Influence of transport and road complex on the natural-technical system

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Abstract. Modern mining enterprises operate in difficult mining and geological conditions that require preliminary consideration of a large number of production development options in order to select the optimal one. The complexity of the large systems under consideration makes it necessary to simulate production and economic processes simultaneously. The aim of the study is to develop a new approach to the processing of large amounts of information and forecasting harmful emissions from vehicles of the mining and processing complex, based on an analysis of the totality of field development parameters. Tasks: analysis of the problem of environmental pollution by vehicles of the mining and processing complex and determination of significant natural and technical factors affecting the emission of pollutants by vehicles during transportation of a useful component; study of the structure of the relationship between natural and technical factors and the values of emissions of harmful substances by road into the atmosphere. Research Methods. The methods used were fuzzy sets, statistical and factor analysis, the theory of multivariate optimization, numerical analysis, computer modeling and experimental modeling, and an application software package. Findings. The analysis of the relationship of technological factors of the main cycles and emission factors of harmful substances is carried out, a complex of mathematical models and methods has been created on the basis of research to improve the accuracy of the forecast for the emission of pollutants into the atmosphere by mining and processing complex vehicles.

1. Introduction

Transport is one of the most important components of social and economic development, absorbing a significant amount of resources and having a serious impact on the environment [1-8]. Nowadays, the impact of transport, but the environment is the most pressing and urgent problem of modern society. The consequences of this impact not only affect our generation, but can also affect the future generation if we do not take serious measures to reduce and even eliminate the effects of the impact and the impact itself.

Technical progress in the field of mining and the consumption of mineral resources is determined by high-performance, environmentally friendly technologies that ensure the integrated use of natural resources at the lowest cost and level of environmental pollution. Modern mining enterprises operate in difficult mining and geological conditions that require preliminary consideration of a large number of production development options in order to select the optimal one. The complexity of the large
systems under consideration makes it necessary to simulate production and economic processes simultaneously.

The development of a new approach to the shipment of a useful component and the creation of information technology that allows the selection of the optimal technology for field development is an urgent scientific and practical task.

The aim of the study is to develop a new approach to the processing of large amounts of information and forecasting harmful emissions from vehicles of the mining and processing complex, based on an analysis of the totality of field development parameters.

Tasks. Study of the specifics, conditions and principles of the process of formation of internal dump formation in the developed space of the natural-technical system; analysis of the problem of environmental pollution by vehicles of the mining and processing complex and determination of significant natural and technical factors affecting the emission of pollutants by vehicles during transportation of a useful component; study of the structure of the relationship between natural and technical factors and the values of emissions of harmful substances by road into the atmosphere.

Research Methods. The methods used were fuzzy sets, statistical and factor analysis, the theory of multivariate optimization, numerical analysis, computer modeling and experimental modeling, and an application software package.

2. Technical part

Studies have shown.

1. At mining enterprises, air emissions from automobiles increased over the period 2015–2019. 20–75%.

2. In quarries, automobile exhaust emissions account for at least 70% of all air pollution. From 40 to 70% of nitrogen oxides, from 70 to 90% of carbon monoxide (CO) and at least 50% of lead in the atmosphere are caused by automobile exhaust.

Air pollutants directly produced by automobiles, such as carbon monoxide, nitrogen oxides, hydrocarbons or lead, mainly accumulate in the vicinity of pollution sources, i.e. along quarries, mining enterprises, in mines, etc. Thus, local geo-ecological impacts of transport are created.

Some pollutants are transported over long distances from the place of emission, are transformed during the transfer process and cause regional geoecological impacts. The most common process in this category is acidification.

Carbon dioxide and other greenhouse gases spread throughout the atmosphere, causing global geo-environmental impacts.

Water pollution research conducted. Surface water bodies with sewage from the mining and processing enterprises of the motor transport complex receive mainly oil products and suspended solids. The surface runoff contains, in addition to suspended particles and oil products, heavy metals (lead, cadmium, etc.) and chlorides. On average, the annual discharge of chlorides from roads with runoff and snow is about 500 thousand tons. In addition, about 35 thousand tons of soot particles are released into the environment annually as a result of the abrasion of car tires on roads.

Studies conducted soil contamination.

A study of soils in the zone of influence of the transport complex of mining and processing enterprises showed that in about 15% of the samples the maximum permissible concentrations of heavy metals were exceeded. At the same time, the number of samples that did not meet the hygienic standards for microbiological indicators decreased. In general, the proportion of soil samples that do not meet the standards for sanitary-chemical and microbiological indicators in the zones of influence of transport is 2-3 times greater than the average for the Russian Federation.

