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ENVIRONMENTAL PROTECTION

EVALUATION PRINCIPLES OF THE DUST INFLUENCE OF MINING ENTERPRISES ON THE ENVIRONMENT

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It has been noted that the areas disturbed by open-pit mining together with the production processes in the extraction of mineral resources (drilling, blasting, transportation, etc.) have a negative influence on the environment in general and the atmosphere in particular. It has been indicated that, in percentage terms, dusting of refuse dumps and tailing dumps plays a prevailing role in the total amount of dust generated. It has been stated that the processes of formation and subsequent transfer of dust in the atmosphere depend on the combination of meteorological and mining factors that have a probabilistic nature in time and space. It has been shown that the maximum value of environmental risk characterises the level of dust influence, at which reduction environmental protection measures should be directed. The present paper proposes a procedure for evaluation of the dusty influence of mining enterprises on the environment. Under the conditions of Olenegorsk GOK, a GIS has been compiled – a project of the study area and, based on geo-information modelling, the results of calculating dust concentrations in the air have been imposed on a digital map of the area.

Keywords: *dust influence, GIS modelling, open cast mining, population intoxication risk, refuse dumps, tailing dumps*

1. INTRODUCTION

The development of deposits by the open method is accompanied by negative influence on the environment, which, first of all, leads to deep and areal disturbances of the natural landscape, changes in hydrometeorological conditions in the area of the open-pit mining, movement of poor breeds or even rocks containing harmful components to the day surface. With an average coal mine of 1,000–2,500 hectares and an iron ore open pit of average thickness of 2,000–3,000 hectares, the total area of disturbed land is 3–12 times greater than the area of the open-pit mining itself, as it includes land occupied by external dumps, industrial sites, transport and energy communications tailing dumps. According to [1], already in 2000, the area disturbed by mining operations in the territory of the Russian Federation amounted to 1,282.6 thousand hectares.

Territories disturbed by open-pit mining together with the production processes in the extraction of minerals (drilling, blasting, transportation, etc.) [2] have a negative impact on the environment in general and on the atmosphere in particular. For example, iron ore enterprises of the European part of Russia annually emit about 94 thousand tons of pollutants, including 60.8 thousand tons of inorganic dust [2]–[5]. A similar situation occurs in a number of foreign open-pit mines [6]–[11].

Sources of inorganic dust formation, in addition to drilling, massive explosions, pit roads, are places for storage overburden (internal and external dumps) and tailing dumps. Moreover, the percentagewise dusting of dumps and tailing dumps play the most important role in the total amount of dust produced.

The characteristic of the formation process and subsequent transfer of dust in the atmosphere is that the factor determining the spatial distribution of dust concentration, under other equal conditions, is the speed and direction of the wind.

On the other hand, the concentration of dust determines the magnitude of the environmental risk and the risk of chronic intoxication of the population living in the area of dust cloud distribution and dust settling on the surface of the earth [12]–[17]. In the present article, an attempt is made to establish a relationship between the magnitude of the dust influence, environmental risk and the risk of population intoxication.

2. METHODOLOGY

Inorganic dust generated as a result of the interaction of atmospheric air flows with the surface of dumps and tailing dumps extends over considerable distances. The distribution of its concentration in atmospheric air is complex determined by the meteorological conditions (temperature, humidity, wind speed and direction) and mining engineering features (physical and mechanical properties of rocks, the geometric sizes of dumps and tailing dumps, their location relative to the contour of the open-pit mining and the wind rose). Dropping from the atmospheric air to the surface of the earth, chemical elements contained in the dust have a depressing effect on water, soil, vegetation, forests, etc. [15].

The processes of formation and subsequent transfer of dust in the atmosphere depend on the combination of meteorological and mining-technical factors that are probabilistic in time and space. Meanwhile, the existing methods for evaluating these processes are based on the use of a deterministic approach, which uses a specific set of initial data for calculating the magnitude of the influencing factor, the choice of which is not always justified [17]. This, ultimately, can lead to a distorted valuation of the negative impact of the dust generated during the open-pit mining of mineral resources on the environment and, consequently, to errors in the choice of strategy for the implementation of environmental protection measures.

In this regard, it is proposed to calculate the final indicators of dust influence (dust load), taking into account random laws, the changes in the determining factors: speed and direction of wind, air temperature, frequency of mass explosions, the amount of simultaneously explosive and its composition, flow diagrams and drilling modes, types of applied vehicles, their parameters and technological schemes of loading and delivery of minerals and host rocks, places of waste dumps and tailing dumps etc. [18]. The solution of this problem can be fulfilled in the following sequence:

