Management of current environmental costs contributing to reduce eco-economic risks

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Abstract. The analyzes of the known approaches to the distribution of environmental and economic resources, including the current environmental costs, in connection with their impact on reducing the level of eco-economic risks, is carried put in the article. The analysis of the dynamics and structure of current environmental costs of large industrial enterprises is carried out, and the dependence of the level of excess emission charges on the magnitude of current environmental costs is graphically presented. A mechanism for adjusting the current system of distribution of such costs has been developed to lead to their proportional reduction relative to an increase in the values of risk level indicators. In order to prepare for an effective management decision, an algorithm for managing the system of distribution of current environmental costs is presented. The analysis of the impact of the adjusted system of distribution of current environmental costs on the technical and economic performance of the enterprise was carried out. The work done is of practical importance for large industrial enterprises that have a complex negative impact on the environment, which significantly affects their technical, economic and financial performance.

1. Introduction

The current environmental costs (CEC), including all types of costs of enforcement of environmental protection measures, ensuring the current work of production processes and specific equipment to reduce or eliminate negative anthropogenic impact are very important for the efficient eco-economic performance of a modern enterprise [1-5]

These costs are reported by enterprises in a special form [6] and are differentiated in the following areas:

- air protection and climate change mitigation;
- wastewater collection and treatment;
- waste management;
- protection and rehabilitation of land, surface and ground water;
- protection of the environment from noise, vibration and other types of physical impact;
- preservation of biodiversity and protection of natural areas;
- ensuring radiation safety of the environment;
- research and development activities to reduce negative anthropogenic impacts on the environment;
- other activities in the field of environmental protection.

Under conditions of a rapidly changing environment, limited economic resources and maintaining the required level of competitiveness [7-11], an effective distribution of such costs, which can be based on the “current environmental costs - the level of risk” dependence, is essential. This is due to the fact that the process of eco-economic risk assessment is of particular relevance in modern conditions of tightening national environmental legislation and increasing the sensitivity of the technical and economic performance of an enterprise to its eco-economic characteristics.

2. Materials and methods

The object of study is industrial enterprises engaged in coal conversion and having a complex negative impact on the environment (air emissions, discharges into water sources, production and consumption waste generation). The subject of the research is the system of distribution of CEC. The study is based on an analysis of modern sources on the problems of the effective allocation of environmental and economic resources, one of which is the CEC. Particular attention is paid to the study of the methodology for the allocation of such costs based on indicators related to the assessment of eco-economic risks. For the purpose of practical implementation of the author's methodology, statistical processing of environmental data of industrial enterprises was carried out on the basis of official reporting forms. On the basis of the developed algorithm of the improved system of distribution of CEC, their impact on the technical and economic performance of the enterprise was analyzed. The work also used elements of system analysis and the results obtained by experts in the field of management of environmental and economic systems at various levels.

3. Results and discussion

To build a system of distribution of current costs on the principles of adequate assessment of eco-economic risks, an analysis of the known mechanisms for evaluating and managing specific types of risks was carried out. Fundamental studies on this issue are given in [12–14], where not only risk assessment methods are considered, but also the most efficient risk management mechanisms at enterprises (fines, risk payment, risk reduction financing, recovery of risk reduction costs and others).

The integrated risk assessment procedure based on discrete scales to reduce the risk rate of a risk event to the required level with minimal costs is proposed in the paper [15].

Studies [16] show that the risk magnitude is defined as the product of damage by the probability of its occurrence, obtained on the basis of the expert evaluation method. This approach should also be used for eco-economic risks, which in many cases are transformed into traditional financial and economic risks.

A significant problem of adequate calculation of eco-economic risks is the choice of a method for assessing the probability of an adverse event. In practice, three such basic methods as statistical, analytical and expert evaluation are most often used.

For the most qualitative and accurate assessment of the probability of occurrence of adverse events, it is necessary to use all methods simultaneously with checking the convergence of results.

A number of experts believe that in addition to the above methods, simulation modeling [17], ensuring greater reliability of the result obtained, is of practical importance.

One of the problems of assessing eco-economic risks is an adequate interpretation of the result. Some experts [18] consider eco-economic risk zones as a normal allocation, similar to the image of speculative risks in the financial sphere, when any deviation from the “normal” situation is considered as a risky event (profit, damage, gain, loss, etc.).

