

# Study on the Physicochemical Characteristics and Dust Suppression Performance of New Type Chemical Dust Suppressant for Copper Mine Pavement

**Zhian Huang**

University of Science and Technology Beijing

**Yang Huang**

University of Science and Technology Beijing

**Zhijun Yang**

Wanbao Mining Ltd

**Jun Zhang**

Wanbao Mining Ltd

**Yinghua Zhang** (✉ [Zhangyinghuaustb@sina.com](mailto:Zhangyinghuaustb@sina.com))

University of Science and Technology Beijing <https://orcid.org/0000-0003-1129-6938>

**Yukun Gao**

University of Science and Technology Beijing

**Zhenlu Shao**

China University of Mining and Technology - Xuzhou Campus: China University of Mining and Technology

**Linghua Zhang**

University of Science and Technology Beijing

---

## Research Article

**Keywords:** mine road, road dust, compound dust suppressant, dust suppressant performance

**Posted Date:** March 25th, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-162783/v1>

**License:**   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

# Abstract

Mine road dust is an important source of dust in mine operations. The dust produced on the road surface is a great hazard to the workers. Aiming at the road dust of an open-pit mine, this paper conducts physical and chemical analysis of a dust suppressant prepared by using sodium polyacrylate as a binder, sodium carbonate as a moisture absorbent, polyethylene glycol as a water-retaining agent, and alkyl glycoside as a surfactant. Characterization of characteristics and dust suppression performance. The results show that the dust suppressant has a pH of 11.03, a viscosity of 18.5 mPa·s, and a surface tension of 28.1 mN/m. The content of heavy metal ions contained is less than the maximum concentration defined by the national standard. Under the same temperature condition, the greater the humidity, the stronger the hygroscopicity, especially when the humidity is 30%, where the better hygroscopic effect than water is obvious. The dust suppressant also has good anti-evaporation properties and it keeps at 4–5% moisture content after 10 days at a normal temperature. Compared with water, the dust suppressant has better resistance to wind erosion and compression. Under the same conditions, the loss rate of water is 2 times that of the dust suppressant and the pressure of the dust suppressant sample is about 3 times that of water. The dust suppressant has a much higher dust removal efficiency for all dust and respirable dust than water under the same conditions. Finally, the test results and mechanism of the dust suppression effect of the dust suppressant are described and analyzed, which shows that the dust suppressant studied in this paper has good performance and is suitable for road dust prevention.

## 1. Introduction

Dust is an environmental hazard. Pneumoconiosis caused by dust seriously threatens the health of workers and reduces the production efficiency of enterprises (Ding et al. 2011; Chen et al. 2015, Sastry et al. 2015; Wang and Zheng 2017). Nearly 34% of the particulate matter in the atmosphere comes from unpaved roads (Csavina et al. 2014; Duan 2013; Azam and Mishra 2019). Research on road dust control is an important issue. General ventilation methods and dust removal equipment have no obvious effect on the prevention and control of road flour dust (Reeks et al. 2014; James et al. 2003), and the current relatively novel and effective method is prevention and control via chemical dust suppressants (Zhang et al. 2018).

Many experts have carried out research on chemical dust suppressants. Goodrich, Koski and Jacobi (2008) studied the performance of synthetic dust suppressants such as magnesium chloride and glycerin and explored their harm to plants. Medeiros et al. (2012) studied dust suppressants produced by glycerol oligomerization under acid and alkaline catalysts, thus obtaining a dust suppressant solution with high viscosity and a good dust suppression effect. Ge et al. (2006) used microwave irradiation to graft acrylic acid onto chitosan to increase the reaction rate and prepare an effective superabsorbent resin. Stabnikov V et al. (2013) conducted performance research on a dust suppressant with calcium chloride as the main component and obtained the conclusion that the dust control rate of the dust suppressant was 99.802%.

Loading [MathJax]/jax/output/CommonHTML/jax.js of dust suppressants synthesized with functional acrylic

resins. S. Gulia et al. (2019) studied the dust suppression effect of calcium magnesium acetate, magnesium chloride, and calcium chloride acting alone or in combination on roads. Chu et al. (2012), Viktor Stabnikov et al. (2013), and others studied the performance of chemically synthesized biopolymer dust suppressants. Sanders (1997) and Edvardsson K. et al. (2012) studied dust suppressants made from lignin derivatives and drew the conclusion that their inhibitory effect is excellent. Jianlong Liu et al. (2000) studied the performance of a MPS dust suppressant which has two mechanisms of wetting and adhesion. Gao et al. (2020) studied a dust suppressant by measuring the pore structure and fractal characteristics of different metamorphic coals. Liang Wenjun et al. (2016) focused on the curing performance of chemical dust suppressants. Zhuoying Tan et al. (2005) studied dust inhibitors using soluble starch, sodium silicate, and glycerin as raw materials which have good wetting, anti-grinding, and anti-evaporation properties. Han et al. (2020) studied a dust suppressant through the effect of a surfactant and ionic liquid on the physical and chemical properties of acidified coal. Xingguang Zhao (2005) studied a dust suppressant made of carboxymethyl starch, glycerin, sodium silicate, and sodium dodecylbenzene sulfonate. After spraying on the road surface, it shows the effect of making the road surface flat and smooth, obviously reducing fine dust and pumice, improving the road surface quality and enhancing the anti-roller performance. Jiayuan Wang et al. (2019) studied the effect of a multi-nozzle atomization interference dust reduction system between hydraulic supports on a fully mechanized mining face. Shuailong Li et al. (2019), Gang Zhou et al. (2018) studied the performance of fire extinguishing adhesives in coal mines. Yongjun Li et al. (2019) studied the dust control of wall-mounted cyclone fans. Pengfei Wang et al. (2019) established a mathematical model of SMD multivariate nonlinear prediction of X-shaped spinning nozzles to investigate the effect of dust suppression.

