Measures to Improve Working Conditions and Reduce Dust and Gas Emissions in the Quarries of the Mining and Processing Plant

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Abstract. Research is carried out on the existing measures to suppress dust and gas emissions during mass explosions at the quarry of a mining and processing plant. Measures have been developed to reduce dust and gas emissions, taking into account the analysis of existing measures to suppress dust and gas emissions during mass explosions at the quarry of the mining plant of JSC «Lebedinsky MPP». Studies of surface active substances on the wettability of dust particles have been carried out. In order to improve working conditions, it was proposed to reduce dust and gas emissions by suppressing them in the source of formation using the method of wetting and sticking together of dust particles. The proposed engineering and technical solution can be used to reduce dust and gas emissions during mass explosions at the quarries of various mining and processing enterprises. The developed method is proposed to be used to ensure environmental safety and improve working conditions in industries with increased dust content by increasing the efficiency of dust collection.

1. Introduction
A significant amount of work has been devoted to the issues of reducing dust emissions at the quarries of mining processing plants [1-5].

Dust formation is the result of technological operations at the plant. In the case of wind amplification, increased dust formation is observed, which negatively affects the plant's working areas and adjacent territories, which can cause serious occupational diseases if exposed for many years. Therefore, it is necessary to improve dust suppression measures in the production areas of enterprises. One of the cost-effective and productive methods of reducing the negative impact of dust from open pit mines is the sprinkling of the blasted block with water air currents, which are formed by a reactive installation, or by another air stream initiator. During the operation of this equipment, a significant water air flow is generated, with the help of which irrigation of vast areas of mining is carried out, also to suppress suspended dust from quarries. During operation of the device, the diffusion and atomization of toxic gases generated during blasting using explosives in open pit mines is enhanced.
2. Analysis of existing environmental measures
Consider a set of environmental measures in the quarry of the mining and processing plant of JSC Lebedinsky MPP. The plant is located in the city of Gubkin, Belgorod Region, about 600 kilometers southwest of Moscow.

The following were developed at the plant: measures to reduce emissions of harmful substances into the atmosphere; for protection against physical influences; a number of security measures.

In 2018, the following work was carried out:
- continuous monitoring of the current state and changeable dynamics of the natural complex on the Yamskaya Steppe site, located in the Belogorye reserve, carried out in order to obtain data on the influence of the Lebedinsky mining and processing plant as a whole on the state of the ecosystem in the reserve;
- to carry out laboratory research and instrumental testing of soil samples as part of production control;
- on the implementation of physico-chemical studies of water samples according to indicators: titanium, barium, lithium, total organic carbon;
- to carry out laboratory tests for legionellosis of water systems (pools, cooling towers, water supply systems);
- biotesting of production wastes;
- to conduct a toxicological study of industrial waste to determine the degree of toxicity;
- the implementation of sanitary - parasitological studies of swimming pool water and sewage sludge;
- conducting a sanitary-epidemiological examination of water intake for drinking and drinking purposes at workshop No. 2 of the DSF of JSC Lebedinsky MPP and issuing an expert opinion;
- step-by-step treatment of ponds for tertiary treatment of mine water with the aim of restoring the biological balance and self-cleaning with the biological product Mikrozim (tm) “POND TRIT”.

Thus, the activities of Lebedinsky MPP, taking into account the envisaged environmental protection measures, may have a slight negative impact on the environment.

3. Development of measures to reduce dust and gas emissions by suppressing them in the source of formation, using the method of wetting and sticking of dust particles
Consideration of projects and literary sources to minimize the negative impact of dust and its suppression in the domestic and foreign sphere indicates that the best results are observed in technological processes associated with the use of aqueous solutions of surface-active substances. This method of dust removal guarantees efficiency and high productivity in vast quarry areas while reducing the volume of water consumed by ~ 50-70% compared to similar technologies practiced for dust suppression based on the use of dispersed water. The profitability of dust suppression with water cannons is ~ 90% [6].

One of the methods of dust suppression is to improve the wettability and stickiness of dust particles. The dust of open pit mines of mining and processing plants is hydrophobic with respect to water; therefore, when dust suppression water is used, the surface tension of which is 72 mJ / m² [7], limited dust humidification takes place and it can again appear in the open pit air.

