Methodical specifics of scenarios development for increasing the level of environmental safety (in the conditions of Novokuznetsk city)

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Abstract. The procedure for developing scenarios of waste processing, land reclamation and creation of recreational zones is proposed. Three types of scenarios for improving the level of environmental safety in mining areas have been developed. On the basis of the software complex, forecast estimates of the scenario indicators have been obtained, the selection of Pareto-optimal solutions and their ranking according to the levels of environmental safety have been carried out.

1. Introduction

Currently, the level of environmental safety in most areas is decreasing due to the permanent growth of waste production. The overwhelming majority of man-caused resources are located in the Siberian Federal District – 18 billion tonnes or more than 57% of the total volume [1, 2]. At the same time, more than 80% of industrial wastes are generated in the process of extraction and processing of minerals [3, 4]. Accordingly, the unfavorable environmental situation has developed and is progressing in the mining areas, especially in the city of Novokuznetsk because of the high concentration of industries where its old industrial areas (for example, Abashevsky and Kuznetsky districts) are especially dangerous.

2. Methods of research

It conditions the necessity to search for effective solutions to overcome the above mentioned negative tendencies. So, it is proposed to use the scenario approach [5]. This task stipulates the development of a procedure for forming the scenarios of waste processing, land reclamation and the creation of recreational zones. In this connection, the task of scenarios development can be presented as follows [6]:

Task 1. A list of options for waste recycling and land reclamation is determined j, $j \in [1; J]$. Each j-th option is characterized by a certain set of technologies Th(j) and indicators $F(j) = \{F_l(j), l \in [1; L]\}$, with $L = 5$: the economic effect is F_1; the area of reclaimed lands – F_2; the amount of pollution resulting from negative production activities – F_3; the population with statutory indicator – F_4; the prevented pollution per capita – F5.

It is required to form a set of scenarios A_n, $n \in [1; N]$ for waste processing with the creation of recreational areas on the reclaimed lands from j-th option, $j \in [1; J]$, which allow the negative effects of production to be eliminated in accordance with the statutory indicators $\{F^*_l\}$:

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$$\sum_{t=1}^{T}\sum_{n=1}^{N}\sum_{i=1}^{I} Kp_{tni} \rightarrow \min \text{ if } A_n = \bigcup_{j=1}^{J} Th(j),$$

provided that:

$$F^*_1(A)<F_1(A);\ F^*_2(A)<F_2(A);\ F^*_3(A)>F_3(A);\ F^*_4(A)<F_4(A);\ F^*_5(A)<F_5(A). \quad (1)$$

To solve this problem, we propose a procedure for creating scenarios for processing waste, land reclamation and creation of recreational zones (figure 1).

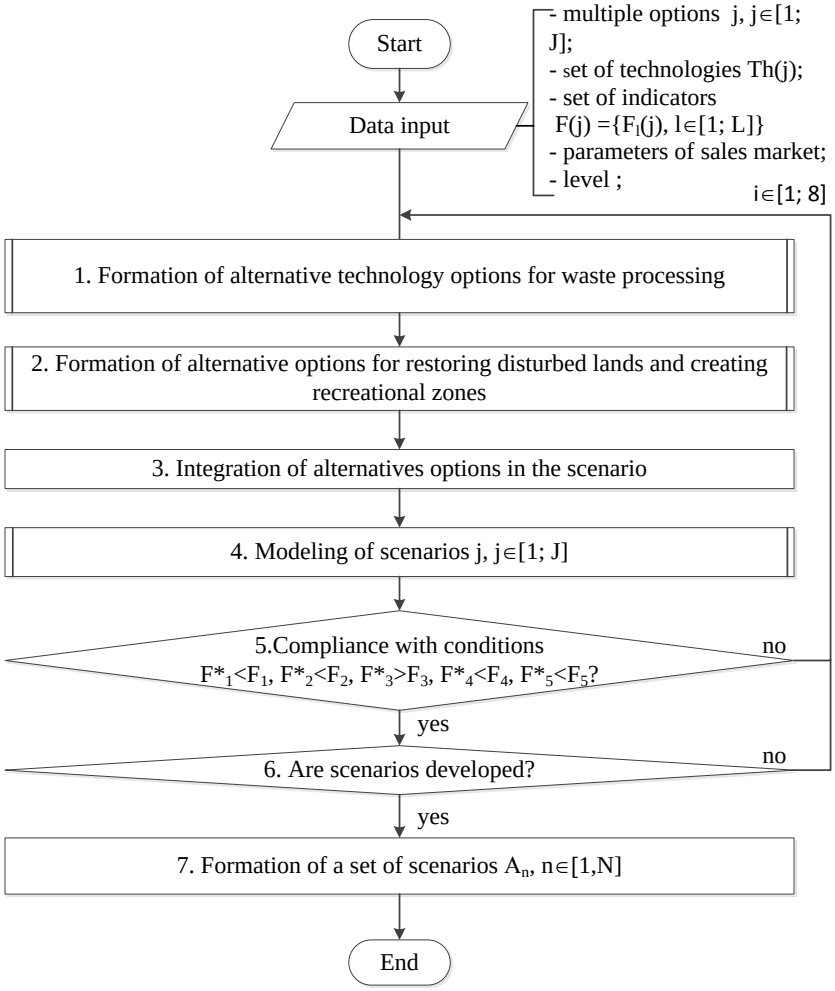


Figure 1. Procedure for the formation of waste treatment scenarios, land reclamation and creation of recreational zones [7].