The practical application of the theory of eco-economic risks is reflected in the analysis of environmental and economic performance of an enterprise [2, 10], when one of the simple options for assessing this type of risk is to determine the proportion of excessive environmental impact fees in the total amount of fees. Analysis of data of large industrial enterprises showed that this value can reach up to 90 %, characterizing the inefficiency of the environmental policy, and negatively affecting the technical, economic and financial performance of the enterprise, reduces its profits. Another aspect of this problem is inadequate rationing of the potential environment impact when the compliance with regulations is impossible due to the technology applied.

The reduction of eco-economic risks at the enterprise is largely associated with internal CEC (figure 1).

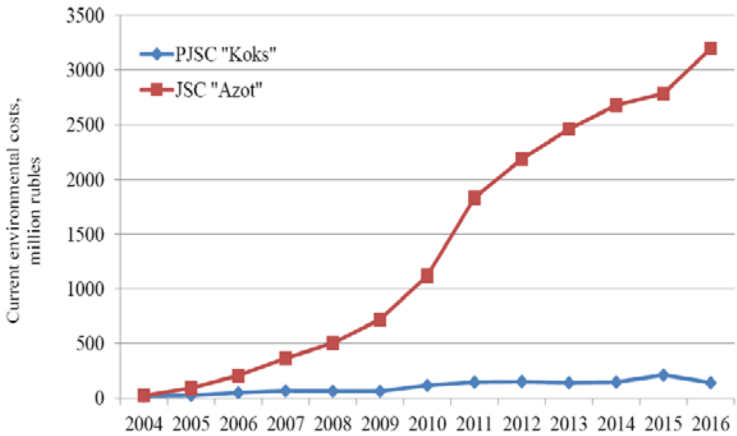

Figure 1. Dynamics of current environmental costs of JSC “Azot” и PJSC “Koks”.

Figure 1 shows that the ranges of changes in CEC of these enterprises differ significantly (from 20.2 to 212.4 million rubles for PJSC “Koks” and from 23.8 to 3198.0 million rubles for JSC “Azot”). The increase in CEC of JSC “Azot” is associated with a highly diversified environmental impact and the construction of a closed water cycle system. Another reason is the increase in depreciation charges for the restoration of basic production assets for environmental protection. Figures 2 and 3 show the structure of CEC of the JSC “Azot и PJSC “Koks” enterprises [19].

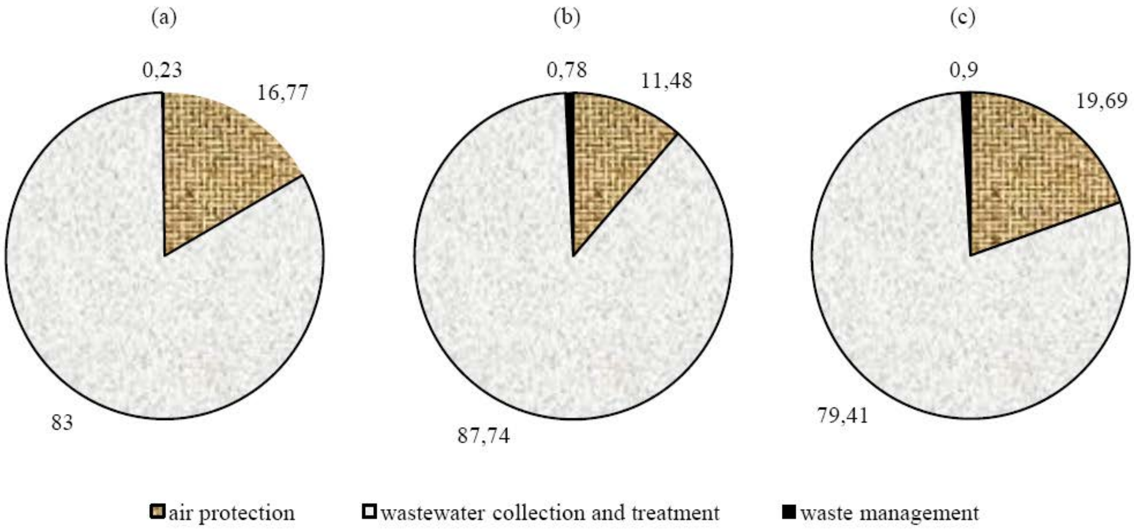

Figure 2. Structure of current environmental costs of PJSC “Koks” enterprise in (a) 2014, (b) 2015, (c) 2016, %.