In general, most dust suppressants currently studied have their own applicable conditions, so they have certain limitations. Inorganic salt can improve the ability of water to wet dust, but it will corrode metal equipment and cause soil salt alkalization. Superabsorbent resin enters the interior of the dust to moisten the dust source, thereby inhibiting the diffusion of dust, but it can only provide a short-term effect, and the ability to resist the wind is poor. Therefore, it is necessary to develop a novel mine compound dust suppressant with high comprehensive benefits.

Therefore, in response to this shortcoming, the research team of this subject has developed a new type of compound chemical dust suppressant, the main components of which are the binder, moisture absorbent, water retention agent, and surfactant. The binder is sodium polyacrylate. Compared with polyacrylamide, sodium carboxymethyl cellulose, and hydroxypropyl methyl cellulose, sodium polyacrylate has a higher viscosity. Sodium carbonate is selected as the hygroscopic agent. The hygroscopic agent determines the anti-evaporation and hygroscopic properties of the dust suppressant. The dust in this study is weakly acidic. Therefore, the alkaline material sodium carbonate with strong water retention is selected as the hygroscopic agent. The moisturizing agent is polyethylene glycol. The commonly used moisturizing agents are glycerol, ethylene glycol and polyethylene glycol. Compared with ethylene glycol, polyethylene glycol is non-toxic and non-irritating. Polyethylene glycol has better moisture retention. Surfactant chooses alkyl glycoside because of its good solubility, strong alkali and electrolyte resistance, good

compatibility with the skin, non-toxic, non-irritating, easy to biodegrade, and can be stored for a long time in a larger temperature range, And has the function of humidification.

In this study, the dust of a surface copper mine road is taken as the research object. First prepare a dust suppressant, and then perform the physical and chemical characterization of the dust suppressant, including the determination of the pH, viscosity, surface tension, and environmental protection. The performance test of the dust agent includes analyzing the hygroscopicity, anti-evaporation, wind erosion resistance, pressure resistance, a corrosiveness test, and a scanning electron microscope experiment. Finally, through the analysis of the dust suppression mechanism, the dust suppression effect of the dust suppression agent is comprehensively evaluated.

## 2. Experimental

### 2.1 Preparation of dust suppressant

According to the best formula of the dust suppressant obtained through the orthogonal experiment (Huang et al. 2021), 500ml of the dust suppressant is configured for subsequent physical and chemical characteristics and dust suppression performance for use. The formula of the dust suppressant is as follows: the mass concentration of sodium polyacrylate is 0.08%, the mass concentration of sodium carbonate is 15%, the volume concentration of polyethylene glycol is 2%, and the volume concentration of alkyl glycosides is 0.15%.

### 2.2 Determination of physical and chemical index characterization of dust suppressant

In this section, the pH value, viscosity value, surface tension and environmental protection of the dust suppressant are measured. The pH value and environmental protection determine whether the dust suppressant can meet the national industrial wastewater discharge standards, and the viscosity value and Surface tension has an influence on the dust suppression effect of the dust suppressant.

#### 2.2.1 Determination of pH

We calibrated the pH meter with the prepared standard buffer solution with pH 4 and pH 9.18 and then used the pH meter to test the pH value of the dust inhibitor solution. The experiment was conducted three times, and the average value was taken as the pH value of the dust suppressant.

#### 2.2.2 Determination of viscosity value

We used the DV2T EXTRA viscometer test to test the viscosity of the prepared solution. At a unit concentration, the higher the viscosity of the bonding factor, the better the bonding effect. The viscosity was measured three times and we took the average value as the viscosity value.

#### 2.2.3 Determination of surface tension

Loading [MathJax]/jax/output/CommonHTML/jax.js

We used the BZY-201 type surface tension meter to test the surface tension of the dust suppressant solution, testing three times and taking the average value as the surface tension value of the dust suppressant solution.

## 2.2.4 Environmental protection test

In order to ensure that the content of heavy metal elements contained in the dust inhibitor solution would not pollute the environment, heavy metal detection of the dust inhibitor solution is required. The contents of selenium, chromium, cadmium, lead, and arsenic in the solution were detected by an ICP-MS plasma mass spectrometer in order to check the heavy metal ion content.

## 2.3 Performance test of dust suppressant

In this section, various performance indicators of the dust suppressant are tested, and the dust suppression effect of the dust suppressant is simulated. The pros and cons of the various performances of the dust suppressant have an impact on the dust suppressant effect, and the simulation test of the dust suppressant effect most intuitively shows the final effect of the dust suppressant.

