoPolitic (2022). *Ecological news of Ukraine and the world.* https://ecopolitic.com.ua/ua/news/stalo-vidomo-skilki-koshtuvatimut-vikidi-v-povitrya-zgidno-ekopodatku-na-2022-rik/

Faivre, N., Fritz, M., Freitas, T., Boissezon, B. & Vandewoestijne S. (2017). Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. *Environ. Res.*, 159, 509–518. DOI: 10.1016/j.envres.2017.08.032.

Farooq, O., Rupp, D.E. & Farooq M. (2017). The multiple pathways through which internal and external corporate social responsibility influence organizational identification and multifocal outcomes: The moderating role of cultural and social orientations. *Academy of Management Review*, 60, 954–985. DOI: 10.5465/amj.2014.0849.

Fokus, News Agency (2022). *Environmental rating of Ukrainian regions.* https://focus.ua/uk/ratings/504721-ekologicheskiy-reyting-oblastey-ukrainy-2021

Graafland, J. & Noorderhaven N. (2018). National culture and environmental responsibility research revisited. *International Business Review*, 27(5), 958–968. DOI: 10.1016/j.ibusrev.2018.02.006.

Guthrie, J. & Parker L.D. (1989). Corporate social reporting: A rebuttal of legitimacy theory. *Accounting and Business Research*, 19, 343–352. DOI: 10.1080/00014788.1989.9728863.

Horoshkova, L., Khlobystov, Ie., Filipishyna, L., Shvydenko, M. & Bessonova S. (2020). Economic and mathematical modeling of ecological expenditure for sustainable development of united territorial communities. In *XIV International Scientific Conference "Monitoring of Geological Processes and Ecological Condition of the Environment"* (pp. 1–5). European Association of Geoscientists & Engineers Source. DOI: 10.3997/2214-4609.202056091.

Jiang, X., López, L., Cadarso, M. & Ortiz M. (2022). The emissions responsibility accounting of multinational enterprises for an efficient climate policy. *Global Environmental Change*, 75, 102545. DOI: 10.1016/j.gloenvcha.2022.102545.

Jones, T.M. & Wicks A.S. (1999). Convergent stakeholder theory. *The Academy of Management Review*, 24(2), 206–221. DOI: 10.2307/259075

Kamianske City Council (2018). *Extended report of the Health Department.* https://kam.gov.ua/ua/osxfile/pg/290319498066748_p38_1o/

Koshkalda, I., Anopriienko, T., Klochko, T., Bieloborodova, M. & Bessonova A. (2022). The Comprehensive Plan of the Territory Spatial Development as a Prospective Plan of United Territorial Communities Development. *Review of Economics and Finance,* 20, 617–622. DOI: 10.55365/1923.x2022.20.71.

Kryvyi Rih City Council (2021). *Environmental Passport of the City of Kryvyi Rih (2015-2020).* https://drive.google.com/file/d/1xmHtu-82Si0pdKLlH_BXjj0P828rxBU9/view

Kubatko, O., Luk`yanenko, V. & Mohylenets´ T. (2010). Economic and mathematical approaches to modeling the processes of sustainable development of territories. *Mekhanizm Rehulyuvannya Ekonomiky,* 2, 193‑199.

Kuznietsova, T.V. & Sipailo L.H. (2016). *Economic mechanism of stimulation of ecologically-innovative development of industrial enterprises of the region.* Rivne: NUVHP.

Main Department of Statistics in Dnipropetrovsk Region (2020a). *Statistical Yearbook of Dnipropetrovsk region. Infographics.* http://www.dneprstat.gov.ua/infografika/2019/shor-obl-2019.pdf

Main Department of Statistics in Dnipropetrovsk Region (2020b). *Annual statistical report No. 1 "Environmental costs".* Dnipro.

Makarenko, I.O., Smolennikov, D.O. & Makarenko S.M. (2019). Ukrainian national strategy for Corporate Social and Environmental Responsibility as a framework of responsible business conduct. *Revista ESPACIOS*, 40(22), 21‑31.

Morf, D., Flesher, D.L., Hayek, M., Pane, S. & Hartmann C.C. (2013). Shifts in corporate accountability reflected in socially responsible reporting: A historical review. *Journal of Management History,* 19, 87–113. DOI: 10.1108/17511341311286213

Myroshnychenko, I., Makarenko, I., Smolennikov, D. Buriak A. (2019). The approach to managing corporate social and environmental responsibility in manufacturing. *TEM Journal*, 8(3), 740‑748. DOI: 10.18421/TEM83-07.

Nickols, F. (2020). The accountability scorecard: a framework for Reconciling & Integrating Stakeholder Needs & Requirements. In N.J. Robbinsville (Ed.), *The Distance Consulting Company* (pp. 48–67).

Obelnytska, H.V. (2019). The application of the multiplicative model for evaluating the synergistic effect of the socio-economic efficiency of the corporate management system of oil and gas enterprises. *Scientific Bulletin of the Uzhgorod National University: series: International Economic Relations and World Economy*, 26, 2, 27‑31.