Figure 2 shows that the cost structure is changing, in particular, there is an increase in the share of current waste management costs from 0.23 % in 2014 to 0.9 % in 2016.

The air protection costs change “nonlinearly” – a decline in 2015 (11.48 %), and then a sharp increase in 2016 to 19.69 %. The reverse trend is observed at current costs associated with the wastewater collection and treatment. The high proportion of this type of cost (up to 87.74 % in 2015) is due to the need for efficient operation of the closed water cycle system.

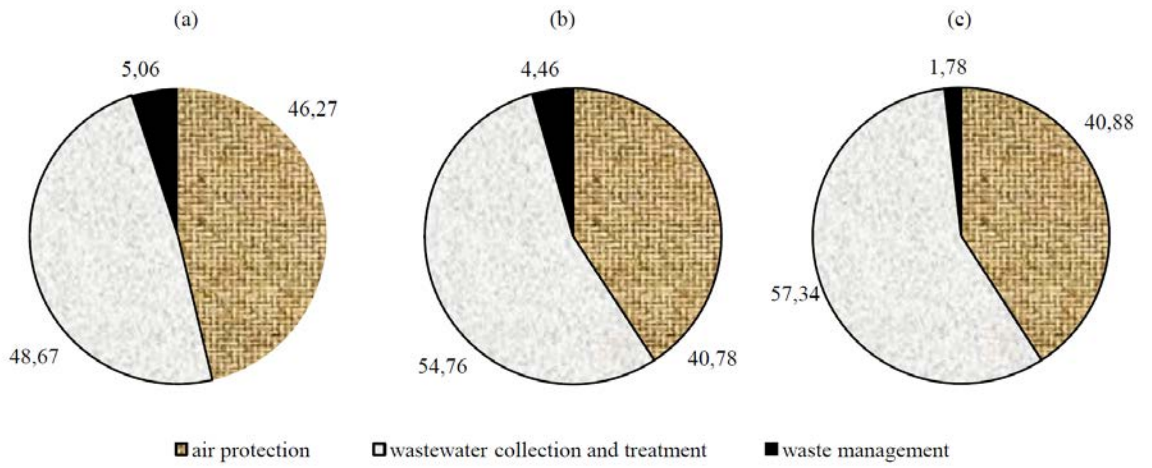

Figure 3. Structure of current environmental costs of JSC "Azot" enterprise in (a) 2014, (b) 2015, (c) 2016, %.

The analysis of CEC of JSC "Azot" shows steady trends in reducing waste management costs (from 5.06 % in 2014 to 1.78 % in 2016) and increasing costs for wastewater collection and treatment (from 48.67 % in 2014 to 57.34 % in 2016). The growth of this type of costs is associated with the installation of a closed water cycle system at the plant. Current air protection costs decreased in 2015 and remained approximately at this level in 2016. This distribution of CEC of JSC "Azot" is associated with the peculiarities of its production program and diversification of the environmental impact types.

Figure 4 shows the correlation field and the empirical regression line of the relationship between CEC and the specific weight of the excessive environmental impact fee in the total fee value $(SW_{j,t})$, which is closely related to the risk level. Points presented on all analyzed charts mean information obtained for a particular enterprise for a calendar year.

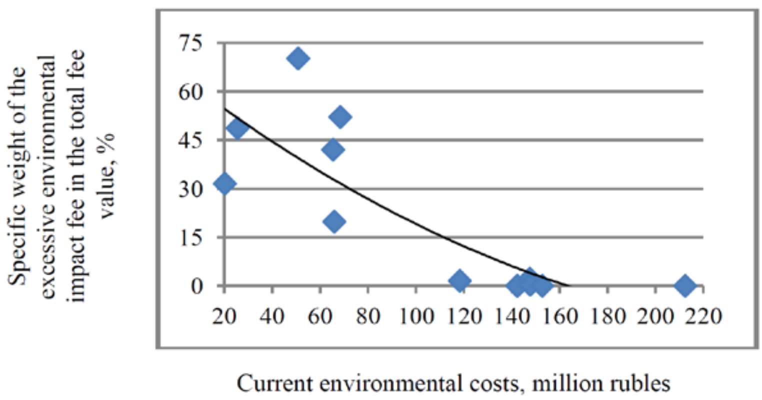

Figure 4. Correlation field and the empirical regression line of the relationship between $SW_{j,t}$ and current environmental costs at PJSC "Koks".