### 2.3.1 Hygroscopicity test

In order to test the hygroscopic performance of the dust inhibitor, this study compared the hygroscopic effect of the dust inhibitor and tap water. Three samples were prepared for each solution and the final result was averaged. We first added the same amount of dust to the 6 watch dishes, added the dust inhibitor to the first three watch dishes, and the tap water to the last three to make them the same moisture content. After the dropwise addition was completed, the dishes were dried in an oven at 105°C for 2 hours and then taken out, and a hygroscopic test was conducted using a temperature and humidity test box. The experiments were conducted at 20%, 30%, 40%, 50%, 60%, and 70% humidity, and the temperature was uniformly set to 25°C. Under each humidity setting for 6 hours of moisture absorption, the weight of the dust sample was weighed once every hour to obtain its moisture absorption effect that had changed with time.

### 2.3.2 Evaporation resistance test

The dust samples were handled in the same way as in high-temperature anti-evaporation experiments. We first weighed 30 g of dust into the watch glass, then sprayed the prepared dust suppressant solution evenly on the dust surface according to a spraying amount of 2 L/m<sup>2</sup>. We then put the dust sample in a normal temperature environment and monitored the temperature and humidity of the air. We recorded the quality of dust samples and environmental data every day to verify the anti-evaporation of the dust suppressants.

### 2.3.3 Wind erosion resistance test

The erosion of wind is one of the important sources of external force for the destruction of road dust. In this experiment, a wind speed of 3–15 m/s was simulated by a fan to verify the anti-wind erosion effect

of the dust under different wind speeds after spraying the dust suppressant. We chose glass sheets of equal size, spread the same amount of dust on the surface of the glass sheet, sprayed the dust inhibitor and tap water on the surface of the dust with a spray amount of  $2 \text{ L}/\text{m}^2$ , and then sprayed the dust sample of the dust inhibitor and tap water. We put these samples in a drying cabinet at  $105 \text{ }^\circ\text{C}$  for 12 hours and weighed them. Finally, we placed the dust sample in an environment with different wind speeds and created wind at different speeds for 30 minutes to calculate the final loss rate. To reduce errors, three experimental samples were prepared for each experiment and the final results were averaged. The greater the loss rate, the weaker the wind erosion resistance. The calculation formula of loss rate is as follows (1):

$$E = \frac{(w_1 - w_2)}{w_1} \times 100 \quad (1)$$

where  $E$  is the loss rate (%);  $w_1$  is the mass of the dust sample before blowing (g); and  $w_2$  is the mass of the dust sample after blowing (g).

## 2.3.4 Water corrosion resistance test

Under the erosion of rainwater, road dust will destroy its own soil structure, resulting in small particle size dust that is unconstrained and easily dispersed in the air. In order to test the water erosion effect of the dust suppressant, this experiment first placed 30 g of dust in a watch glass, sprayed the dust suppressant and tap water uniformly on the dust surface with a spray amount of  $2 \text{ L}/\text{m}^2$ , and then placed it in a drying cabinet at  $105 \text{ }^\circ\text{C}$  for 12 hours. We weighed the sample after drying, soaked the dust sample in water so that the water could submerge it, then took it out after soaking for 10 minutes. We then put it in the drying cabinet again to dry until the water had evaporated, then weighing and calculating the loss rate after the first water erosion. We repeated the experiment, soaked the dust sample dried in the previous step into the water again, then took it out and dried it after 10 minutes, then weighing. This was repeated 8 times to get the dust loss rate of the dust sample under the repeated erosion of tap water.

## 2.3.5 Compression test

The rolling of vehicles is also one of the external forces that destroys road dust. The stronger the pressure resistance of the dust, the less likely it is to be destroyed by the vehicle, the smaller the generation of dust with a smaller particle size, and the less likely it is to propagate. The purpose of this experiment is to verify whether the dust under the spray dust suppressor has a certain compressive strength to resist the rolling of a vehicle without losing its own dust suppression factor.

First, we took 30 g of dust, sprayed the dust suppressant and tap water evenly on the surface of the dust with a spray amount of  $2 \text{ L}/\text{m}^2$ , and then placed it in a drying cabinet at  $60 \text{ }^\circ\text{C}$  for 12 hours. We used a blade to remove the dust sample from the watch glass, cut out a block of soil of an approximately equal area, and then used a pressure gauge to test its pressure.

## 2.3.6 Corrosion test

In order to measure the corrosiveness of the dust suppressant to metal materials, the corrosiveness was measured. A salt spray corrosion test box was used to detect the corrosion ability of the dust suppressant on the metal material by means of salt spray corrosion. Tap water and the dust suppressant solution were respectively introduced into the salt spray corrosion test box for corrosion detection. In this experiment, 6 carbon steel plates with standard metal corrosion test pieces in accordance with ISO3574 were used for the experiment. The sample size was  $40 \times 13 \times 2 \text{ mm}^3$ . We immersed the carbon steel sheet in alcohol for cleaning. After cleaning, we removed the steel sheet and blow dried to weigh the sample. Finally, we put the sample into the corrosion test box and conducted the experiment for 10 hours. After the experiment, the sample was taken out, and the steel sheet was immersed in a 20% aqueous solution of diammonium citrate. After 10 minutes it was taken out, washed with ethanol, and finally dried and weighed. By calculating the exposed area and density of the sample, the corrosion rate was obtained. The calculation formula is given as follows (2):

$$\eta = \frac{m_0 - m_1}{S \times T} \times \frac{8.76}{\rho} \quad (2)$$

where  $m_0$  is the initial mass of the sample (mg);  $m_1$  is the end mass of the sample (mg);  $S$  is the surface area of the sample ( $\text{cm}^2$ );  $T$  is the experimental time (h); and  $\rho$  is the density of the sample.