Based on a study of existing measures, it was proposed to reduce dust and gas emissions by suppressing it at the source of formation using the method of wetting and sticking of dust particles [7] on the career of a mining and processing plant for suppressing dust and gas emissions during mass explosions. In the works [8, 9] P. Rebinder set the rules for equalizing polarities. Based on this rule, the adsorption of substances at the interface is predicted, as well as the orientation of the molecules in the adsorption monolayers. Starting from these works, it is customary to scientifically substantiate the use of surfactants in order to control wetting. As surfactants that improve the wettability of a solid surface, organic compounds consisting of diphilic molecules that simultaneously have a hydrophobic hydrocarbon radical and hydrophilic or polar groups are most often used [7].
Rebinder P.A with colleagues [8, 9] show that the molecular nature of surfaces coated with adsorption layers of surfactants can be studied by measuring its wetting (specifically, the contact angle). In a polar medium - water, surfactant adsorption leads to hydrophilization and a decrease in surface tension is observed at the “liquid – solid particle” interface, which leads to a decrease in the wetting angle, and, accordingly, an acceleration of the wetting process and an increase in dust particle aggregation.

The effect of surfactant concentration on the reduction of surface tension and the wettability of the surface of dust particles should be emphasized. A decrease in surface tension and an improvement in wetting is observed only at a certain surfactant concentration in the solution; therefore, it is necessary to determine the optimal surfactant concentration that has the maximum effect.

In order to increase the efficiency of dust collection, a study was made of the effect of surface-active substances on the dust wettability. Currently, there is a huge variety of surfactants. The study of the mechanism of surfactant adsorption on the solid phase (dust particles) is an independent task, which was not put in this paper. The main goal of the work was to determine the fundamental possibility of using anionic surfactants based on triethanolamine salts of alkyl sulphates [10], which contain diphilic molecules and have a greater potential to improve the wettability of solid materials (dust) in contrast to non ionic and cationic surfactants. Specifically, the triethanolamine salt of sodium lauryl sulphate, an anionic surfactant, was used in the work [10].

The determination of the above characteristics was carried out on surfactant solutions prepared using distilled and tap water in the city of Gubkin. The concentration of surfactants in water (by weight) ranged from 0.1 to 6%. The surface tension measurements (mJ / m²) are given in table. 1. and in fig. 1. Experimental procedure: the surface tension coefficient (σ) is determined on a TD1 / LAUDA tensiometer at the interface between the liquid-air phase and the Wilhelmy plate. The device allows you to immediately determine the value of the surface tension force in mJ / m². The measurements were carried out in a thermostatically controlled chamber at a constant temperature of 25° C [11].

Table 1. The relationship between the surface tension coefficient (mJ / m²) and concentration in solutions (wt.%).

| Water sample * | The value of the surface tension coefficient (mJ / m²) at surfactant concentrations in aqueous solutions (wt.%) |
|----------------|------------------------------------------------------------------------------------------------------------------|
|                | 0 | 0.1 | 0.25 | 0.5 | 1  | 2  | 3  | 4  | 5  | 6  |
| 1              | 72 | 70  | 66  | 61  | 53 | 42 | 37 | 35 | 33 | 28 |
| 2              | 71 | 67  | 61  | 51  | 41 | 33 | 28 | 24 | 21 | 18 |

*1 – distilled; 2 – water, water sampling was carried out in the city of Gubkin

From the above data it is seen that with an increase in the concentration of the triethanolamine salt of sodium lauryl sulphate from 0.5 to 6 wt. % in the water used for pit irrigation, a decrease in surface tension is observed from 71 to 18 mJ / m², and this favors the wetting of dust. When a surfactant, a triethanolamine salt of sodium lauryl sulfate, is introduced into water, σ decreases by a factor of ~ 2 for distilled water at a surfactant concentration of ~ 4 wt. %, and for tap water used for irrigation pit - at a concentration of ~ 2 wt. % The data table. 2 and fig. 2 show that the increase in the concentration of surfactants over 5 wt. % in distilled and tap water does not contribute to a further significant decrease in surface tension. This phenomenon indicates the complete saturation of the adsorption layer when the maximum orientation of the surfactant molecules at the liquid – solid particle interface is reached, according to the data of [8, 9].
Processing with surfactant solutions in open pit mines of MPP can be carried out by irrigation of a source of dust formation or dust. In addition, it is possible to process in foam mode (foam can be obtained using a foam generator from aqueous solutions of blowing agents). This method is more effective and has a number of advantages [12].

![Figure 1](image-url) **Figure 1.** The relationship between the surface tension coefficient and the concentration of triethanolamine salt of sodium lauryl sulfate in solutions prepared using: 1 - distilled water; 2 - tap water.

