Improvement of the organizational and economic mechanism of waste management at a coal-mining enterprise

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Abstract. The paper provides the analysis of the structure and dynamics of production and consumer waste generation at a coal-mining enterprise. The authors consider the organizational and economic mechanism of environmental management acting according to the environmental protection law, with a focus on the negative impact in the form of production and consumer waste generation. The analysis of the main environmental and economic indicators of the enterprise was performed, the result of which is the conclusion about the need to improve the existing organizational and economic mechanism of environmental management. Innovative elements of this mechanism, including ones adapted to this type of negative environmental impact, were developed. The charging scheme for providing false information, including in the official environmental reporting forms, is of current importance. Another innovative direction is connected with the algorithm for the formation of production program, taking into account the environmental constraints, and the system of distribution of current environmental costs depending on the level of environmental and economic risks. The work performed is of practical importance for industrial enterprises engaged in the formation and use of production and consumer waste in order to switch to a sustainable environmental and economic development.

1. Introduction

The development of the coal-mining industry forms the socio-economic infrastructure associated with the growth of the population wellbeing and increase in the budget funds at all levels, the emergence of new jobs and other positive aspects [1]. The “reverse side of the coin” is determined by a wide range of forms of negative impact on all elements of the environment, where the production and consumer waste generation occupies a special place [2-4]. In such conditions, the effectiveness of the organizational and economic mechanism of environmental management, as defined by the provisions of the Law on Environmental Protection [5], is important.

Restructuring of international environmental policy and high national requirements motivate government bodies and industrial enterprises to improve the organizational and economic mechanism of environmental management, especially in terms of production and consumer waste generation [6, 7]. To implement the proposed management approach, it is necessary to identify the most significant environmental and economic factors of negative impact and their assessment using the proposed system of environmental and economic indicators. The prerequisite for the development and practical implementation of innovative elements of the organizational and economic mechanism is their
compliance with national environmental legislation and potential profitability for enterprises in the short term.

2. Materials and methods
The object of study is a coal mining enterprise (mine) as a source of production and consumer waste generation. The subject of the research is the organizational and economic mechanism of production and consumer waste management. The study is based on the analysis of literary sources on the problems of the effective functioning of the organizational and economic mechanism of environmental management in the field of production and consumer waste. The development of innovative elements of the organizational and economic mechanism of production and consumer waste management was carried out taking into account the requirements of the external environment.

For the purpose of practical implementation, a statistical processing of the environmental data of the coal mining enterprise was carried out on the basis of the official reporting form No. 2-TP – Information on the formation, processing, utilization, neutralization, transportation and disposal of production and consumer waste.

3. Results and discussion
The analysis of the structure of waste production and consumption of a coal-mining enterprise in the case of OJSC “SUEK-Kuzbass” mine n.a. S.M. Kirov" showed that more than 95% is occupied by waste of the 5th hazard class, which ranges from 2.12 million tonnes in 2013 to 3.63 million tonnes in 2017 (table 1).

| Hazard class and waste type | 2013      | 2014      | 2015      | 2016      | 2017      |
|----------------------------|-----------|-----------|-----------|-----------|-----------|
| I (mercury lamps)          | 0.024     | 0.023     | 0.021     | 0.056     | 0.021     |
| II (waste batteries)       | 0.594     | 0.417     | 0.24      | 0.084     | 0.343     |
| III (oils and others)      | 35.272    | 39.976    | 44.679    | 7.68      | 6.197     |
| IV (solid waste of rubber and others) | 406.4 | 335.4 | 264.4 | 162.729 | 71.481 |
| V (ash and slag, other solid mineral waste, mineral sludge, waste from the extraction of coal and oil shale, scrap of ferrous metals, tailings and others) | 2122040 | 2420482 | 2718924 | 3356117 | 3633554 |
| Total                      | 2122482   | 2420858   | 2719233   | 3356288   | 3633632   |

It can also be seen from table 1 that many waste products of the enterprise have positive prospects from the point of view of their processing and obtaining additional income.

The existing organizational and economic mechanism for environmental management is regulated by the Law on Environmental Protection and includes the following elements [5]:

- charging for a negative impact on the environment, including the use of stimulating reduction factors for production and consumer waste;
- state support of economic activities carried out in order to protect the environment:
  - introduction of BAT (best available technologies), other environmental protection measures;
  - tax exemptions;
  - reduced payment for a negative impact on the environment;
  - allocation of budget funds;
- environmental insurance;
- cadastral registration of natural resources;
- environmental safety planning;
- environmental audit;
- charging for natural resources;
- other elements.
At present, the process of improving the organizational and economic mechanism of environmental management, which is adapted to individual sectors or elements of the environment, is taking place [8-10]. In connection with the large values of economic damage caused by the disposal of production and consumer waste, the importance of corrective actions aimed at this element of organizational and economic mechanism increases [11-14].

