Study of basic environmental performance indicators of a coal mining enterprise

Vladimir Mikhailov[1*], *Tatyana* Galanina[1], *Svetlana* Bugrova[1], *Yana* Mikhailova[1], and *Evdokiya* Kulpina[1]

[1]T.F. Gorbachev Kuzbass State Technical University, Department of Production Management, 650000 Kemerovo, 28 Vesennyaya st., the Russian Federation

Abstract. Current processes of environmental law enforcement require the use of innovative approaches to the problem of environmental management. In this regard, an adequate choice of the environmental performance indicators of an enterprise and the technique for their analysis, aimed at developing efficient, environmentally friendly management decisions, is of great importance. The technique for calculating the environmental and eco-economic performance indicators of a coal mining enterprise, including using the weighted average hazard class of pollutants or production and consumption waste is discussed in the article. Various options for the application of this approach, which is of practical importance for reducing the labor intensity of management decision-making by industrial enterprises, are considered.

Introduction

One of the main functions of environmental management at an enterprise is the analysis of cost effectiveness of environmental activities. The analysis of environmental performance indicators of enterprises, especially in coal mining [1-3], is the most important component of the environmental management system at the macro and micro levels [4, 5].

The purpose of the analysis of environmental performance indicators of enterprises is to form an information basis for making decisions in the field of environmental management, focused on improving the environmental protection activities of an enterprise and increasing the efficiency of the use of natural resources.

To assess the balance between production activities and environmental protection at an enterprise, the most informative indicators (capable of providing a complete analysis in terms of temporal relationships and relationships within the “environment-production” system) should be selected, since the quality of the source information largely depends on the quality of environmental management models.

*Corresponding author: mvg.eohp@kuzstu.ru

Results and Discussion

Improving environmental protection at the present stage of economic development consists in the efficient management of eco-economic systems of various levels [6-11], which requires the use of eco-economic indicators providing maximum information content with minimum labor intensity of their calculation.

At the same time, it is important to keep an accurate record of the mass of pollutants, which can be expressed not only by the sum of the actual values, but also by the reduced mass, which makes it possible to determine the toxicity of each ingredient to obtain a mono-pollutant. Many eco-economic indicators, such as economic damage from negative impact on the environment and its derivatives [12, 13] are calculated on the basis of a mono-pollutant.

When solving most of eco-economic problems, the problem of taking into account the hazard class of pollutants arises, which is especially important for large industrial enterprises with highly diversified negative impact.

The calculation of the weighted average hazard class of a pollutant [12, 13], determined by the actual or reduced weight of a pollutant, is proposed in this paper. The reduced mass of a pollutant allows determining the toxicity of individual ingredients through the indicator of relative hazard as the reciprocal of the maximum allowable concentration - formula (1).

$$HC_{WA} = \frac{\sum_{i=1}^{n} M_i \cdot HC_i}{M_{total}}, \quad (1)$$

where HC_{WA} – weighted average hazard class of pollutants; i – type of pollutant; n – total amount of pollutants; HC_i – hazard class of the i-th pollutant; M_{total} – total reduced weight of pollutants, conv. t.

$$M_{total} = \sum_{i=1}^{n} M_i, \quad (2)$$

where $\mathrm{M_i}$ – reduced mass of the i-th pollutant, conv. t, which is calculated by the formula (3):

$$\mathrm{M_i} = \mathrm{m_i} \cdot \mathrm{A_i}, \quad (3)$$

where m_i – actual mass of the i-th pollutant, t; A_i – indicator of the relative hazard of the i-th pollutant, conv. t/t, which is calculated by the formula (4):

$$A_i = \frac{1}{RI_i}, \quad (4)$$

where RI_i – regulatory indicator of the i-th pollutant, mg/m^3. The daily average maximum allowable concentration of the i-th pollutant (MAC_{Di}), the one-time maximum allowable concentration of the i-th pollutant (MAC_{OTi}) or the approximate safe level of exposure to the i-th pollutant ($ASLE_i$) can be used as a regulatory indicators.

Table 1 shows the results of calculating the reduced mass of pollution by the JSC Chernigovets enterprise on the basis of official data. Codes of pollutants are shown in brackets.