The results of measuring the values of the contact angles of dust wetting $\Theta$ (degrees) or the angle of contact with water solutions in the presence of a surfactant — the triethanolamine salt of sodium lauryl sulphate at various concentrations are given in table 2 and in fig. 2. It is believed that if the value of the contact angle is less than $\Theta < 90^\circ$, then the liquid will be wetted by the solid surface, and the surface itself is called lyophilic (in our case, liquid water is hydrophilic). If the contact angle is greater than $\Theta > 90^\circ$, then the solid surface is not wetted by the liquid and is lyophobic (hydrophobic). With full or absolute wetting (spreading), the edge angle is zero, with full or absolute non-wetting it is $180^\circ$ according to [8, 10]. The cosine of the contact angle determines the wettability of the solid surface of the dust by a liquid. It was determined by the drop projection method [11]. For distilled water without surfactant, the value is $\Theta \sim 68$ deg., And for tap water $\Theta \sim 62$ deg.

The equilibrium contact angle is calculated according to Young's law:

$$\cos\Theta = \frac{\sigma_{23} - \sigma_{13}}{\sigma_{12}},$$

where $\sigma_{23}$, $\sigma_{13}$, $\sigma_{12}$ - surface energies respectively, and at the interface the solid is gas, the liquid is solid and the liquid is gas.

Analyzing the results, we can conclude the following, with an increase in the concentration of triethanolamine salt of sodium lauryl sulphate from 0.5 to 6 wt. % in distilled water and water used for pit irrigation, the value decreases, which indicates an improvement in the wetting of the surface of dust particles. The largest decrease to 25 degrees is typical for solutions of tap water with a surfactant concentration of 6 wt. % in contrast to solutions based on distilled water is 43 degrees at the same surfactant concentration. The optimal concentration of surfactants for solutions prepared with distilled water to improve the wettability of the surface of dust particles is ~ 4 wt. %. For solutions prepared on the basis of tap water, the optimal concentration of surfactant is ~ 5 wt. %. A further increase in the concentration of surfactants, the triethanolamine salt of sodium lauryl sulphate, is not advisable, since there is no significant decrease.

So, as a result of measuring the physico-chemical parameters (surface tension coefficient and contact angle) for water solutions used to irrigate quarries with surfactants, a concentration of...
triethanolamine salt of sodium lauryl sulphate of ~ 4-5 wt. %, since the hydrophilic characteristics of the liquid - solid system (dust) increase ~ 2-3 times.

**Table 2.** The relationship between the value of the contact angle $\Theta$ (deg.) and the concentration of surfactants in solutions (wt.%).

| Water sample* | 0   | 0.1 | 0.25 | 0.5 | 1 | 2 | 3 | 4 | 5 | 6 |
|---------------|-----|-----|------|-----|---|---|---|---|---|---|
| 1             | 68  | 65  | 62   | 60  | 58 | 55 | 50 | 47 | 44 | 43 |
| 2             | 62  | 59  | 56   | 53  | 47 | 39 | 34 | 30 | 27 | 25 |

*1 – distilled; 2 – water, water sampling was carried out in the city of Gubkin

**Figure 2.** The relationship between the contact angle and the concentration of the triethanolamine salt of sodium lauryl sulphate in solutions prepared using: 1 - distilled water; 2 - tap water.

The results obtained indicate an improvement in the wetting and sticking together of dust particles, therefore, the use of surfactants is rational and effective for solving problems with dust in open pit mines of MPPs, and specifically at JSC Lebedinsky MPP of the Belgorod Region, as well as for other industrial facilities in order to optimize the environmental situation and conditions labor on the objects of the technosphere, by analogy with the problems considered in [4, 5, 13, 14, 15] using information technology [16, 17, 18].

**4. Conclusion**

1. Based on a study of the enterprise’s activities to suppress dust and gas emissions during mass explosions at a quarry of a mining and processing plant, it was proposed to reduce dust and gas emissions by suppressing it at the source of formation using the method of wetting and sticking of dust particles.

2. Conducted studies of surface-active substances on the wettability of bulk materials showed that improving wettability and adhesion helps to reduce dust formation, therefore, the use of foaming agents is appropriate for dust control.

3. Based on the results of measuring the physico- chemical parameters (surface tension coefficient and contact angle) for solutions of water used for irrigation of quarries with surfactants, a concentration of triethanolamine salt of sodium lauryl sulphate ~ 4-5 wt. %, since the hydrophilic characteristics of the liquid-solid system (dust) increase ~ 2-3 times.
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