Environmental-Economic Assessment Of Generation, Flow And Efficiency Of Use Of Production And Consumption Waste

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Abstract. The article deals with the issues of environmental and economic analysis of industrial and economic activities of an enterprise to assess the generation, flow and efficiency of production and consumption waste. The purpose of research is the analysis and the development of theoretical propositions for the functioning of the system of environmental and economic indicators for the effective management of production and consumption waste in the enterprise. The analysis of the existing systems of environmental and economic indicators taking into consideration the industry characteristics and the types of negative impacts is carried out. The main result of the study is the development of the system of environmental and economic indicators of production and consumption waste, adapted to the modern requirements. The results of the study can be recommended to support the effective management decision-making concerning waste management and the establishment of appropriate infrastructure.

Introduction
Management of waste treatment is a complex process, which includes legal, technical, economic and environmental aspects. The efficient management of waste treatment, ensuring the achievement of the objectives should be in accordance with the management theory when management is understood as a system of various forms and methods of influence of the subject of management on the object of management to achieve the objectives [1]. To improve the efficiency of waste treatment management treatment of management of waste is necessary to build a system of environmental and economic indicators characterizing the production process [2].

Material and methods
The object of study is the current system of accounting, flow and use of industrial and consumer waste. The subject of research is the environmental and economic efficiency of generation, flow and use of industrial and consumer waste. The study is based on the analysis of domestic and foreign literature on the problems of environmental-economic analysis of enterprise. Particular attention is paid to the methodology for calculating the environmental and economic indicators related to the dynamics of waste flow and usage. The statistical processing of environmental data of an industrial
enterprise on the basis of the reporting form № 2-TP (wastes) – Report on generation, use, neutralization, transportation and disposal of industrial and consumer waste – has been carried out to test the proposed methodology. The elements of the system analysis and the results obtained by specialists in the field of environmental-economic analysis of the enterprise are also used in the paper.

Results and Discussion
Currently, there are different approaches to the assessment and interpretation of environmental and economic performance of an enterprise, including the study of waste flow, the efficiency of its use and the analysis of production waste volume. A number of authors determine the environmental performance indicators describing the negative impact on the environment:

• profits and revenue per 1 ton of production waste;
• profit and revenue value attributable to 1 ruble of charges for the negative impact on the environment;
• specific profit and sales revenue per unit of environmentally hazardous materials used [3].

Other experts have developed a set of criteria of environmental and economic sustainability of the enterprise, including the following elements:

• criterion of ecological safety of an enterprise;
• criteria of eco-efficiency of company as a comprehensive characterization of nature use efficiency – resource- and energy consumption, production waste volume, efficient use of consumed "external" and "internal" resources of an enterprise;
• criterion of constant improvement of indicators of development of environmental and economic system of an enterprise [4].

The environmental and economic indicators are of great importance for the comprehensive assessment of the environmental safety of the enterprise [5]. If we consider the current activities of the company, the developed schemes of production environmentalization, including the environmental-economic assessment of human impact on the environment, can be used to make the environmentally-oriented economic decision [6].

Environmental and economic indicators of production and consumption waste should be maximally adapted to the particular industry, which has its own characteristics. Due to the fact that the coal industry is a major source of waste generation, the environmental performance indicators of mining companies are divided into 3 groups: environmental, social and economic. Environmental indicators reflect the level of use of various natural resources and the environment state before and after the environmental protection measures, including:

• the level of achievement of the science-based standards or the established limits of use of natural resources and the environment state;
• the areas of damaged and reclaimed lands, land consumption of production;
• the amount of water consumption, the amount of recycled water, re-use of water in sequence, water consumption of products;
• the ratios of mineral resource recovering, the complexity of used mineral raw materials and waste-free production, mineral consumption of products;
• the total and specific (per unit of output) volumes of generation education, capture, utilization and entry of harmful substances into the environment;
• the productivity of agricultural lands, water bodies and forest lands located within the area of mining operations [7].