The work [15] shows that in the conditions of reserves depletion and in order to fully utilize the mineral resource base, the intensification of production becomes most acceptable, including the following areas:

- reduction of losses and dilution;
- mining the previously written off and non-commercial reserves;
- an increase in the recovery rate of the useful component during enrichment and others.

An important practical value is the work on the complex processing of coal slimes from external settlers of Processing Plant “Chernigovskaya” [16] as a result of the current organizational and economic mechanism for environmental management.

The developed technology has the following main advantages:

- high economic efficiency (installation payback period – 1.6 years, profitability in the first 5 years – 341 million rubles);
- environmental safety (the territory of drained slimepits is further suitable for reclamation).

Table 2 presents the result of the calculation of environmental and economic indicators applied for the environmental and economic analysis of an enterprise in order to develop measures to improve the organizational and economic mechanism of waste management. From table 2 it can be seen that the magnitude of the economic damage from environmental pollution during the period under review significantly decreased from 157.48 mln rub. in 2013 to 27.11 mln rub in 2017. Such a situation in 2013 was caused by a high value of economic damage from water pollution (143.89 mln rub.).

If we consider the change in economic damage from the production and consumer waste in the total value of consumption (from 13.23 mln rub. in 2013 to 20.25 mln rub. in 2017), then there is a steady negative trend of its increase. A similar situation takes place in terms of the share of economic damage from production and consumer waste in the total value of economic damage (74.7% in 2017). At the same time, the fee for disposal of production and consumer wastes is low and ranges from 0 to 59.9 thousand rub., which is no more than 0.3% of the total amount of payment for the negative impact on the environment. As a result, the compensating function of the charge for negative impact is almost not performed. A positive trend is a decrease in the rate of damage from coal mining in terms of production and consumer waste placement to 2.82 rub. per tonne in 2017. Zero values of paying capacity of coal-mining for the production and consumer waste placement do not allow this indicator to be interpreted.

Table 2. The main environmental and economic indicators of the company OJSC “SUEK-Kuzbass” mine n.a. S.M. Kirov” associated with the placement of production and consumer waste.

| Indicator                                                                 | 2013   | 2014   | 2015   | 2016   | 2017   |
|--------------------------------------------------------------------------|--------|--------|--------|--------|--------|
| Economic damage from environmental pollution, mln rub.                   | 157.48 | 74.13  | 21.23  | 25.77  | 27.11  |
| Economic damage from placement of production and consumer wastes, mln rub. | 13.23  | 13.23  | 16.13  | 19.04  | 20.25  |
| The share of economic damage from the placement of production and consumer waste in the total economic damage, % | 8.40   | 17.85  | 75.98  | 73.89  | 74.70  |
| The total payment for the negative impact on the environment, thousand rub. | 7453.4 | 7813.3 | 7061.0 | 6970.0 | 4553.0 |
| Payment for placement of production and consumer waste, thousand rub.   | 0      | 0      | 0      | 0      | 59.9   |
| The proportion of fees for placement of production and consumer waste in the total amount of fees, % | 0      | 0      | 0      | 0      | 1.32   |
The coefficient of compensation for the economic damage caused by the placement of production and consumer waste, %  

|                   | 0     | 0     | 0     | 0     | 0.30  |
|-------------------|-------|-------|-------|-------|-------|
| Production volume (coal mining), thousand tonnes | 3747  | 4198  | 4668  | 5720  | 7177  |
| Total damage of coal mining from placement of production and consumer waste, rub./tonne | 3.53  | 3.15  | 3.46  | 3.33  | 2.82  |
| The payment capacity of coal mining for placement of production and consumer waste, rub./tonne | 0.00  | 0.00  | 0.00  | 0.00  | 0.01  |

The conducted environmental and economic analysis showed the need to improve the organizational and economic mechanism of waste management. Figure 1 presents innovative elements of such mechanism that can be effectively used to reduce the negative impact of production and consumer waste on the environment [6, 17].

![Innovative elements](image)

**Figure 1.** The developed innovative elements of the organizational and economic mechanism of production and consumer waste management.