Ociepa-Kubicka, A. & Pachura P. (2017). Eco-innovations in the functioning of companies. *Environ. Res.*, 156, 284‑290. DOI: 10.1016/j.envres.2017.02.027.

OECD/European Union (2020). *Health at a Glance: Europe 2020: State of Health in the EU Cycle.* Paris: OECD Publishing. DOI: 10.1787/82129230-en.

Pluta, W. (1972). *Przyczynek do grafowej metody klasyfikacji cech.* Wroclaw: Prace Naukowe WSE.

Prokopenko, O.V. (2010). *Socio-economic motivation of environmentalization of innovative activity.* Sumy: Publishing House of Sumy State University.

Reese, G. & Jacob L. (2015). Principles of environmental justice and pro-environmental action: A two-step process model of moral anger and responsibility to act. *Environmental Science & Policy*, 51, 88‑94. DOI: 10.1016/j.envsci.2015.03.011.

Savosko, V., Bielyk, Y., Lykholat, Y. & Heilmeier H. (2022). Assessment of heavy metals concentration in initial soils of post-mining landscapes in Kryvyi Rih District (Ukraine). *Ekológia (Bratislava)*, 41(3), 201‑211. DOI: 10.2478/eko-2022-0020.

Serdiuk, A.M. & Kartashova S.S. (2019). Lost years of potential life among the population of Ukraine as an indicator of determining health care priorities. *Environment and Health*, 3(92), 4‑10. DOI: 10.32402/dovkil2019.03.004.

Singer, A., Branham, M., Hutchins, M., Welker, J., Woodard, D., Badurek, C., Ruseva, T., Marland, E. & Marland G. (2014). The role of CO2 emissions from large point sources in emissions totals, responsibility, and policy. *Environmental Science & Policy*, 44, 190‑200. DOI: 10.1016/j.envsci.2014.08.001.

SMIDA (Stock market infrastructure development agency of Ukraine) (2021a) *Regular information about the issuer: PJSC "ArcelorMittal Kryvyi Rih",* retrieved from: https://smida.gov.ua/db/prof/24432974 (accessed: 20.08.2022).

SMIDA (Stock market infrastructure development agency of Ukraine) (2021b). *Regular information about the issuer: PJSC "Dniprovsky metallurgical plant" (2014-2020).* https://smida.gov.ua/db/prof/05393043

SMIDA (Stock market infrastructure development agency of Ukraine) (2021c). *Regular information about the issuer: PJSC "EVRAZ - Dnipro metallurgical plant" (2014‑2020).* https://smida.gov.ua/db/prof/05393056

Taghipour, A., Akkalatham, W., Eaknarajindawat, N. & Stefanakis A. (2022). The impact of government policies and steel recycling companies' performance on sustainable management in a circular economy. *Resources Policy*, 77. DOI: 10.1016/j.resourpol.2022.102663.

Taraniuk, L., Melnyk, L., Kozmenko, O. & Sineviciene L. (2017). Influence of the minimum salary level increase on the business entities activity in the context of the transition to the sustainable development. *Problems and Perspectives in Management,* 15(1), 72‑79. DOI: 10.21511/ppm.15(1).2017.07.

Trujillo-Gallego, M., Sarache, W. & Sellitto M. (2021). Identification of practices that facilitate manufacturing companies' environmental collaboration and their influence on sustainable production. *Sustainable Production and Consumption*, 27, 1372‑1391. DOI: 10.1016/j.spc.2021.03.009.

Ukrstat (2019). *Emissions of pollutants and greenhouse gases into atmospheric air from stationary sources of pollution.* https://ukrstat.gov.ua/operativ/operativ2020/ns/vzrap/vzrap_u.xls

Ukrstat (2020a). *Gross regional product (2004-2019).* https://ukrstat.gov.ua/operativ/operativ2020/vvp/vrp/vrp2019_ue.xls

Ukrstat (2020b). *Environment of Ukraine 2019.* https://ukrstat.gov.ua/druk/publicat/kat_u/2020/zb/11/Dovk_19.pdf

Ukrstat (2020c). *Capital investments for environmental protection by types of economic activity with distribution by types of environmental protection measures.* https://ukrstat.gov.ua/operativ/operativ2020/ns/kap_in/kionps_ek_u19.htm

World Health Organization, and Regional Office for Europe (2018). *European health report 2018: more than numbers – evidence for all.* https://apps.who.int/iris/handle/10665/279904

Yankovy, O.G. (2011). Mathematical methods of factor economic analysis based on multiplicative models. In *Proceedingd of 6th International Conference "Modern technologies of enterprise management and possibilities of using information systems: state, problems, prospects"*(pp. 217‑221). Odesa: ONU.

Zhong, Z. & Peng B. (2022) Can environmental regulation promote green innovation in heavily polluting enterprises?. *Sustainable Production and Consumption*, 30, 815‑828, DOI: 10.1016/j.spc.2022.01.017.