Table 1 shows that the enterprise emits pollutants of III and IV hazard classes into the air. Nitrogen dioxide (III hazard class), inorganic dust with SiO_2 content up to 20% (IV hazard class), carbon monoxide (IV hazard class) and inorganic dust with SiO_2 content from 20 to 70% (IV hazard class) have the largest actual mass. Based on the data from the Table, and in accordance with formulas (1) - (4), the calculation of the weighted average hazard class of pollutants emitted by the JSC Chernigovets enterprise into the air, which is equal to III.

$$HC_{WA} = \frac{17833.2 \cdot 3 + 10600.7 \cdot 4}{28433.9} = 3.37 \approx 3$$

Table 1. The results of calculating the reduced mass of the main air pollutants by the JSC Chernigovets enterprise

Pollutant	**Code**	**m_i, t/y**	**Regulatory indicator, mg/m³**		**A_i, conv. t/t**	**M_i, conv. t/t**
			Indicator	Value		
Iron oxide	0123	1.020	MAC_{Di}	0.04	25	25.5
Nitrogen dioxide	0301	2851.996	MAC_{OTi}	0.2	5	14260
Nitrogen oxide	0304	464.428	MAC_{OTi}	0.4	2.5	1161.1
Carbon (soot)	0328	225.186	MAC_{OTi}	0.15	6.67	1502
Sulfur dioxide	0330	321.196	MAC_{OTi}	0.5	2	642.4
A mixture of C_1 - C_5 saturated hydrocarbons	0415	56.83	$ASLE_i$	50	0.02	1.1
A mixture of C_6 - C_{10} saturated hydrocarbons	0416	32.680	$ASLE_i$	30	0.03	1
Kerosene	2732	389.236	$ASLE_i$	1.2	0.83	240.1
III hazard class total						17833.2
Carbon monoxide	0337	1724.286	MAC_{OTi}	5	0.2	344.9
Methylbenzene (Toluene)	0621	1.064	MAC_{OTi}	0.6	1.67	1.8
A mixture of C_{12} - C_{19} saturated hydrocarbons	2754	10.836	MAC_{OTi}	1	1	10.8
Inorganic dust: 70-20% of SiO_2	2908	1444.583	MAC_{OTi}	0.3	3.33	4810.5
Inorganic dust: up to 20% of SiO_2	2909	1739.373	MAC_{OTi}	0.5	2	3478.7
Wood dust	2936	3.405	$ASLE_i$	0.5	2	6.8
Coal ash	3714	70.128	$ASLE_i$	0.3	3.33	233.5
Coal dust	3749	171.365	$ASLE_i$	0.1	10	1713.7
IV hazard class total						10600.7
TOTAL						28433.9

Economic damage from negative impact on the air (ED_a) is calculated by the formula (5):

$$ED_a = \gamma_a \cdot C_{ind} \cdot C_{ESa} \cdot M_a, \tag{5}$$

where γ_a Equation.3 – specific economic damage from air pollution by one conventional ton of harmful substances, 47,5 RUB/conv. t; C_{ESa} Equation.3 – the coefficient of the environmental situation for the air (for the Kemerovo region, as for an industrialized region, is 1.44); $\gamma_{a\ \mathrm{Equation.3}}$ – reduced mass of the annual emission of harmful substances into the air, conv. t/y. $M_{a\ \mathrm{Equation.3}}$ is calculated by the formula 6:

$$M_a = \sum_{i_a=1}^{n_a} m_{a_i} \cdot A_{a_i}, \tag{6}$$

where m_{a_i} – actual mass of the *i*-th air pollutant, t; i_a – type of air pollutant; n_a – total amount of air pollutants; A_{a_i} – indicator of the relative hazard of the *i*-th pollutant (conv. t/t), which is determined by the formula 4.

For this calculation, the daily average maximum allowable concentration, and in its absence, the one-time maximum allowable concentration or an approximate safe level of exposure, is used as a priority regulatory indicators.

$$ED_a = 47.5 \cdot 1.08 \cdot 1.44 \cdot 28433.9 = 2100.47\ thousandRUB$$

Table 2 presents data on production and consumption waste of the JSC Chernigovets enterprise, indicating their codes in accordance with the Federal Waste Classifier Catalogue (WFCC).

The Table 2 shows that waste of the V hazard class (mainly overburden) amounts for more than 99% of the total mass of the generated waste. If we consider other types of waste, then the maximum mass is this type of waste of the IV hazard class as sludge from cesspools (3375 tons). The method of waste management is of great importance for increasing the efficiency of environmental protection activities. In this case, 93.7% of the total amount of waste transferred for recycling to external parties is waste of IV hazard class. Overburden (low hazard waste of V class) is disposed by the enterprise independently in compliance with environmental requirements.