1. At the first stage, the type of statistically distributed laws of factor change determining the level of dust load is established and, on their basis, the probabilities pi of value equality of each of the determining factors to a specific value of vi are calculated. For example, the probability that the air velocity will be equal to $V1$ is $p1$, the probability that the air temperature equals the temperature $T_1 - p_2$, the probability that the angle of wind direction is equal to $Y - p_3$, the probability of the frequency of mass explosions to the frequency $K_1 - p_4$, etc. [16].
2. If we assume that the situation in which the above given parameters become equal to specific values forms independent events in aggregate, then the probability of their combination is $\Sigma P_j = \prod_1^n p_i$ (n is the total number of factors taken into account when calculating the final value of the dust load value, i.e., the concentration of dust, gas, etc., j – the sequence number of the combination of source data).
3. At the given combination of initial data characterising the factors under consideration, based on the UPRZA Ecolog program [11], numerical values are established characterising the dust load, for example, the contrast ratio Cj, equal to the ratio of the calculated dust concentration to the maximum allowable concentration [18]. The probability of the dust load achievement of the calculated value of Cj will be ΣPj $(j = 1, 2, 3 \ldots\ldots)$.

   If it turns out that the value of Cj (or a value close to it) is achieved with different m combinations of the original data, the total probability of reaching the dust load value of the calculated value of Cj will be $m\Sigma Pj$.
4. After the completion of the numerical experiment in the coordinates Cj, ΣPj, the probability distribution function of the random variable Cj is constructed.

3. RESULTS AND DISCUSSION

The level of dust influence (the numerical value of Cj) will determine the ecological damage (the effects of technogenic impact expressed in value form), which is applied to the environment, including human health as a result of mineral extraction. In this case, the larger the absolute value of *Cj*, the greater the magnitude of environmental damage. On the other hand, each value *Cj* is realised with a certain probability, which will have a minimum value in cases of minimum and maximum values *Cj*. In this regard, the integral indicator that determines the level of dust load should be considered the environmental risk calculated as the product of environmental damage and the probability of its occurrence [13]. The maximum value of environmental risk characterises the level of dust exposure, and environmental protection measures should be directed to reduce it [19]. The establishment of a specific set of these measures will be related to the number of influencing factors and the degree of their influence on the final value of *Cj*. In this case, the compensation of factors determined by the peculiarities of the extraction of a mineral (controlled factors) should be carried out by direct influence on the technological processes determining them.

The maximum value of environmental risk in the case when the dust cloud reaches places of compact residence of people will correspond to the maximum risk of chronic intoxication of the population, the value of which, depending on the ratio of the actual concentration of harmful substances in the air to the maximum allowable concentration and hazard class of the substance, looks the following way [18]:

$$R = 1 - exp\left(-0.174\frac{C^b}{K_3 C_{mpc}}\right), \tag{1}$$

where C – the concentration of the pollutant, mg/m^3; C_{mpc} – the maximum permissible concentration of the substance in question, mg/m^3; b and $K_з$ – coefficients taking into account the toxic properties of the substance.

For the development of environmental measures, environmental action to reduce the risk of intoxication of the population, information is needed on its distribution over the territory adjacent to dusty surfaces: overburden rocks and tailing dumps [20].

Valuation of the dusty impact of open-pit mining on the environment was carried out on the basis of Olenegorsk GOK. The procedure for zoning a territory by the magnitude of technological risk can be carried out as follows. First, the calculation of the inorganic dust concentration distribution over the area of the study territory was performed. For this purpose, the software complex “UPRZA Ecologist” [13] was used. Then a GIS project was formed, with the help of which the results of calculations on the distribution of the inorganic dust concentration were processed and areas were allocated, which were characterised by the magnitude of technogenic risk exceeding the safe value [21]. The implementation of the GIS project was carried out on the basis of the Surfer software package [22]. For the conditions of Olenegorsk GOK, the determination of the level of dust influence was carried out for the overburden dump, having an area of 53 hectares, height of 150 m, and moisture content of stored rocks of 8.1–9 %. First, the amount of inorganic dust emitted from the surface of the blade was calculated, and then the area of inorganic dust distribution was calculated. For further data processing, a GIS was formed – a project to the site, which was a rectangle with length of 13.8 and width of 9 km. The total area of the study area was 124.2 km^2.

As a result of the numerical implementation of this GIS – areal project, the spatial distribution of technological risk was also established (Figs. 1 and 2).

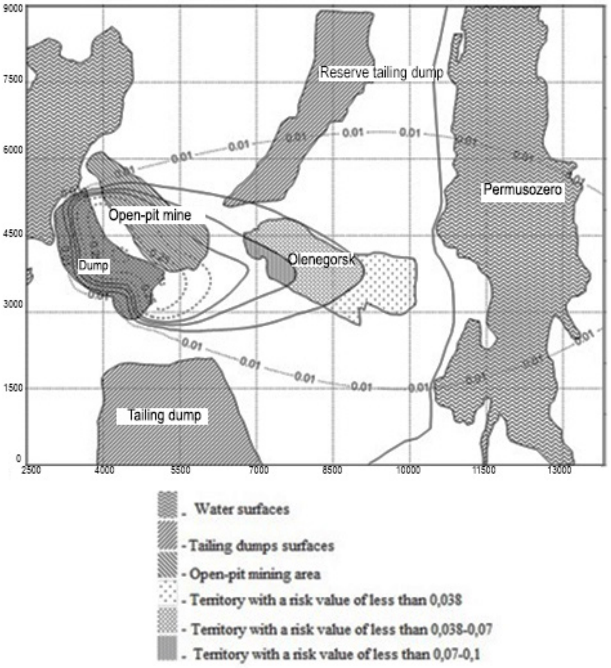

Fig. 1. Area distribution of the technogenic risk (isolines correspond to specific risk values).