Other features are the environmental and economic indicators, designed for refineries. In this case, the main (see table) criteria of differentiation of these indicators are the following:

• the cohesion of economic and environmental aspects in one indicator at a time;
• the ability to determine the value of the indicator not only in volume but also in terms of value.
Table 1 - Classification of environmental and economic performance of manufacturing processes (as exemplified in refinery)

| Criterion                        | Indicator types               | Indicator examples                                                                 |
|----------------------------------|-------------------------------|-------------------------------------------------------------------------------------|
| Purpose of indicators            | Core operation indicators     | Consumption of resources in core operations                                          |
|                                  | Auxiliary operation indicators| Consumption of resources in auxiliary operations                                      |
| Application range                | General                       | Energy intensity, material consumption                                              |
|                                  | Particular                    | Octane and cetane number (refining)                                                 |
| Evaluation method                | Qualitative                   | The contents of harmful impurities in the waste water                                 |
|                                  | Quantitative                  | The volume of wastewater discharged                                                 |
| Aggregation                      | Special                       | Environmental capacity, energy consumption                                            |
|                                  | Integral                      | Index of environmental friendliness of production                                    |
| Innovativeness of manufacturing  | Indicators, characterizing the | Oil refining ratio                                                                    |
| processes                        | product output                |                                                                                      |
|                                  | Indicators, characterizing     |                                                                                      |
|                                  | waste generated by technology | The volume of waste generation per unit of output, measured in terms of value         |

The table shows that the manufacturing process the oil refining industry is its differentiation into core and auxiliary operations. On this basis, all environmental and economic indicators can be attributed, respectively, to core and auxiliary operations. These indicators which are significant for other industries will determine the proportion of useful product and the waste volume of core and auxiliary operations, as well as to relate them to each other [1].

The efficiency of ecological and economic performance calculation depends significantly on the used tools. In particular, the flexibility and the power of the methods of fuzzy set theory can be considered as a promising and effective tool for the evaluation of environmental and economic security of industrial enterprises on the basis of the calculation of the system of ecological and economic indicators [8, 9, 10, 11, 12].

For most enterprises, the actual problem is the estimation of flow and efficiency of production and consumption waste. To this end, the system of basic ecological and economic indicators of production and consumption waste, presented in Figure 1, has developed on the basis of official statistical reporting forms.
Figure 1 - Relationship of the basic environmental and economic waste indicators.

The formulas for the environmental and economic indicators of generation, flow and efficiency of use of production and consumption waste have been developed on the basis of the proposed scheme.
The average annual availability of waste in the enterprise (AAAWE) is determined from the formula:

$$\text{AAAWE} = \frac{\text{AWBY} + \text{AWEY}}{2},$$

where $\text{AWBY}$ – availability of waste at the beginning of year, tons; $\text{AWEY}$ – availability of waste at the end of year, tons. This indicator "averages" the waste flow stream in the company during the year.

The specific waste generation (SWG) is computed using the following formula:

$$\text{SWG} = \frac{\text{WGY}}{\text{OP}},$$

where $\text{WGY}$ – waste generation for the year, tons; $\text{OP}$ – output of products, thousands of tons. The presented indicator shows the waste content of the manufacturing processes of the enterprise.

The coefficient of internal waste use (CIWU):

$$\text{CIWU} = \frac{\text{WUY}}{\text{AWBY} + \text{WGY} + \text{WIOC}},$$

where $\text{WUY}$ – waste use for the year, tons; $\text{WIOC}$ – waste input from other companies, tons. This coefficient shows the level of autonomous use of waste at the enterprise.

The coefficient of internal waste neutralization (CIWN):

$$\text{CIWN} = \frac{\text{WN}}{\text{AWBY} + \text{WGY} + \text{WIOC}},$$

where $\text{WN}$ – waste neutralization for the year, tons. The relative measurement of the coefficient reflects the internal waste neutralization capabilities of the enterprise.

The coefficient of waste import (CWI):

$$\text{CWI} = \frac{\text{WIOC}}{\text{WGY}}.$$

This coefficient indicates the ratio of the "external" waste mass inflowing from outside companies and the own waste generated during the reporting year.

The coefficient of waste export (CWE):

$$\text{CWE} = \frac{\text{SWTOC}}{\text{WGY}},$$

where $\text{SWTOC}$ – the summary waste transfer to other companies, tons. The presented indicator shows the ratio of the mass of waste directed to other companies, and the amount of own waste generated during the reporting year. The coefficients of the import and export of waste can be used in the analysis of the total waste mass balance.

The coefficient of external waste use (CEWU):

$$\text{CEWU} = \frac{\text{WTOCU}}{\text{AWBY} + \text{WGY} + \text{WIOC}},$$

where $\text{WTOCU}$ – waste transfer to other companies for the utilization, tons. This indicator represents the ratio of the amount of waste sent to third-party companies for the utilization, and own waste, including those obtained from external sources.

The coefficient of external waste neutralization (CEWN):

$$\text{CEWN} = \frac{\text{WTOCN}}{\text{AWBY} + \text{WGY} + \text{WIOC}},$$

where $\text{WTOCN}$ – waste transfer to other companies for the neutralization, tons. The coefficient shows the ratio of waste sent for the neutralization to outside companies, and own wastes, including those obtained from external sources.