In this study, a comparative experiment of the dust suppressant and tap water was carried out. Each group of experiments measured three samples, and the average value was taken as its corrosion rate. In this study, the test piece  $S = 0.001252 \text{ m}^2$ ,  $\rho = 7.84 \text{ g/cm}^3$ , and  $T = 10 \text{ h}$ .

## 3. Results And Analysis

### 3.1 Test results and analysis of physical and chemical indicators

#### 3.1.1 pH test results

The pH of the solution was 11.03, which meets the requirements of pH between 7–12 in the China National Industrial Wastewater Discharge Standard. Therefore, the pH of the dust suppressant solution complies with national standards and will not cause a serious impact on machinery or the environment, etc.

#### 3.1.2 Measurement result of viscosity value

The average value of three results of the solution for the viscosity was  $18.5 \text{ mPa}\cdot\text{s}$ . The viscosity of the solution at this viscosity value can not only play a cohesive role, gather dust particles, and increase the

particle size, but also will not slow down the penetration rate of the solution due to the excessive viscosity. Thus, it can exert a good dust suppression effect.

### **3.1.3 Surface tension measurement results**

The experimental results show that the average surface tension of the solution was 28.1 mN/m. The smaller the surface tension, the stronger the permeability of the solution, which accelerates the wetting speed of the dust. Comparing the orthogonal experiment results, the surface tension of the developed dust suppression solution has reached the effect of quickly wetting the dust, enabling the dust to be captured faster and suppressing flight of the dust.

### **3.1.4 Environmental test results**

The environmental protection test results were as follows: Cr < 1.5 mg/L, As < 0.63 mg/L, Se < 0.01 mg/L, Cd < 0.1 mg/L, Pb < 1 mg/L, which complies with the China National Industrial Wastewater Discharge Standard Requirements. Therefore, the dust suppressant can be discharged normally.

## **3.2 Performance test results and analysis**

### **3.2.1 Test results of moisture absorption**

The experimental results are shown in Fig. 1.

It can be seen from Fig. 1 that when the humidity is 20%, both the dust suppressant dust sample and the tap water dust sample are in a humidity releasing state, indicating that 20% humidity is too small, which will promote moisture to evaporate under both the conditions of the dust suppressant and tap water. When the humidity is 30%, after 6 hours, the dust sample sprayed with the dust suppressant maintains a certain moisture absorption rate, and the dust sample sprayed with tap water is in a humidity releasing state. It can be seen that under this humidity condition, the dust suppressant exerts its own hygroscopic function. With the increase of humidity, both the dust suppressant dust sample and tap water dust sample show better and better moisture absorption effect. The higher the humidity, the greater the moisture absorption rate, and the moisture absorption rate is first fast and then slow. When the humidity is 40%, the final moisture content of the dust sample sprayed with dust suppressant is 0.06%, and the final moisture content of the sprayed tap water is 0.03%; when the humidity is 50%, the final moisture content of the dust sample sprayed with dust suppressor is 0.08% and the final moisture content of sprayed tap water is 0.04%; when the humidity is 60%, the final moisture content of the dust sample sprayed with dust inhibitor is 0.15%, and the final moisture content of the sprayed tap water is 0.06%; when the humidity is 70%, the final moisture content of the dust sample sprayed with dust inhibitor is 0.3%, and the final moisture content of the sprayed tap water is 0.1%. Therefore, it can be concluded that the hygroscopic effect of the dust suppressant is significantly better than that of tap water. The dust suppressant solution can effectively absorb the moisture in the air, increase the moisture content of the dust, and achieve a good dust suppression effect.

### **3.2.2 Evaporation test results**

Loading [MathJax]/jax/output/CommonHTML/jax.js

The experimental results are shown in Fig. 2 and Fig. 3.

It can be seen from Fig. 2 and Fig. 3 that the ambient temperature is basically maintained at about 25°C, and the rate of decrease of the dust sample moisture content changes with the change of humidity. When the humidity is high, the moisture content decreases slowly. When the humidity is low, the moisture content decreases rapidly. However, the humidity of the dust sample under the tap water does not change significantly when the humidity changes. After the moisture content decreases to almost zero on the second day, the moisture content no longer changes significantly, and the dust suppression effect is basically not achieved. The dust sample under the dust suppressant still maintains a moisture content of about 5% on the 10th day, and has the dust suppressant effect, indicating that the dust suppressant has played a significant effect.

We put dust samples that were processed in the same way into the drying cabinet at 30 °C, 40 °C, 50 °C, 60 °C, and 70 °C, evaporating continuously for 6 hours, then weighing the dust sample every hour and observing the moisture content of dust samples at different temperatures changes with time (Omane, Liu, & Pourrahimian, 2018). The experimental results are shown in Fig. 4.