Below is the calculation of the weighted average waste hazard class.

$$HC_{WA} = \frac{12.31 \cdot 2 + 88.332 \cdot 3 + 3502.599 \cdot 4 + 175001378.868 \cdot 5}{175004982.109} = 4.99 \approx 5$$

Table 2. Generation of production and consumption waste at the JSC Chernigovets enterprise

Waste type and hazard class	**WFCC code**	**m_i, t/y**	**Waste use, t/y**	
			Transfer to external parties	**Disposal, t/y**
Used undamaged lead-acid batteries with electrolyte	92011001532	12.31	12.31	-
II hazard class total		12.31	12.31	-
Waste mineral motor oils	40611001313	49.316	49.316	-
Waste mineral gear oils	40615001313	5.559	5.559	-
Halogen-free waste mineral hydraulic oils	40612001313	27.738	27.738	-
Used oil filters for motor vehicles	92130201523	3.774	3.774	-
Used fuel filters for motor vehicles	92130301523	1.945	1.945	-
III hazard class total		88.332	88.332	-
Unsorted waste of office and domestic premises (excluding bulky waste)	73310001724	67.315		67.315

Waste tires	92111001504	56.648	56.648	-
Used air filters for motor vehicles	92130101524	3.636	3.636	-
Waste from cesspools	73210001304	3375	3375	-
IV hazard class total		3502.599	3435.284	67.315
Mechanical sludge from open pit water treatment in coal mining	21128111395	128.868	128.868	-
Low hazard overburden mix	20019099395	175001250	-	127570250
V hazard class total		175001378.868	128.868	127570250
TOTAL		175004982.109	3664.794	127570317.315

Accounting for waste transferred to external parties organizations is of great importance in the analysis of eco-economic indicators. Weighted average hazard class of waste transferred to third parties:

$$HC_{wa} = \frac{12.31 \cdot 2 + 88.332 \cdot 3 + 3435.284 \cdot 4 + 128.868 \cdot 5}{3664.794} = 4$$

The economic damage from the disposal of production and consumption waste, differentiated by hazard classes (ED_{WASTE}), can be calculated by the formula 7:

$$ED_{WASTE} = 5 \sum_{j=1}^{n_{WASTEX}} R_{P\_ELj} \cdot C_{ind} \cdot C_{ESn} \cdot m_{wastej}, \quad (7)$$

where 5 – five-fold multiplier; R_{P_ELj} – the rate of payment within the established limits for the disposal of production and consumption waste of the *j*-th hazard class, RUB/t; n_{WASTE} – number of waste hazard classes (differentiated from 1 to 5); $К_{ЭСп}$ – the coefficient of the environmental situation for the soil (differentiated by region and for the Kemerovo region is 1.2); m_{wastej} – actual mass of waste of the *j*-th hazard class, t.

Table 3 shows the results of calculating the economic damage from the negative impact on the soil of production and consumption waste of the JSC Chernigovets enterprise

Table 3. The results of calculating the economic damage from the negative impact on the soil of production and consumption waste of the JSC Chernigovets enterprise

Waste hazard class	M_{wastej}, t/y	R_{PELj}, RUB/t	Economic damage	
			thousand RUB	%
II	12.31	1990.2	158.76	0.01
III	88.332	1327	759.56	0.06
IV	3502.599	663.2	15052.55	1.19
V	175001378.868	1.1	1247409.83	98.74
Total			1263380.70	100.00

The table 3 shows that during the operation of a coal mining enterprise, the maximum share in the total value of the economic damage caused is occupied by waste of V hazard class - 98.74%, which is about 1.25 billion rubles.

The main idea of using this regulatory method modification is that the entire mass of pollution is considered in excess of limits, for which a five-fold multiplier is applied.

Conclusion

Analysis of the environmental performance indicators of a coal mining enterprise using the technique for calculating the weighted average hazard class of pollutants based on the actual or reduced mass or production and consumption waste is of practical importance when conducting the following studies:

- calculation of economic damage from negative impact on the environment and other eco-economic indicators;
- determination of the hazard class of an enterprise, including for the purpose of exemption from pollution charges;
- calculating the level of penalties for violation of environmental legislation and excessive negative impact;
- identification of environmental "bottlenecks" of an enterprise to plan the priority environmental protection measures;
- substantiation of the effectiveness of the use of one-time and current environmental costs;
- solving other eco-economic problems.

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