The data on the correlation field have a large scatter, which, apparently, is explained by different environmental policies at the enterprise in different years. The values in the left part of the correlation field show a significant variation of $SW_{j,t}$ with relatively small changes in the CEC. It is noteworthy that there is a large variation in $SW_{j,t}$ values (from 19.8 to 52.06 %) with almost the same values of CEC. The remaining values in the correlation field cover the period from 2010 to 2016, when the CEC significantly increased (from 118.3 to 212.4 million rubles). With such funding, there was a sharp decline of $SW_{j,t}$ which for these years fluctuated around zero.

The considered periods characterize the situation of changes in environmental policy since 2010. This was due to the tightening of environmental legislation. As a result, the company switched to the BAT (best available technologies) standards, ensuring a minimum negative load on the environment. Due to standard, the company has a close water cycle system, and as a result, since 2012, PJSC “Koks” has stopped the wastewater discharge. This trend of tightening environmental legislation is to improve the system of environmental impact charges, which has been in effect since January 1, 2016 and is aimed at additional fines for enterprises that do not implemented the transition to the BAT standards.

Figure 5 shows the correlation field of the relationship between similar variables for JSC “Azot”.

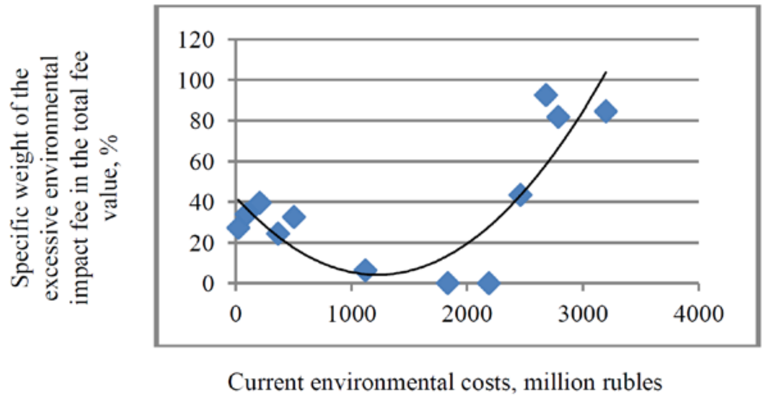

Figure 5. Correlation field and the empirical regression line of the relationship between $SW_{j,t}$ and current environmental costs at JSC “Azot”.

Figure 5 shows that the dependence is non-linear in nature, in particular, until 2013 there is an inverse relationship, when an increase in current costs leads to a decrease in $SW_{j,t}$. From 2013, a further increase in current costs is accompanied by a sharp increase in $SW_{j,t}$ to 92.58 %, which is explained by a sharp increase in fees for excessive pollution of water sources and may be caused by large-scale technical re-equipment of sewage treatment plants, which was planned to be completed in 2017.

Due to the fact that the analysis showed a lack of efficiency of the CEC in several enterprises, it is proposed to adjust the current system of distribution of these costs by proportionally decreasing them relative to an increase in indicators related to the level of risk. In this case, for the criteria presented in [20], the adjusted value of the CEC of the planned period for the *j*-th element of the environment ($CEC_{j,1}$) is determined by the formula (1):

$$CEC_{j,1} = CEC_{j,0} \cdot [1-(CIR_{\beta,j,0} - SIR_{\beta,j})] \text{ ,} \qquad (1)$$

where $CEC_{j,0}$ – value of current environmental costs in *0*-th time period for *j*-th element of the environment, rubles.; $[1-(CIR_{\beta,j,0} - SIR_{\beta,j})]$ – reduction ratio of CEC in *0*-th time period for *j*-th element of the environment ($RR_{CECj,0}$),the operating time of the current system of distribution of CEC is taken as *0*-th period, and the next year with the adjusted value of the CEC is taken as *1*-st period (for example, if the *0*-th period is 2016, then the *1*-st is 2017); $CIR_{\beta,j,0}$ calculated indicator associated with the level of risk for the *β*-th criterion and the *j*-th element of the environment in the *0*-th time period; $SIR_{\beta,j}$ – the standard indicator associated with the level of risk for the *β*-th criterion and the *j*-th element of the environment, determined on the basis of the expert evaluation method.

