Assessment of coal dust adhesion under the action of reagents

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Abstract. The coal mining industry in Russia is developing rapidly. In this regard, the increase in emissions of coal dust into the environment leads to a serious threat to the safety and health of employees of enterprises and to deterioration of environmental situation. One of the methods in the fight against coal dust pollution is the use of dust-settling reagents. Studies for developing the composition of dust-binding mixtures, characterized by a minimum adhesion (wettability) of coal dust particles, have been conducted. The kinetics of the process of wetting dust with various dust-settling reagents has been studied. It is established that the use of solutions of sodium oleate with the addition of linseed oil is a good dust-settling reagent of natural origin. The adhesion time significantly reduces by adding linseed oil. The greatest efficiency of dust deposition was noted when interacting with a solution of sodium oleate with the addition of linseed oil with a concentration of 4 g/l, when the moisture content of dust was 60 %. The results obtained will contribute to improve the environmental and sanitary conditions of settlements located near operating coal mining enterprises and reduce the incidence of specific diseases among employees of the enterprise.

1. Introduction
The coal mining industry in Russia is developing rapidly. Due to the peculiarities of the technological process and the methods used for coal mining, the environmental load is increasing [1, 2]. It means that the safety and health of employees of enterprises are under a significant threat [3, 4, 5]. National and foreign legislation clearly regulate the requirements for measures to protect the environment from coal dust. The main direction in the complex of measures to control dust effects is to prevent its formation or entry into the air during mining, processing, storage of coal, as well as loading and unloading operations.

The use of various methods and tools aimed at reducing and eliminating the negative impact of dust is an integral procedure at all technological stages. According to a researchers’ opinion, one of the most promising methods to fight coal dust is the use of vacuum binding solutions [6, 7, 8, 9].

However, the information on monitoring the effectiveness of using such solutions, the real time of their action and the impact on the quality of coal sold is not provided in the literature.

Thus, the development of an effective dust suppressing reagent that reduces the amount of dust entering the atmospheric air during the operation of enterprises engaged in coal mining is relevant.
The purpose of the study is to develop the composition of dust-binding mixtures characterized by the minimum adhesion (wettability) time of coal dust particles.

2. Objects and methods of the study
The object of the study is dust-binding mixtures. The subject of the study is the process of adhesion of coal dust particles.

Experimental studies were conducted at the Department of Chemistry and Geoecology FSBEI HE “Khakass State University named after N.F. Katanov”.

Coal dust adhesion was assessed by capillary absorption [10]. The experiment was carried out with an averaged coal dust sample (averaging by quartering [11]) passing through a sieve of 0.5 mm diameter.

To quantify the wettability of dust, the following installation was constructed (figure 1).

![Figure 1. Installation diagram for determining the wettability of coal dust.](image)

1 – Schott funnel; 2 - porous gasket; 3 - connecting tubes; 4 - capillary tube; 5 - crane; 6 – funnel.

The capillary tube, represented by a 2 ml pipette with a scale graduation value of 0.01 mm, is installed strictly horizontally at one level with the porous Schott funnel gasket. The test solution was poured through the funnel into the apparatus to fill the pipette and wet connecting tubes and the Schott funnel to the porous septum. The prepared test coal dust (1 g) was quickly placed in a uniform layer in a Schott funnel. The liquid level in the capillary tube was taken every 5 seconds. It decreased due to the absorption of water by a layer of dust. The changes in the liquid level in the tube continued to be examined until equilibrium was established (exposure time 180 sec).

The maximum water absorption was determined as the ratio of the volume of the absorbed solution to the mass of wetted coal. The intensity of the process was identified as the logarithmic multiplier of the function with an approximation coefficient of at least 0.98.

The experiment to assess the adhesion of coal dust was carried out in three stage frequency.

3. Results and discussion
Assessment of the wettability of coal dust particles allows to a certain extent to characterize the effectiveness of the action of chemical reagents in the studied solutions.

As criteria for the selection of reagent the authors used:

- Effectiveness of reagents in the process of dust suppression;
- Sustainability of reagents;
- The effect of the solution components on each other should not cause destruction and delamination of solutions.
In this regard, the use of substances of natural origin with surface activity is considered to be appropriate. Oleic acid sodium salt was used as a similar component. Oleic acid is one of the most common unsaturated acids in nature, found in various vegetable oils and animal fats. Sodium oleate was obtained by saponification of oleic acid. 30 ml of water and 6 g of sodium hydroxide were added to 8 g of oleic acid, then it was heated to 90 - 95 °C and brought to 1 l with water after cooling. In industry, oleic acid is obtained by hydrolysis of natural oils or synthetically. Thus, in comparison with other surface-active substances (surfactants), sodium oleate is highly environmentally friendly.

Linseed oil can also be considered as a natural, ecofriendly reagent. It refers to quick-drying oils, as it polymerizes easily in the presence of atmospheric oxygen (“dries”) with the formation of a strong transparent film. Linseed oil and its technical varieties has long and successfully been used in most countries of the world, including Russia.

The components of the studied systems included:

- **Oleic acid** (\(\text{HC}_{18}\text{H}_{33}\text{O}_2\)) - a surfactant that reduces the adhesion of non-polar substances in the "solid, non-polar body: polar liquid" surface system.
- **Sodium hydroxide** (\(\text{NaOH}\)) – a reagent that interacts with oleic acid to form water-soluble sodium oleate.
- **Linseed oil** – a reagent causing particles to stick together through the affinity of the polarity of oil and coal particles. In addition, under the action of air oxygen and ultraviolet radiation, the reagent polymerizes, forming a stronger bond between coal particles.
- **Sodium chloride** (\(\text{NaCl}\)) – a reagent that does not react with sodium oleate. It is a cryoscopic additive in the studied aqueous solutions, in case when lowering its freezing temperature is a necessity.