It can be drawn from Fig. 4 that the dust sample under the dust suppressant has a significant anti-evaporation effect compared to tap water. As the temperature increased, the moisture content of the dust sample showed a downward trend. However, the moisture content of the dust sample under running water dropped rapidly. When the temperature was 30 °C, the moisture content of the dust sample was basically 0 after 4–5 hours. At 40 °C, the dust sample was basically unchanged after 4 hours. At 50 °C, the moisture content of the dust sample was basically zero after 3 hours. At 60 °C and 70 °C, the dust content did not continue to change after the moisture content became zero after 2 hours. For the dust samples under the dust inhibitor after 6 hours, with the temperature rising, the final moisture content showed a downward trend, i.e., from 30 °C to 70 °C, the moisture contents were 9%, 7%, 6%, 5%, and 3%, respectively. It can be seen that at higher temperatures, the dust suppressant can still keep the dust at a certain humidity.

### 3.2.3 Wind erosion resistance test results

The experimental results are shown in Table 1.

**Table 1**

Loss rate at different wind velocities.

Wind velocity (m/s)	Dust suppressant		Loss rate (%)	Running water		Loss rate (%)
	Before the experiment (g)	After the experiment(g)		Before the experiment (g)	After the experiment (g)	
3	54.7372	54.7349	0.004	44.4476	44.0031	1
6	54.8854	54.8811	0.008	53.5633	51.5815	3.7
9	54.0774	54.0726	0.009	53.3777	44.0366	17.5
12	54.4275	54.4213	0.01	53.1375	32.4670	38.9
15	58.3663	58.3162	0.18	54.8847	26.1251	52.4

From Table 1, the dust sample sprayed with dust suppressant has a loss rate of only 0.004% at a wind speed of 3 m/s, while the loss rate of sprayed tap water at this wind speed is 1%. With the increase of wind speed, the dust loss rate of spraying dust suppressant increased slowly, while the dust loss rate of spraying tap water increased obviously. When the wind speed increases to 12 m/s, the loss rate of tap water reaches 38.9%, while the loss rate of dust suppressant is only 0.01%, thus, the loss rate of dust samples sprayed with tap water is much greater than the loss rate of sprayed dust suppressants. When the wind speed is 15 m/s, the loss rate of the dust sample sprayed with dust suppressant becomes larger because the wind speed is too large, which causes some small particles in the dust sample to be separated from the dust body and blown away by the wind. As a result, the loss rate has increased. However, compared with the dust samples sprayed under tap water, the loss rate of dust samples sprayed with dust suppressant is much lower than that of the dust samples sprayed under tap water. Therefore, the dust suppressant exhibits very good resistance to wind erosion.

### 3.2.4 Water corrosion resistance test results

The experimental results are shown in Fig. 5.

It can be seen from Fig. 5 that the loss rate of the dust sample sprayed with the dust suppressant increased relatively slowly. However, the dust sample sprayed with tap water began to rise rapidly after the third experiment. After 8 experiments, the loss rate of the dust sample sprayed with the dust suppressant was less than 5%. The loss rate of the dust sample under running water showed a rapid growth trend, and the growth rate accelerated in the later period, and the final loss rate was as high as 27%. Therefore, the dust suppressant has very good water corrosion resistance.

### 3.2.5 Compression resistance test results

The result of the experiment is that the pressure of the dust sample sprayed with dust suppressant is 275 kPa, and the pressure of the dust sample sprayed with tap water is 73.6 kPa. Therefore, it can be concluded that compared with the dust samples under running water, the dust suppressant has good

compressive performance and can withstand the rolling compaction of transport vehicles with a larger load on the premise of no damage to the soil.

### 3.2.6 Corrosion test results

The experimental results are shown in Table 2.

**Table 2**

Corrosion rate test results.

	Before the experiment (g)	After the experiment (g)	Corrosion rate (g/m <sup>2</sup> ·h)	Corrosion rate (mm/a)	Average value (mm/a)
Dust suppressant	22.1856	22.183	0.20	0.22	0.17
	22.1858	22.1837	0.17	0.19	
	21.7482	21.747	0.10	0.11	
Running water	22.0099	22.0084	0.12	0.13	0.11
	21.8038	21.8024	0.11	0.12	
	21.8614	21.8606	0.06	0.07	

### 3.2.7 Research on dust suppression mechanism of dust suppressant

The results of the scanning electron microscopy are shown in Fig. 6. The experimental results of the dust suppression effect of the dust suppressant and the results of the scanning electron microscope show that the dust suppressant has a good dust removal and dust reduction effect (Huang et al. 2021). The results of the experiment are as follows: the dust removal efficiency of dust suppressant to total dust is 97.62%, the dust removal efficiency of water to total dust is 42.06%, the dust removal efficiency of dust suppressant to respirable dust is 88.97%, and the dust removal efficiency of water to respirable dust It is 48.53%. In these two kinds of dust experiments, the dust removal efficiency of the dust suppressant solution is much higher than that of water. From the results of scanning electron microscopy, it can be seen that spraying the dust suppressant has a good consolidation effect, forming a compact structure on the surface of the dust suppressing agent, which can effectively resist wind erosion and is not easy to generate secondary dust; the dust-like surface dust after spraying tap water There are many small-size dusts dispersed, and these dust particles are easily separated from the dust body under the action of external force and dispersed in the air, causing dust. The scanning electron microscope results are shown in Fig. 6.