The value of the minimum required level of current environmental costs for items of expenditure in the *0*-th time period for the *j*-th element of the environment ($V^{min}_{CECj,0}$) is determined using the expert evaluation method, based on the ecological and economic feasibility of the required amount of CEC.

If the calculated and regulatory indicator associated with the risk level has a dimension of %, then the adjusted value of current costs is determined by the formula (2):

$$CEC_{j,1} = CEC_{j,0} \cdot [100 - (CIR^{*}_{\beta,j,0} - SIR^{*}_{\beta,j})] \, , \quad (2)$$

where $CIR^{*}_{\beta,j,0}$ – calculated indicator и $SIR^{*}_{\beta,j}$ – regulatory indicator, associated with the risk level, having a dimension of %.

For other criteria, the adjusted value of CEC is determined by formulas (3) and (4):

$$CEC_{j,1} = CEC_{j,0} \cdot [1 - (SIR_{\beta,j} - CIR_{\beta,j,0})] \, , \quad (3)$$

where $[1 - (SIR_{\beta,j} - CIR_{\beta,j,0})]$ – $RR_{CECj,0}$ indicator;

$$CEC_{j,1} = CEC_{j,0} \cdot [100 - (SIR^{*}_{\beta,j} - CIR^{*}_{\beta,j,0})] \, , \quad (4)$$

where $[100 - (SIR^{*}_{\beta,j} - CIR^{*}_{\beta,j,0})]$ – $RR_{CECj,0}$ indicator.

The decrease in the value of current environmental costs (ΔCEC_j) is determined by the formula (5):

$$\Delta CEC_j = CEC_{j,0} - CEC_{j,1} \, . \quad (5)$$

The suggested limitations for using this algorithm:

$CEC_{j,1} \le CEC_{j,0}$ provided that the inflation rate for the study period does not change.

Consider the formulation of the problem of distribution of current environmental costs, taking into the account the efficiency of their use.

Given:

1. The current system of distribution of CEC by items of expenditure.
2. Indicators of the efficiency of the use of CEC associated with the risk level [20].
3. The technical and economic performance (TEP) of the enterprise.
4. Limitations: 1) $CEC_{j,1} \le CEC_{j,0}$; 2) $RR_{CECj,0} \ge V^{min}_{CECj,0}$.
5. Criterion: the annual eco-economic efficiency of the system of CEC distribution.

Required: to build an algorithm for managing the system of CEC distribution meeting the limitations and maximizing the criterion.

Figure 6 shows a flowchart of the algorithm for distribution of CEC, taking into account the efficiency of their use.

Unit 1 provides for the input of all necessary data, including the CEC, criteria for the efficiency of the distribution of CEC, and other indicators. In Unit 2, the current system of distribution of CEC by item of expenditure is presented. Unit 3 is needed to select the criterion for the efficiency of the adjustment of CEC. In logical Unit 4, on the basis of previous calculations, a conclusion is made about the efficiency (or inefficiency) of using CEC. In the case of efficient use of CEC, the existing distribution system, presented in Unit 2, is preserved. Otherwise, first $V^{min}_{CECj,0}$ (Unit 5) is determined and compared with $RR_{CECj,0}$ (Unit 6). If the result of this comparison a positive, the adjustment of the value of CEC for the individual elements of the environment is made in Unit 7, and if negative - in Unit 8. Unit 9 corrects the entire system of distribution of CEC by item of expenditure. An analysis of the impact of the adjusted system of distribution of CEC on the main technical and economic performance of the enterprise is presented in Unit 10.