Based on a preliminary analysis of the main factors of the field development technological process, a statistical information basis has been formed that allows us to determine significant groups of factors that determine the emissions of harmful substances by road during transportation of a useful component.
As a result of the study, a list of factors characterizing the activity of the process of formation of the internal dump was determined, and their classification was carried out according to the following groups: technological, transport and environmental.

According to the results of a statistical analysis of the main characteristics of factors, heterogeneity of the presentation of data in the form of qualitative and quantitative indicators was revealed. To formalize the source data and present statistical information in a single unified format, quantization of qualitative factors was carried out.

As a result of the digitization of the qualitative values of some factors, all types of factors are brought into a single format.

To study the influence of technological, transport and environmental factors on output indicators, the method of factor analysis of data was chosen [9-14]. The factor analysis method allows you to concentrate the initial information, expressing a large number of the considered features through a smaller number of more capacious internal characteristics of the phenomenon (factor groups), which, however, are not directly measurable.

According to the results of factor analysis, three groups of significant indicators were identified (table 1), the factor load of which was higher than the threshold: \( a_{ij} > a_{extr} = 0.67 \).

The total number of significant factors in these groups was 19 factors.

**Table 1.** Factors affecting emissions of pollutants into the atmosphere by road.

| № | Group of factors | Factor Name | Factor |
|---|-----------------|-------------|--------|
| 1. | Technological (\( F_{TECH} \)) | Annual mine productivity, t | 0.95 |
| 2. | | Annual vehicle productivity, t | 0.94 |
| 3. | | The volume of rock transported to the dump, t | 0.93 |
| 4. | | Mining front movement, m² | 0.08 |
| 5. | | Land requirement for external dumps, m² | 0.48 |
| 6. | | The volume of the removed soil layer, m³ | 0.42 |
| 7. | | Volume of potential fertile soils removed, m³ | 0.34 |
| 8. | | The number of flights of one dump truck | 0.88 |
| 9. | | Diesel consumption, l | 0.89 |
| 10. | Transport (\( F_{TRANS} \)) | Gasoline consumption, l | 0.87 |
| 11. | | Fuel oil consumption, l | 0.95 |
| 12. | | Natural gas consumption, m³ | 0.92 |
| 13. | | The consumption of liquefied gas, kg | 0.54 |
| 14. | | Dust emission from the surface of the transported material, kg | 0.78 |
| 15. | | Dust emission from the roadbed, kg | 0.72 |
| 16. | | CO emission of a bulldozer, kg | 0.61 |
| 17. | | NO\(_x\) emission of a bulldozer, kg | 0.68 |
| 18. | | Emission of C\(_n\)H\(_m\) bulldozer, kg | 0.65 |
| 19. | | Emission of soot bulldozer, kg | 0.55 |
| 20. | Ecological (\( F_{ECOL} \)) | The mass of solid particles released in the area of unloading / laying rocks, kg | 0.73 |
| 21. | | The mass of solid particles released during excavation and loading operations, kg | 0.51 |
| 22. | | Dust mass emitted during dumping, kg | 0.59 |
| 23. | | The mass of solid particles blown off the surface of a freshly dumped blade, kg | 0.57 |
| 24. | | The mass of solid particles blown from 1m² of defiling surfaces of the blade, kg | 0.54 |
| 25. | | Mass emission of air pollution, condition. | 0.63 |
| 26. | | The amount of damage caused by polluting emissions of | 0.55 |
Each factor group describes the influence of factors on the emission of pollutants into the atmosphere by open pit vehicles. As a result of the studies, it was revealed that within each group there is a regression relationship between its elements. Determine its structure allows the values of the factor loads of the elements of the factor group.

Guided by a priori information, the following functional dependencies can be distinguished from the first factor group:

\[ X_{\text{TECH}} = f_1(k_1, k_2, k_3, k_4) \]  \hspace{1cm} (1)
\[ Y_{\text{TECH}} = f_2(k_1, k_2, k_3, k_4) \]  \hspace{1cm} (2)
\[ Z_{\text{TECH}} = f_3(k_1, k_2, k_3, k_4) \]  \hspace{1cm} (3)

where \( X \) – carbon dioxide emissions of the car, kg;
\( Y \) – emissions of nitric oxide of the car, kg;
\( Z \) – car aldehyde emissions, kg;
\( k_i \) – values of digitized technological factors included in the first factor group.