The dust suppressant studied in this paper is composed of binder, moisture absorbent, water-retaining agent and surfactant. Their respective dust suppressing mechanism has an important influence on the

Loading [MathJax]/jax/output/CommonHTML/jax.js

choice of dust suppressant formulation and the effect of dust suppressant.

#### (1) Dust suppression mechanism of binder sodium polyacrylate

The dust suppression mechanism of the binder sodium polyacrylate is mainly reflected in its thickening effect. There are two main thickening mechanisms: neutralization thickening and hydrogen bond thickening. Neutralization and thickening by the same-sex electrostatic repulsion of carboxylate ions, the molecular chain stretches from a spiral to a rod shape, thereby increasing the viscosity of the water phase. Hydrogen bond thickening is the combination of polyacrylic acid and water molecules to form hydrated molecules, and hydroxyl and polyacrylic acid will form hydrogen bonds. The hydrogen bonds will cause the molecular chains of polyacrylic acid to be unwound in water to form a network structure. The viscosity is increased, as shown in Fig. 7. The greater the viscosity, the easier it is for the solution to stick dust particles together, reduce the amount of small-size dust, and reduce the possibility of it being dispersed in the air under the action of power.

#### (1) Dust suppression mechanism of hygroscopic agent sodium carbonate

When sodium carbonate is exposed to the air for a long time to absorb moisture in the air, it will react with carbon dioxide to form sodium bicarbonate, as shown in Fig. 8. The sodium bicarbonate generated by the reaction will form hard lumps to prevent the evaporation of water, covering the surface of the dust to play a good water retention effect, so that the moisture absorption rate of the dust suppressant is increased, so that the dust can maintain a certain moisture content and is not easily damaged by external forces.

#### (2) Dust suppression mechanism of water retaining agent polyethylene glycol

The molecular structure of polyethylene glycol contains a large number of hydroxyl groups. The hydroxyl group is a hydrophilic group, and the hydrogen bond formed with water molecules is a strong intermolecular force. In addition, the hydroxyl group has a large polarity and is easy to combine with water with a large dielectric constant and therefore retains water. When the external humidity is low, it will further absorb water to achieve the effect of water retention, as shown in Fig. 9.

#### (3) Dust suppression mechanism of surfactant alkyl glycosides

Alkyl glycoside molecules have a hydrophilic group and a lipophilic group. Due to the repulsion between the lipophilic group and the water molecule, in order to seek the lowest energy form of existence, the surfactant molecule will first turn the hydrophilic group downwards and the lipophilic group upwards. The forms are arranged on the surface of the aqueous solution, as shown in Fig. 10.

Hydrophilic groups are attracted downward by water molecules, but this attraction is weaker than the attraction between water molecules. The reason is that the polarity of hydrophilic groups is weaker than water molecules; lipophilic groups are attracted upward by air molecules. This attraction is stronger than that of air molecules and water molecules. The reason is that the relatively large volume allows the

better It merges and attracts air molecules. Therefore, the downward force decreases and the upward force increases, and the imbalance of the force is improved, so the surface tension is reduced. At the same time, there is the surface of the aqueous solution of surfactant molecules, and the attraction between the molecules is weakened, so that the surfactant can reduce the surface tension. The smaller the surface tension, the smaller the contraction force, the easier it is to spread on the surface, and the easier it is for the dust suppressant solution to wet the dust.

## 4 Conclusions

1. Through the analysis of the physical and chemical properties, the viscosity value of the dust suppressant is 18.5 mPa·s and the surface tension is 28.1 mN/m. The pH value and the content of heavy metal ions contained in the dust suppressant both meet the requirements of the National Industrial Wastewater Discharge Standard. Therefore, the dust suppressant can be discharged normally.
2. The dust suppressant has good hygroscopicity and anti-evaporation performance. At the same temperature, the greater the humidity, the stronger the hygroscopicity. When the humidity is 30%, it shows an obviously better hygroscopic effect than water. This further proves the hygroscopic performance of the dust suppressant. The dust suppressant also has good anti-evaporation properties and maintains a moisture content of 4–5% after 10 days at room temperature and has the ability to suppress dust.
3. The dust suppressant has good wind erosion resistance, water erosion resistance, compression resistance, and corrosion resistance. Under the same conditions, the water loss rate is much greater than that of the dust suppressant, and the pressure of the dust sample sprayed with the dust suppressant is about 3 times that of the tap water. In the water corrosion resistance test, compared with the 27% loss rate of tap water, the loss rate of the dust suppressant is only 5%.
4. SEM Both the SEM experiment and the dust suppression effect experiment show that the dust suppressant has a good dust suppression effect. Through the research on the dust suppression mechanism of each component of the dust suppressant, it is found that the binder can increase the viscosity of the dust, the moisture absorbent and the water retaining agent can increase the water absorption rate so that the absorbed dust is not easily damaged by external forces, and the surfactant can reduce Surface tension makes it easier for the dust suppressant to wet the dust.