Based on the analysis, it can be concluded that the data on the actual mass of waste provided by industrial enterprises are in many cases unreliable, which requires a search for organizational measures that motivate business entities to minimize active interference in data transfer [18]. Additional penalties are offered for the quality of the provided data as such organizational measures. In this case, the information provided by Federal Supervisory Natural Resources Management Service (RPN) is accepted as more reliable.

One of the options for such penalty is presented in formula (1), where the penalty coefficients ($C_P$) depend only on the range of deviations between the results of measurements of the actual waste mass by RPN and by the enterprise. They are applied to the total base penalty (payment for negative impact from the production and consumer waste placement) without differentiation by hazard class, which simplifies the calculation procedure:
\[ C_p = \begin{cases} 
5, & \text{if } 0 \% < \Delta \text{DENT} \leq 30 \% \\
10, & \text{if } 30 \% < \Delta \text{DENT} \leq 70 \% \\
25, & \text{if } \Delta \text{DENT} > 70 \% 
\end{cases} \]

where \( \Delta \text{DENT} \) – the exceedence of the actual mass of waste according to RPN data over the data of the enterprise, \%; 5, 10, 25 – the values obtained by expertise.

\[ \Delta \text{DENT} = \left( \frac{M_{\text{RPN}} - M_{\text{ENT}}}{} \right) \times 100 \% , \]

where \( M_{\text{RPN}} \) is the actual mass of waste according to RPN, t; \( M_{\text{ENT}} \) – the actual mass of waste according to the company, t.

The total value of penalties (\( P_\Sigma \)) is determined by the formula:

\[ P_\Sigma = P_{\text{ BAS}} \cdot C_p, \]

where \( P_{\text{ BAS}} \) – the base value of penalties.

Another option for calculating the penalty coefficient is based on the weighted average hazard class of the pollutant, determined by the actual or reduced mass of the pollutant.

The next innovative element of the organizational and economic mechanism of waste management is based on the formation of an environmentally safe production program of the enterprise. The idea of the proposed approach is that for enterprises with a diversified production program it is important to plan the release of such types of products according to nomenclature and assortment positions, which to a lesser extent have a negative impact on the environment (in the form of production and consumer waste) and environmental-economic result of the enterprise activity.

The main restrictions on the use of this mechanism are associated with a specific production program, which must have a certain “degree of freedom” when choosing environmentally friendly products. Other possible constraints may be strategic production, as well as the uniqueness of technological equipment, which cannot be reoriented or if is unprofitable to reorient them to the production of other types of products. Further, let us consider the formulation of this problem.

Given:
1. Production program of the enterprise.
2. Nomenclature positions of enterprise products.
3. Assortment positions of enterprise products.
4. Profit from the sale of products of a specific nomenclature or assortment position.
5. Environmental and economic indicators of products output associated with the placement of production and consumer waste, a specific nomenclature or assortment position \( \text{PN, A} \).
6. Constraint: \( \text{PRN,A} \geq \text{CS,T} \), where \( \text{PRN,A} \) is the profit from the sale of products of a specific item or assortment position, \( \text{C}_{\text{S,T}} \) is the marginal value of direct, indirect costs and risks associated with the liquidation of the nomenclature or assortment position of the company’s products.
7. Criterion: the annual environmental and economic efficiency of the production program of the enterprise on production and consumer waste, mln rub.

Required: to develop an algorithm for managing the production program of the enterprise, which with upholding of restrictions maximizes the criterion.

An important innovative element of the organizational and economic mechanism of waste management is the mechanism for managing the enterprise production capacity, taking into account environmental restrictions on the production and consumer waste placement.

The statement of the task on coefficient optimization of the utilization of production capacities for the products of the \( i \)-th type (\( C_{\text{USE}, PC} \)): 

Given:
1. Baseline data for the calculation of the average annual production capacity for the output of the $i$-th type of a product ($PC_{AVAi}$): 1) production capacity at the beginning of the year for the output of the $i$-th type of a product ($BY_{i}$); 2) production capacity for the production of $i$-th type of a product, put into operation during a year, taking into account the $j$-th number of the input month ($\sum_{j}PC_{PIO_{j}}$); 3) production capacity for the production of the $i$-th type of a product, putting out of operation during a year, taking into account the $j$-th month number for the putting out of operation ($\sum_{j}PC_{PO_{j}}$);