Based on the selected components, 6 model systems were developed:

- water (H2O).
- sodium oleate solution (H2O + NaC18H33O2).
- sodium oleate solution with linseed oil Cm 1 g/l.
- sodium oleate solution with linseed oil Cm 4 g/l.
- sodium oleate solution with linseed oil Cm 8 g/l.
- sodium oleate solution with linseed oil Cm 20 g/l.

The analysis of coal dust adhesion under the action of each of the developed model systems was carried out. The maximum water absorption and the intensity of the adhesion process were determined. The results of assessment of coal dust adhesion under the action of water are presented in figure 2. The maximum water absorption of coal dust and the intensity of the process (logarithmic multiplier of the function) are presented in table 1.

![Figure 2. The change in the volume of absorbed liquid (water) with coal dust over time.](image-url)
Table 1. The results of coal dust particles adhesion under the action of water.

| Reagent                | Maximum moisture capacity % | Average moisture capacity % | Logarithmic factor of the moisture absorption process |
|------------------------|----------------------------|----------------------------|-----------------------------------------------------|
| Water                  | 52; 58; 54                 | 53                         | 0.162; 0.193; 0.149                                   |

* Approximation validity coefficient less than 0.98

According to the obtained results, water is absorbed by the samples of wetting the surface of coal dust being in contact with water. The average moisture capacity of dust is 53%. This value is reached within 210 seconds. When applied, period of the maximum action of water as a wetting agent seems too large. Spraying water droplets cannot remain in suspension for such a long time with any technology. It is necessary to use additional components in the solution by increasing the effectiveness of the action of water.

In order to increase the wettability of dust particles, a second model system - a solution of sodium salt of oleic acid (sodium oleate) obtained by saponification of oleic acid with an alkali solution was used.

The maximum water absorption and intensity of the process when using a solution of sodium oleate are presented in table 2.

Table 2. The results of adhesion of coal dust particles under the action of a solution of sodium oleate.

| The reagent used in the experiment | Maximum moisture capacity % | Average moisture capacity % | Logarithmic factor of the moisture absorption process |
|-----------------------------------|----------------------------|----------------------------|-----------------------------------------------------|
| Sodium Oleate Solution            | 59; 42; 58; 56; 56; 50     | 55.8                       | 0.152; 0.097; 0.164; 0.149                            |

* Approximation validity coefficient less than 0.98

The use of sodium oleate solution showed the increase in the average moisture capacity of coal dust compared to water.

In order to stick coal particles, linseed oil was added to a solution of sodium oleate in the amount of 1, 4, 8, 20 g/l. The maximum water absorption and the intensity of the process of moisture absorption were discovered (table 3).

Table 3. The results of adhesion of coal dust particles under the action of a sodium oleate solution when linseed oil is added.

| Model system                        | Maximum moisture capacity % | Average moisture capacity % | Logarithmic factor of the moisture absorption process |
|-------------------------------------|----------------------------|----------------------------|-----------------------------------------------------|
| Sodium oleate solution with linseed oil Cm 1g/l | 56                         | 56.0                       | 0.145                                               |
| Sodium oleate solution with linseed oil Cm 4g/l | 58; 62; 66                 | 60.0                       | 0.146; 0.146; 0.174                                 |
| Sodium oleate solution with linseed oil Cm 8g/l | 55; 59; 62; 51; 58         | 58.5                       | 0.121; 0.169; 0.169; 0.074a; 0.170                   |
| Sodium oleate solution with linseed oil Cm 20g/l | 64; 57; 58                 | 59.7                       | 0.158; 0.151; 0.163                                 |

* Approximation validity coefficient less than 0.98

Studies have shown that the moisture capacity of coal dust depends on the reagent used. When dust is wetted with water, the moisture capacity indicator is 53% - the smallest indicator of all studied systems. The addition of sodium oleate led to a slight increase in the moisture capacity of coal to 56%.
A more significant increase in the quality of adhesion is observed when using a solution of sodium oleate with linseed oil added. The greatest efficiency of dust deposition is noted when interacting with a solution of sodium oleate with the addition of linseed oil in the amount of 4 g/l, with the moisture capacity 60%.

The kinetics of the dust wetting process is presented in figure 3.

![Figure 3. Changes in the volume of liquid absorbed by coal dust in the studied systems over time.](image)

The highest wetting rate was shown when using solutions of sodium oleate with the addition of linseed oil in the amount of 8 g/l and 4 g/l. Thus, the average volume of absorbed liquid of 0.5 ml/g reached by the systems in 40 seconds, while the other model systems reached this indicator within 100 seconds or more.

Taking into account that the fourth model system \((\text{H}_2\text{O} + \text{NaC}_{18}\text{H}_{33}\text{O}_2 + \text{linseed oil 4g/l})\) also has the greatest ability to increase wettability, it can be recommended in technologies for reducing coal dust in the air.

### 4. Conclusion

The study of the dependence of the adhesion time of coal dust particles on the chemical composition of the reagent showed the feasibility of using solutions of sodium oleate with the addition of linseed oil. The optimal composition of the dust-binding mixture, with the highest efficiency of coal dust deposition, is a solution of sodium oleate with the addition of 4 g/l of linseed oil.

It was found that adding linseed oil to the dust precipitation solution reduces the period of adhesion by more than 2 times. The moisture content of coal dust with the optimal composition of the dust-binding mixture was 60%.

The use of the proposed dust-binding mixture will help to improve the environmental and sanitary-hygienic conditions of settlements located near existing coal mining enterprises and reduce the incidence of diseases of a specific nature among the employees of the enterprise.

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