## Declarations

**Authors' contributions** The authors' individual contributions to the paper are as follows: Zhian Huang: Mechanism analysis. Yang Huang: Laboratory experiments. Zhijun Yang and Jun Zhang: Field effect test. Yinghua Zhang: Results analysis. Yukun Gao, Zhenlu Shao and Linghua Zhang: Laboratory experiments.

**Conflicts of interest** The authors declare no conflict of interest.

**Availability of data and materials** The data and materials used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Loading [MathJax]/jax/output/CommonHTML/jax.js

**Ethics approval and consent to participate** Not applicable.

**Consent for publish** Written informed consent for publication was obtained from all participants.

## Funding

The authors appreciate the financial support of project No. 51974015, No. 51904292, and No. 51474017 provided by the National Natural Science Foundation of China, project No. FRF-IC-20-01 and project No. FRF-IC-19-013 provided by the Fundamental Research Funds for the Central Universities, project No. 2018YFC0810601 provided by the National Key Research and Development Program of China, project No. 2017CXNL02 provided by the Fundamental Research Funds for the Central Universities (China University of Mining and Technology), project No. BK20180655 provided by the Natural Science Foundation of Jiangsu Province, project No. WS2018B03 provided by the State Key Laboratory Cultivation Base for Gas Geology and Gas Control (Henan Polytechnic University), and project No. E21724 provided by the Work Safety Key Lab on Prevention and Control of Gas and Roof Disasters for Southern Coal Mines of China (Hunan University of Science and Technology).

## References

1. Azam S, Mishra DP (2019) Effects of Particle Size, Dust Concentration and Dust-Dispersion-Air Pressure On Rock Dust Inertant Requirement For Coal Dust Eplosion Suppression In Underground Coal Mines. *Process Saf Environ* 126:35–43. <https://doi.org/10.1016/j.psep.2019.03.030>
2. Chen RH, Wang BQ, Wang ZB, Yao S (2015) The pollution character analysis and risk assessment for metals in dust and PM10 around road from China. *Biomed Environ Sci* 28:44–56. <https://doi.org/10.3967/bes2015.005>
3. Chu J, Stabnikov V, Ivanov V (2012) Microbially in- duced calcium carbonate precipitation on surface or in the bulk of soil. *Geomicrobiol J* 29: 544–549. <https://doi.org/10.1080/01490451.2011.592929>
4. Csavina J, Taylor MP, Felix O, Rine KP, Saez AE, Betterton EA (2014) Size-resolved Dust and Aerosol Contaminants Associated with Copper and Lead Smelting Emissions: Implications for Emission Management and Human Health. *Sci Total Environ* 493:750–756. <https://doi.org/10.1016/j.scitotenv.2014.06.031>
5. Cui D, Nie BS, Yang H, Dai LC, Zhao CH, Zhao F, Li HL (2011) Experimental research on optimization and coal dust suppression performance of magnetized surfactant solution. *Procedia Eng* 26:1314–1321. <https://doi.org/10.1016/j.proeng.2011.11.2306>.
6. Duan ZY (2013) Research on Dust Suppression of a Copper Mine Underground Middle Level Crushing Station. *Adv Environ Technol* 726–731:907–912. <https://doi.org/10.4028/www.scientific.net/AMR.726-731.907>
7. Edvardsson K, Gustafsson A, Magnusson R (2012) Dust suppressants efficiency study: in situ measurements of dust generation on gravel roads. *Int J Pavement Eng* 13(1):11–13. <https://doi.org/10.1080/10298426.2011.561844>