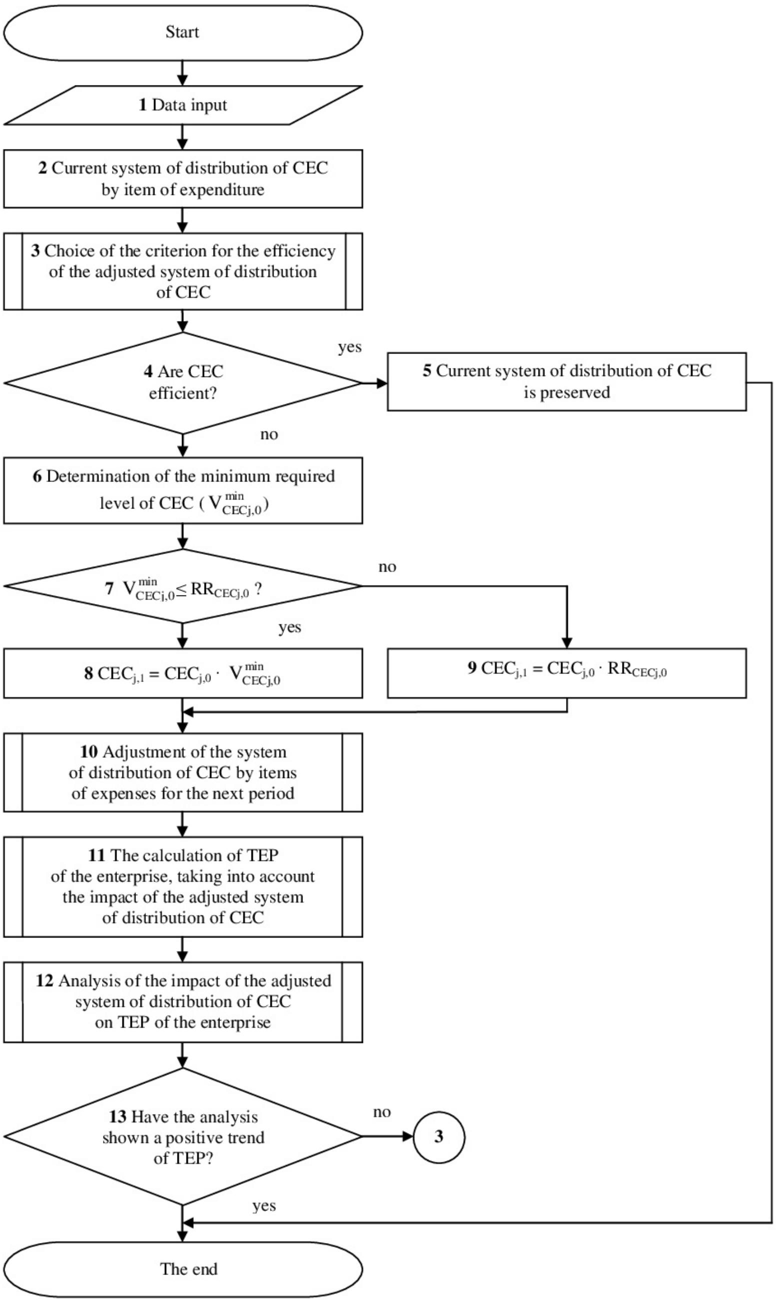

Figure 6. Flowchart of the algorithm for distribution of current environmental costs, taking into account the efficiency of their use.

The calculations carried out for JSC “Azot” show a wide range of changes in the values of performance related to the level of risk determined using criteria - integral indicators of the proportion of excessive environmental impact fees in the total amount of fees (SW^{int}) and growth rate of environmental impact fees (GR_{eif}^{int}). The SW^{int} values vary in the range from 0 to 0.93, and the criterion GR_{eif}^{int} values vary over wider limits from 0.24 to 3.94. The regulatory values of the indicators associated with the risk level are 0.2 for SW^{int} and 1.0 for GR_{eif}^{int}, and the minimum required level of CEC is equal to 0.5, which is determined using the expert evaluation method. These values significantly affect the adjustment (decrease) in $CEC_{j,1}$ value. As a result, the range of change in ΔCEC_j is from 13.1 to 1599.0 million rubles. The ΔCEC_j value leads to a decrease in cost, increase in profits, and increase in product competitiveness. Calculations showed that ΔCEC_j, presented as a percentage of profits, ranges from 3.16 to 24.66.

Calculations made according to the data of PJSC “Koks” also indicate a wide range of changes in indicators that affect the risk level and are determined using SW^{int}, GR_{eif}^{int} criteria and the integral indicator of the growth rate of the economic damage compensation coefficient (GR_{edcc}^{int}).