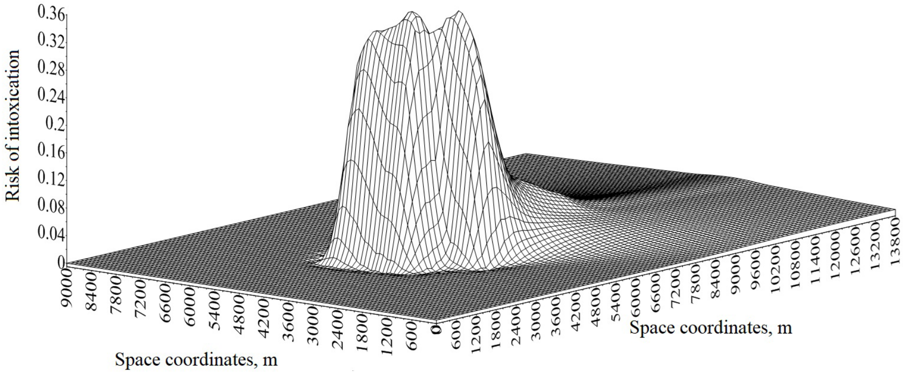

Fig. 2. Space distribution of the technogenic risk.

Based on the map (Fig. 1), the zoning of the territory occupied by Olenegorsk was made in accordance with the risk values (Table 1).

Table 1

Differentiation of the Territory of Olenegorsk Depending on the Magnitude of the Risk

R	Area size, m^2	%
0.1 – 0.07	353394	10
0.07 – 0.038	1850023	51
Less than 0.038	1389637	39

Analysis of the data presented in Table 1 suggests that the dust influence of overburden dumps leads to the following negative consequences:

- 10% of the territory of Olenegorsk is in the area of technogenic risk, which determines the possibility of toxic effects with a probability of 0.07 – 0.1.
- 51% of the area of Olenegorsk belongs to the field of technogenic risk, which determines the possibility of toxic effects with a probability of 0.07 – 0.038.
- 39% of the area of Olenegorsk is characterised by technogenic risk values not exceeding 0.038, which corresponds to the concentration of inorganic dust equal to the MPC.

4. CONCLUSIONS

Consequently, in order to evaluate the dust influence of the mining enterprises on the environment, the following stages should be followed:

- establishing the number of influencing factors and random laws of their distribution;
- defining the maximum values of the ecological risk;
- compiling of the GIS project of the study area and the implementation with geo-information modelling the imposition of the calculation results of dust concentrations in the air on a digital map of the area;
- allocating areas characterised by pollution of various levels (C_i / C_{mpc}), and the calculation of the proportion of contaminated areas relative to the total area of the study area;
- establishing areal distribution of risk of population intoxication;
- justifying the strategy of environmental protection measures, taking into account the areal distribution of the risk of intoxication.

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KALNRŪPNIECĪBAS UZŅĒMUMU PUTEKĻU IETEKMES UZ VIDI NOVĒRTĒŠANAS PRINCIPI

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Kopsavilkums

Teritorijas, kur notiek atklāta derīgo izrakteņu ieguve, kā arī ražošanas procesi, kas saistīti ar derīgo izrakteņu ieguvi (urbšana, spridzināšana, transportēšana u.c.), negatīvi ietekmē apkārtējo vidi un it īpaši atmosfēru. Atkritumu izgāztuvju putekļu noņemšanai ir dominējošā loma kopējā saražoto atkritumu procentuālā apjomā. Putekļu veidošanās procesi atmosfērā ir atkarīgi no meteoroloģiskajiem un kalnrūpniecības faktoriem, kuriem ir varbūtības raksturs laikā un telpā. Pierādīts, ka vides riska maksimālā vērtība raksturo putekļu iedarbības līmeni, kas ir jāņem vērā vides aizsardzības pasākumu īstenošanai. Rakstā piedāvāta procedūra, kā novērtēt kalnrūpniecības uzņēmumu ietekmi uz vidi. Oļeņegorskas ieguves un pārstrādes rūpnīcas apstākļos sastādīts ĢIS – pētījuma projekts un, pamatojoties uz ģeoinformācijas modelēšanu, putekļu koncentrācijas gaisā aprēķināšanas rezultāti ir uzlikti uz teritorijas digitālās kartes.

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