The number of iterations of the procedure is i∈[1; 8]. After i=8, the procedure stops. If no solution is found, the source data (a set of technologies and their parameters), constraints are changed. The cycle is restarted to find the solution.

Based on the proposed procedure, three types of scenarios have been developed:

- pessimistic scenario is characterized by a low level of investments into the implementation of non-waste technologies and the creation of recreation areas (the total amount of financing is up to 100 million rubles), the total capacity of the waste recycling facility is less than 0.7 million tonnes per year;

- moderate scenario is characterized by an average level of investments into the implementation of non-waste technologies and the creation of recreation areas (the total amount of financing is 100-195 million rubles), the total capacity of the waste recycling facility is 0.7-1.0 million tonnes per year;
- optimistic scenario is characterized by a high level of investments into the implementation of non-waste technologies and the creation of recreation areas (total financing over 195 million rubles), the total capacity of the waste recycling facility is more than 1.0 million tonnes per year.

3. Results and discussion

During the scenarios development, the level of possible funding was taken into account – in this regard, moderate scenarios for increasing the level of environmental safety in Novokuznetsk in the conditions of coal preparation plants [5] (table 1) are considered, taking into account the best domestic and world practices for processing coal sludges [8-10] and rocks [11-13].

Table 1. Scenarios for increasing the level of environmental safety in Novokuznetsk in the conditions of coal preparation plants.

Script ID	Production	Indicators
C1	Coal concentrate obtained by gravity enrichment methods (separators with a shaken bed), and materials for construction needs.	The productivity of faculties is 0.7 and 0.2 million tonnes per year. The volume of investments is 120 million rubles.
C2	Coal concentrate obtained by the oil granulation method and materials for construction needs. It is possible to use waste industrial and machine oil for the enrichment of coal slurries. The use of oil granulation increases the heat from combustion of the combustible material.	The productivity of faculties is 0.8 and 0.2 million tonnes per year. The volume of investments is 135 million rubles.
C3	Coal concentrate, obtained by gravity methods of enrichment in heavy mediums, and bricks for construction needs.	The productivity of faculties is 0.8 and 0.2 million tonnes per year. The volume of investments is 156 million rubles.
C4	Coal concentrate obtained by gravity enrichment methods (oil granulation), and construction bricks.	The productivity of faculties is 0.8 and 0.2 million tonnes per year. The volume of investments is 135 million rubles.
C5	Coal concentrate obtained by oil granulation and clinker with preliminary crushing and firing.	The productivity of faculties is 0.8 and 0.2 million tonnes per year. The volume of investments is 165 million rubles.
C6	Coal concentrate obtained by the oil granulation method and additives to concrete.	The productivity of faculties is 0.7 and 0.3 million tonnes per year. The volume of investments is 136 million rubles.
C7	Coal concentrate obtained by gravity enrichment methods (in hydrocyclones), and additives to concrete.	The productivity of faculties is 0.7 and 0.3 million tonnes per year. The volume of investments is 178 million rubles.
C8	Fertilizers for agriculture.	The productivity of faculties is 0.8 and 0.2 million tonnes per year. The volume of investments is 100 million rubles.

The implementation of scenarios is considered in the period 2019-2032. Based on the software complex implemented in Scilab environment, the forecast estimates of the scenarios indicators [5] were obtained (table 2).

Table 2. Indicators of scenarios for improving the level of environmental safety in Novokuznetsk in the conditions of coal preparation plants.

Scenario	F_1, mln. rub	F_2, thous. m^2	F_3, t/rub	F_4, person	F_5, t/person
C1	822.3	9.4	0.049	710	19.4
C2	820.8	9.8	0.029	754	20.9
C3	821.4	9.6	0.045	750	21.9
C4	823.8	9.2	0.042	720	20.7
C5	801.7	9.1	0.039	735	20.6
C6	819.3	9.3	0.034	732	21.2
C7	817.6	9.1	0.04	725	20.1
C8	810.4	8.9	0.054	701	18.5

Based on the obtained indicators of scenarios and in accordance with the developed selection procedure [6, 14], Pareto-optimal solutions were chosen aimed at reducing the technogenic load of mining enterprises and a high level of environmental safety (figure 2).