2. Starting data for calculating the base value of the $i$-th $USE_{PC}$: base value of the volume of output of products of the $i$-th type ($P_{i0}$);

3. Economic damage caused by the negative impact of production capacity on the environment (in the form of production and consumer waste generation) because of the output of the $i$-th type product at regulatory (basic) load level ($ED_{i}$) of production capacity;

4. Payment for placement of production and consumer waste during manufacture of products of the $i$-th type with a regulatory (basic) level of production capacity for the product output of this type ($P_{NIENV_{i}}$);

5. Constraints: 1) the demand for manufactured products is assumed to be constant; 2) the price of the manufactured products is a constant value; 3) $\Delta P \leq \Delta ED$, where $\Delta P$ – an increase in the output volume of products of the $i$-th type in terms of cost measurement, necessary to increase the level of production capacity utilization; $\Delta ED$ – increase in economic damage from the negative impact of production capacity for the product output of the $i$-th type on the environment (in the form of production and consumer waste generation); 4) $\Delta P \geq \Delta P_{NIENV}$, where $\Delta P_{NIENV}$ is the increment of payment for the production and consumer waste placement as a result of an increase in the production capacity utilization for product output of the $i$-th type;

6. Criterion: the coefficient of production capacity utilization for the product output of the $i$-th type ($USE_{PC}$).

Required: to solve the criterion optimization problem with regard to the constraints.

Solution. It was established from experience (and according to experts) that a step-by-step increase in the coefficient of production capacity utilization should be chosen at a rate of 1-2% with an assessment of the level of change in economic damage and payment for production and consumer waste placement. The result – optimal values of the increase in the volume of product output of the $i$-th type ($V_{i}$) and the increased coefficient of production capacity utilization for the product output of the $i$-th type ($USE_{PC}$).

Due to the fact that the analysis showed insufficient efficiency of current environmental protection costs for several enterprises, it is proposed to adjust the current system of distribution of these costs by decreasing them proportionally relative to the increase in indicators related to the level of risk [19]. In this case, the adjusted value of current costs is determined by the formula (4):

$$ CC_{k,1} = CC_{k,0} \cdot [1 - (E_{m,k,0} - S_{m,k})], \quad (4) $$

where $[1 - (E_{m,k,0} - S_{m,k})]$ is the reduction coefficient for the level of current costs for the environmental protection in the $\theta$-th time period for the $k$-th element of the environment ($CC_{m,k}$); and for the $1^{\text{st}}$ period – the next year with an adjusted amount of current costs (for example, if the $0$-th period is 2016, then the $1^{\text{st}}$ year is 2017); $CC_{k,1}$ – the adjusted value of current costs in the planning period for the $k$-th element of the environment, rub.; $CC_{k,0}$ – the value of current expenses in the $0$-th period of time for the $k$-th element of the environment, rubles; $E_{m,k,0}$ – estimate indicator associated with the level of risk, for the $m$-th criterion and the $k$-th element of the environment in the $0$-th time period.
period; $S_{m,k}$ – standard indicator associated with the level of risk for the $m$-th criterion and the $k$-th element of the environment, determined on the basis of using the method of expert assessments.

The value of the minimum required level of current costs on environmental protection by expenditure items in the $0$-th period of time for the $k$-th element of the environment ($C_{cc,0}^{min}$) is determined using the method of expert estimates, based on the environmental and economic feasibility of the required level of current costs for environmental protection.

For the automated calculation of the movement indicators and the use of production and consumer waste, an officially registered software package was developed to increase the effectiveness of support for management decision making.

4. Conclusion
The conducted study leads to the following conclusions:
- the analysis of the dynamics of production and consumer waste generation at a specific coal-mining enterprise was performed;
- the current organizational and economic mechanism for environmental management, as well as options for its practical implementation, is considered;
- the environmental and economic analysis of production and consumer waste placement at a specific coal-mining enterprise was performed;
- innovative elements of the organizational and economic mechanism of environmental management, adapted for this type of negative impact such as production and consumer waste placement, were developed:
  - penalties scheme for providing inaccurate information about the amount of negative environmental impact;
  - mechanism of formation of the enterprise production program, taking into account environmental restrictions;
  - mechanism for managing the production capacity of an enterprise, taking into account environmental restrictions;
  - system of distribution of current costs for environmental protection, taking into account indicators related to environmental and economic risks;
  - automatisation of indicators of accounting and movement of production and consumer waste;
- partial testing of the developed elements of the organizational and economic mechanism of environmental management was carried out.

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