From the second factor group, we can distinguish the dependence:

\[ X_{\text{TRANS}} = f_4(k_5^2, k_6^2, k_7^2, k_8^2, k_9^2) \]  \hspace{1cm} (4)
\[ Y_{\text{TRANS}} = f_5(k_5^2, k_6^2, k_7^2, k_8^2, k_9^2) \]  \hspace{1cm} (5)
\[ Z_{\text{TRANS}} = f_6(k_5^2, k_6^2, k_7^2, k_8^2, k_9^2) \]  \hspace{1cm} (6)
\[ X_{\text{TRANS}} = f_7(k_5^2, k_6^2, k_7^2, k_8^2, k_9^2) \]  \hspace{1cm} (7)
\[ Y_{\text{TRANS}} = f_8(k_5^2, k_6^2, k_7^2, k_8^2, k_9^2) \]  \hspace{1cm} (8)
\[ Z_{\text{TRANS}} = f_9(k_5^2, k_6^2, k_7^2, k_8^2, k_9^2) \]  \hspace{1cm} (9)

where \( X \) – carbon dioxide emissions of the car, kg;
\( Y \) – emissions of nitric oxide of the car, kg;
\( Z \) – car aldehyde emissions, kg;
\( k_i^2 \) – the values of digitized capital factors included in the second factor group.

Further, based on a priori information, types of mathematical models were determined that allow minimizing emissions of harmful substances by road. Regression analysis was carried out for the identified models, according to the results of which the most accurate and reliable models were selected. A method has been developed to minimize the emission of harmful substances by quarry vehicles. A method has been developed to improve the accuracy of forecasting the emission of harmful substances by road. An algorithm has been developed to minimize the emission of harmful substances and improve the accuracy of forecasting the emission of harmful substances by road.

For the regression dependencies (1) - (9), the parameters of nonlinear-type models were determined using the method of step-by-step regression analysis. Corresponding developed models were evaluated using the Fisher test (F), correlation coefficient, and mean square error (RMS). In addition, each parameter of the models was evaluated using Student's criterion (t). The values of the relevant criteria for the developed models are shown in table 1.

The coefficient of determination shows how fully the parameters used in the model describe this model. The higher the coefficient of determination, the less the model depends on factors not included in the model. The Fisher test shows how adequate the developed model is. The lower the Fisher criterion (provided that its value is less than the table value), the more adequate is the developed model.
model. The root-mean-square error shows how accurately the developed model describes the simulated process. The smaller its value, the more accurate the developed model is considered.

The analysis showed that the most accurate, reliable and adequate models describing the dependence of emissions on transport factors are:

\[
X_{\text{TRANS}} = -8547.55 + 964.55 \cdot \ln k_5 - 0.88 \cdot (k_6)^{0.5} + 557.10 \cdot \log k_7 - 0.15 \cdot k_8 + 154.72 \cdot (1/k_9) \tag{10}
\]

\[
Y_{\text{TRANS}} = -3512.12 + 274.44 \cdot \ln k_5 + 1.57 \cdot (k_6)^{0.5} + 114.68 \cdot \log k_7 - 0.03 \cdot k_8 + 85.54 \cdot (1/k_9) \tag{11}
\]

\[
Z_{\text{TRANS}} = -598.174 + 98.154 \cdot \ln k_5 + 0.22 \cdot (k_6)^{0.5} + 4.52 \cdot \log k_7 - 0.05 \cdot k_8 - 2.184 \cdot (1/k_9), \tag{12}
\]

where \(k_5\) – the number of flights of one dump truck;
\(k_6\) – diesel fuel consumption;
\(k_7\) – gas consumption;
\(k_8\) – fuel oil consumption;
\(k_9\) – dump height;
\(X\) – vehicle CO emission;
\(Y\) – car NO\(_2\) emission;
\(Z\) – car aldehyde emission.

The revealed non-linear mathematical models allow us to analyze the nature of emissions, plan and develop measures to prevent environmental pollution correctly. The non-linear appearance of the models allows us to consider factors that were not previously taken into account, which allows us to increase the accuracy of the forecast of emissions of harmful substances, to review the capacity of the internal dump.

The amount of harmful emissions into the atmosphere depends on a large number of transport and operational factors. Given the sharply increased cost of environmental protection fees and in connection with the signing of the Kyoto Agreement by Russia, the task of conducting the process with minimal fuel costs is very urgent. Hence, the need arises to minimize emission criteria for carbon monoxide, nitric oxide and aldehyde.

To find the transport factors that provide the optimal values of the above criteria, it is necessary to take into account the restrictions imposed on transport factors [15-20].

3. Conclusion

The studies have confirmed the effectiveness of forecasting using a predictive model based on non-linear regression for predicting the emission of harmful substances by vehicles, taking into account significant environmental and technological factors. During the experiment, the simulated forecast and real results obtained in previous years, practically repeat each other. The forecast error was 4.25%. Forecast accuracy increased by 18% compared with previously used forecasting methods.

Thus, the use of this approach to the formation of an internal dump in tiers allows to reduce harmful emissions of road transport and increase the capacity of dumps.

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