The scatter of $SW^{инт}$ and GR_{eif}^{int} values has a smaller value than those for the previous enterprise and varies, respectively, in the interval from 0 to 0.70 and from 0.69 to 2.71.

In turn, the values of the GR_{edcc}^{int} criterion vary in a very wide range from 0.43 to 17.21 with $SIR_{\beta, j} \geq 1.0$, also determined using the expert evaluation method. As a result, the ΔCEC_j change interval for the enterprise PJSC “Koks” has a smaller range from 1.03 to 106.2 million rubles, which is a percentage of the profit, varying in the range from 0.02 to 2.33.

4. Conclusion

The study leads to the following conclusions:

- the analysis of known approaches to the allocation of environmental and economic resources, including CEC, in connection with their impact on reducing the level of eco-economic risks, is carried out;
- the analysis of the dynamics and structure of CEC of large industrial enterprises was conducted and the dependence of the excessive environmental impact fees on the value of CEC was graphically presented;
- the adjusted system of distribution of the values of the CEC was developed, leading to their proportional reduction relative to the increase in the performance values related to the risk level;
- the problem statement is presented and the algorithm for managing the system for the distribution of the values of the CEC is built, taking into account the efficiency of their use;
- the analysis of the impact of the adjusted system of distribution of the values of the CEC on the main technical and economic performance of the enterprise was conducted.

References

[1] Trushina G S 2017 *Ugol* **3** 52–55
[2] Mikhailov V G, Kiseleva T V, Karasev V A, Mikhailov G S and Skukin V A 2017 *IOP Conf. Series: Earth and Env. Sci.* **66** 012008
[3] Kiseleva T V, Mikhailov V G and Mikhailov 2017 *IOP Conf. Series: Earth and Env. Sci.* **84** 012044
[4] Prokopenko S A, Ludzish V S, Lesin Y V, Tyulenev M A and Sushko A V 2017 *Journal of Mining Science* vol 53 **1** 92–98
[5] Fridman Y A, Rechko G N and Pimonov A G 2017 *Regional Research of Russia* vol 7 **4**

333-341
[6] Chernikova O P and Baranov P P 2018 *Gornyi Zhurnal* **3** 82–85
[7] Tumin V M and Koryakov A G 2013 *Middle East Journal of Scientific Research* 2013 vol 17 **9** 1350–1355
[8] Zhernov E, Nekhoda E 2018 *E3S Web of Conf.* **41** 04009
[9] Zolotukhin V, Zolotukhina N, Yazevich M, Rodionov A and Kozyreva M 2017 *E3S Web of Conf.* **21** 04008
[10] Zhironkin S, Khloptsov D, Skrylnikova N, Petinenko I and Zhironkina O 2018 *E3S Web of Conf.* **41** 04010
[11] Novichikhin A V, Fryanov V N, Petrova T V, Pavlova L D and Temlyantsev M V 2017 *IOP Conf. Series: Earth and Env. Sci.* **84** 012036
[12] Burkov V N, Novikov D A and Shchepkin A V 2015 *Studies in Systems, Decision and Control* **10** 1-24
[13] Burkov V N, Novikov D A and Shchepkin A V 2015 *Studies in Systems, Decision and Control* **10** 117–154
[14] Titarenko B, Hasnaoui A and Titarenko R 2018 *IOP Conf. Series: Materials Sci. and Eng.* vol 365 **4** 042019
[15] Poryadina V, Burkov V and Barkalov S 2018 *MATEC Web of Conf.* **170** 01122
[16] Makhutov N, Gadenin M 2016 *Ecology and Industry of Russia* vol 20 **3** 47–51
[17] Tikhomirov N, Tikhomirova T, Khamitov E and Ponomarev V 2017 *European Research Studies Journal* vol 20 **2** 321–333
[18] Murzin A D and Anopchenko T Y 2014 *Asian Social Science* 2014 vol 10 **15** 249–254
[19] Mikhailov V, Kiseleva T, Bugrova S, Muromtseva A and Mikhailova Ya 2017 *E3S Web of Conf.* **21** 02004
[20] Kiseleva T V, Mikhailov V G and Stepanov T V 2018 *Control Systems and Information Technology* vol 73 **3** 32–37