The coefficient of internal waste disposal (CIWD):

$$\text{CIWD} = \frac{\text{WDFO}}{\text{AWBY} + \text{WGY} + \text{WIOC}},$$
where WDFO – waste disposal at facilities in operation, tones. The coefficient under consideration characterizes the level of technical capacity of waste disposal coming from internal and external sources at own facilities in operation (sites, polygons).

The coefficient of external waste disposal (CEWD):

\[
CEWD = \frac{WTOCS + WTOCB}{AWBY + WGY + WIOC},
\]

(10)

where WTOCS – waste transfer to other companies for the storage, tones; WTOCB – waste transfer to other companies for the burial, tones. This coefficient shows the ratio of waste sent to third parties for the storage and burial and own waste, including those obtained from external sources.

The model calculation of environmental and economic indicators for the specific enterprise - JSC "Open-pit mine Inskoy" is shown to test the methods proposed in Table 2

Table 2 - The model calculation of basic environmental and economic indicators of production and consumption waste of JSC "Open-pit mine Inskoy" in 2014.

| Indicator name                                      | Unit of measurement | Value  |
|----------------------------------------------------|---------------------|--------|
| Availability of waste at the beginning of year     | tones               | 10.351 |
| Availability of waste at the end of year           | tones               | 444.037|
| Average annual availability of waste in the enterprise | т               | 227.194|
| Output of products                                  | thousand of tones   | 2190   |
| Specific waste generation                          | tones / thousand of tones | 0.322   |
| Waste use for the year                             | tones               | 0.025  |
| Waste generation for the year                      | tones               | 706.206|
| Waste input from other companies                   | tones               | 0.000  |
| Coefficient of internal waste use                  | tones               | \(3.49 \times 10^{-5}\) |
| Waste neutralization for the year                  | tones               | 0.000  |
| Coefficient of internal waste neutralization       |                     | 0.000  |
| Coefficient of waste import                        |                     | 0.000  |
| Summary waste transfer to other companies          | tones               | 272.495|
| The coefficient of waste export                    |                     | 0.386  |
| Waste transfer to other companies for the utilization | tones             | 0.000  |
| Coefficient of external waste use                  |                     | 0.000  |
| Waste transfer to other companies for the neutralization | tones          | 3.952  |
| Coefficient of external waste neutralization       |                     | 0.006  |
| Waste disposal at facilities in operation          | tones               | 0.000  |
| Coefficient of internal waste disposal             |                     | 0.000  |
| Waste transfer to other companies for the storage  | tones               | 0.000  |
| Waste transfer to other companies for the burial   | tones               | 268.543|
| Coefficient of external waste disposal             |                     | 0.375  |

The analysis of Table 1 shows that the average annual availability of waste at the enterprise (227.194 tons) is significantly higher than the amount of waste at the beginning of the year at the company (10.351 tons), describing an active waste inflow during the year from internal and external sources. The indicator of specific waste generation characterizes the low waste content in manufacturing processes when 0.322 tons of waste are generated per 1 thousand of tons of output. Several calculated indicators have zero value: coefficients of internal waste neutralization, waste import, external use of waste and internal waste disposal. Two indicators are characterized by low
values: the coefficient of internal waste use (3.49 $10^{-5}$) and the coefficient of external waste neutralization (0.006). This situation stems from the fact that the company has almost no waste use and disposal, including with the involvement of third-party companies. The comparison of the coefficients of external waste disposal (0.375) and internal waste disposal (0.000) shows that the company is actively uses the services of third parties, without developing its own infrastructure (sites and polygons).

The study conducted can be used to support the effective environmentally safe management decision-making to treat production and consumption waste and to develop the appropriate infrastructure in the enterprise [13, 14, 15].

**Conclusions**

The conducted study of environmental and economic evaluation of generation, flow and efficiency of use of production and consumption waste led to the following conclusions:

1. The analysis of different approaches to assessment and interpretation of environmental and economic indicators of the enterprise, including the study of waste flow, the efficiency of its use and the analysis of production waste volume is carried out;
2. The basic criteria and factors of formation of environmental and economic indicators, adapted to the conditions of a particular company are found;
3. The system of interconnected environmental and economic indicators that characterize the dynamics and the efficiency of production and consumption waste is developed;
4. The model calculations of the basic environmental and economic indicators of production and consumption wastes based on the data of industrial enterprises are done;
5. The proposals for improving the waste management system of the evaluated company on the basis of the assessment of macroeconomic indicators, taking into account the environmental characteristics obtained by the integrated monitoring system, are made.

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