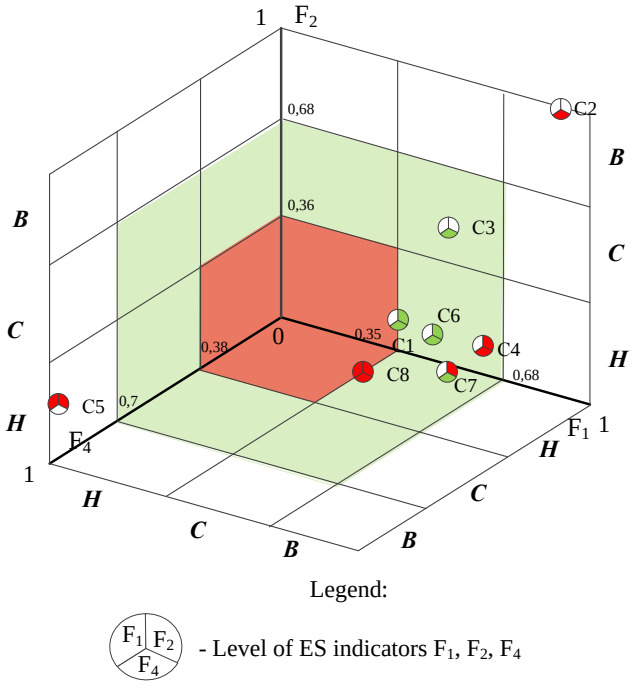


Figure 2. Definition of Pareto-optimal scenarios for increasing the level of ecological safety in Novokuznetsk.

The economic effect (F_1), the area of the reclaimed land (F_2), the population with normative indices (F_4), determined by the specifics of the mining area and the focus on coordinating the interests of the state, investors and production workers, were taken as criteria. Pareto-optimal scenarios are: C1, C2, C3, C4, C5, C6, C7.

Due to the large number of Pareto-optimal scenarios for the coordination of environmental, social, economic interests and ensuring a high level of environmental safety, their ranking is proposed. The problem of *ranking Pareto optimal set of scenarios* can be formulated as follows:

Problem 2. There are many Pareto-optimal scenarios A_m, $m \in [1, M]$. Each m-th scenario is characterized by normalized criteria fx, $x \in [1, X]$, consisting of three levels of environmental safety:

low (L) $fn_x \in [0; Y_{x1}]$; moderate (M) $fy_x \in [Y_{x1}; Y_{x2}]$; and high (H) $fv_x \in [Y_{x2}; 1]$, where Yx_1 and Yx_2 are the values of the boundaries between low and moderate, moderate and high levels of environmental safety, respectively. Moreover, each m-th scenario is characterized by w number of high, g number of moderate, b number of low levels of environmental safety [6].

Scenario ranking *is required*. The scenario $A_1^{rank(1)}$, surpassing the scenario $A_m^{rank(z)}$ by w number of high level of environmental safety, is assigned the first rank if the following is fulfilled:

$$\sum_{t=1}^{T}\sum_{n=1}^{N}\sum_{i=1}^{I}(Kp_{tni} + Kz_{tni} - Gi_{tni}) \to \min, \quad (2)$$

provided that:

$$w(A_1^{rank(1)}) \geq w(A_m^{rank(z)}) \text{ if } z \in [1, 3]. \quad (3)$$

If necessary, the g-th and b-th number of moderate and low levels of environmental safety are additionally taken into account:

$$g(A_1) \geq g(A_m),\ b(A_1) \geq b(A_m). \quad (4)$$

Scenarios, characterized by the number w=3, are priority, w=2 – prospective, w=1 – stabilizing. Within the framework of this work, stabilizing scenarios are understood that provide adjustment and regulation of the level of environmental safety. Prospective scenarios are aimed at increasing the level of environmental safety. The values Yx_1 and Yx_2 are determined by the expert decision method [15] in accordance with the social, economic and environmental conditions of the mining area. Ranked Pareto-optimal scenarios are presented in table 3.

Table 3. Ranking of Pareto-optimal scenarios for increasing the level of environmental safety in Novokuznetsk.

Scenario	F_1	F_2	F_4	Pareto-optimal scenarios	Level of environmental safety			Place
					F_1	F_2	F_4	
C1	0.932	0.556	0.585	+	H	M	M	3
C2	0.864	1	0	+	H	H	L	2
C3	0.891	0.778	0.453	+	H	H	M	1
C4	1	0.333	0.358	+	H	L	L	4
C5	0	0.222	1	+	L	L	H	4
C6	0.796	0.444	0.641	+	H	M	M	3
C7	0.719	0.277	0.925	+	H	L	H	2
C8	0.394	0	0.17	-	L	L	L	-

From table 3 it follows that Pareto-optimal scenarios of the first rank are C3, of the second one is C2, of the third is C1, C6, of the fourth is C4, C5.

The scenarios of high ranks are aimed at eliminating the negative impact of coal preparation plants, increase in the economic effect, improvement by reducing environmental fees, the quality of life of the population through the creation of new jobs and recreational areas.

4. Conclusion

Thus, the proposed methodological features of the scenarios development take into account the investment potential, the waste characteristics, and are aimed at maintaining the main production, creating additional products from waste that is in demand on the market. Increase in the level of environmental safety in Novokuznetsk in the conditions of coal preparation plants is planned through recycling waste and reclamation of disturbed lands with the receipt of additional products: coal concentrate from substandard fines (sludge), materials for construction needs from the rock.

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