8. Ge HC, Pang W, Luo DK (2006) Graft copolymerization of chitosan with acrylic acid under microwave irradiation and its water absorbency. *Carbohydr Polymers* 66:372–378.  
<https://doi.org/10.1016/j.carbpol.2006.03.017>.
9. Goodrich BA, Koski RD, Jacobi WR (2008) Roadside Vegetation Health Condition and Magnesium Chloride (MgCl<sub>2</sub>) Dust Suppressant Use in Two Colorado, U. S. Counties. *J Arboric* 34(4):252–259
10. Gulia S, Goyal P, Goyal SK, Kumar R (2019) Re-suspension of road dust: contribution, assessment and control through dust suppressants—a review. *Int J Environ Sci Technol* 16:1717–1728.  
<https://doi.org/10.1007/s13762-018-2001-7>.
11. Han WB, Zhou G, Gao DH, Zhang ZX, Wei ZY, Wang HT, Yang HQ (2020) Experimental analysis of the pore structure and fractal characteristics of different metamorphic coal based on mercury intrusion-nitrogen adsorption porosimetry. *Powder Technol* 362: 386–398. <https://doi.org/10.1016/j.powtec.2019.11.092>
12. Han WB, Zhou G, Zhang QT, Pan HW, Liu D (2020) Experimental study on modification of physicochemical characteristics of acidified coal by surfactants and ionic liquids. *Fuel* 266: 116966.  
<https://doi.org/10.1016/j.fuel.2019.116966>
13. Huang ZA, Zhao W, Yang ZJ, Zhang J, Gao YK, Shao ZL, Zhang YH, Zhang LH, Wen SY (2021) Preparation and characterization of an environmentally friendly compound chemical agent for road dust suppression in a copper mine. *Environ Prog Sustainable Energy* 40:e13532.  
<https://doi.org/10.1002/ep.13532>
14. James PW, Wang Y, Azzopardi BJ, Hughes JP (2003) The Role of Drainage Channels in the Performance of Wave-Plate Mist Eliminators. *Chem Eng Res Des* 81(6):639–648.  
<https://doi.org/10.1205/026387603322150499>
15. Liang WJ, Ren CD, Ma H, Wang S, Zhao J (2016) Research progress on the preparation of chemical dust suppression agent and the mechanism of dust suppression. *Guangzhou Chemical Industry* 44(15):22–23
16. Li SL, Zhou G, Wang YY, Jing B, Qu YL (2019) Synthesis and characteristics of fire extinguishing gel with high water absorption for coal mines. *Process Saf Environ Prot* 125:207–218.  
<https://doi.org/10.1016/j.psep.2019.03.022>
17. Liu JL, Li J, Peng XW, Zhou XJ (2000) MPS type dust suppressant and its application. *Industrial Health Occupational Diseases* 84–88. <https://doi.org/10.13692/j.cnki.gywszyzb.2000.02.007>
18. Ma YL, Zhou G, Ding JF, Li SL, Wang G (2018) Preparation and characterization of an agglomeration-cementing agent for dust suppression in open pit coal mining. *Cellulose* 25:4011–4029.  
<https://doi.org/10.1007/s10570-018-1826-z>.
19. Medeiros MA, Leite CMM, Lago RM (2012) Use of glycerol by-product of biodiesel to produce an efficient dust suppressant. *Chem Eng J* 180:364–369. <https://doi.org/10.1016/j.cej.2011.11.056>.
20. Omori E, Zhang YC, Zhu CQ, Yu SX (1993) Functional acrylic resin. *tran. Chemical Industry Press, Beijing*, pp 308–312

21. Omane D, Liu WV, Pourrahimian Y (2017) Comparison of chemical suppressants under different atmospheric temperatures for the control of fugitive dust emission on mine hauls roads. *Atmos Pollut Res* 9:561–568. <https://doi.org/10.1016/j.apr.2017.12.005>.
22. Reeks M, Jin C, Potts I (2014) A simple stochastic quadrant model for the transport and deposition of particles in turbulent boundary layers. *Aps Meeting. APS Meeting Abstracts*
23. Sanders TG (1997) Relative Effectiveness of Road Dust Suppressants. *J Transp Eng* 123(5): 393–397. [https://doi.org/10.1061/\(ASCE\)0733-947X\(1997\)123:5\(393\)](https://doi.org/10.1061/(ASCE)0733-947X(1997)123:5(393))
24. Sastry VR, Chandar KR, Nagesha KV, Muralidhar E, Shoeb M (2015) Prediction and analysis of dust dispersion from drilling operation in Opencast Coal Mines. *Procedia Earth Planet Sci* 11:303–311. <https://doi.org/10.1016/j.proeps.2015.06.065>
25. Stabnikov V, Chu J, Myo AN, Ivanov V (1993) Immobilization of Sand Dust and Associated Pollutants Using Bioaggregation. *Water Air Soil Pollut* 224(9):1–9. <https://doi.org/10.1007/s11270-013-1631-0>
26. Tan ZY, Liu WJ, Zhao XG, Cai MF (2005) Selection of Ecological Dust Inhibitor and Experimental Simulation Research. *Acta Sci Circum* 675–680. <https://doi.org/10.13671/j.hjkxxb.2005.05.019>
27. Wang PF, Li YJ, Liu RH, Shi YJ (2019) Effect of forced-to-exhaust ratio of air volume on dust control of wall-attached swirling ventilation for mechanized excavation face. *Tunn Undergr Space Technol* 90: 194–207. <https://doi.org/10.1016/j.tust.2019.04.026>
28. Wang PF, Tian C, Liu RH, Wang J (2019) Mathematical model for multivariate nonlinear prediction of SMD of X-type swirl pressure nozzles. *Process Saf Environ Prot* 125:228–237. <https://doi.org/10.1016/j.psep.2019.03.023>
29. Wang J, Zheng LJ (2017) Development tendency and monitoring technology of dust occupational hazard in coal mine. *Coal Science Technology* 45(11):119–125. <https://doi.org/10.13199/j.cnki.cst.2017.11.020>
30. Wang JY, Zhou G, Wei X, Wang SC (2019) Experimental characterization of multi-nozzle atomization interference for dust reduction between hydraulic supports at a fully mechanized coal mining face. *Environ Sci Pollut Res* 26(10):10023–10036. <https://doi.org/10.1007/s11356-019-04413-w>
31. Zhang HH, Nie W, Wang HK, Jin BQ, Liu H YH (2018) Preparation and experimental dust suppression performance characterization of a novel guar gum-modification-based environmentally-friendly degradable dust suppressant. *Powder Technol* 339: 314–325. <https://doi.org/10.1016/j.powtec.2018.08.011>
32. Zhao XG (2005) Research on Control of Dust Suppression in Transportation Road of Tonglushan Mine. Guangxi University

## Figures

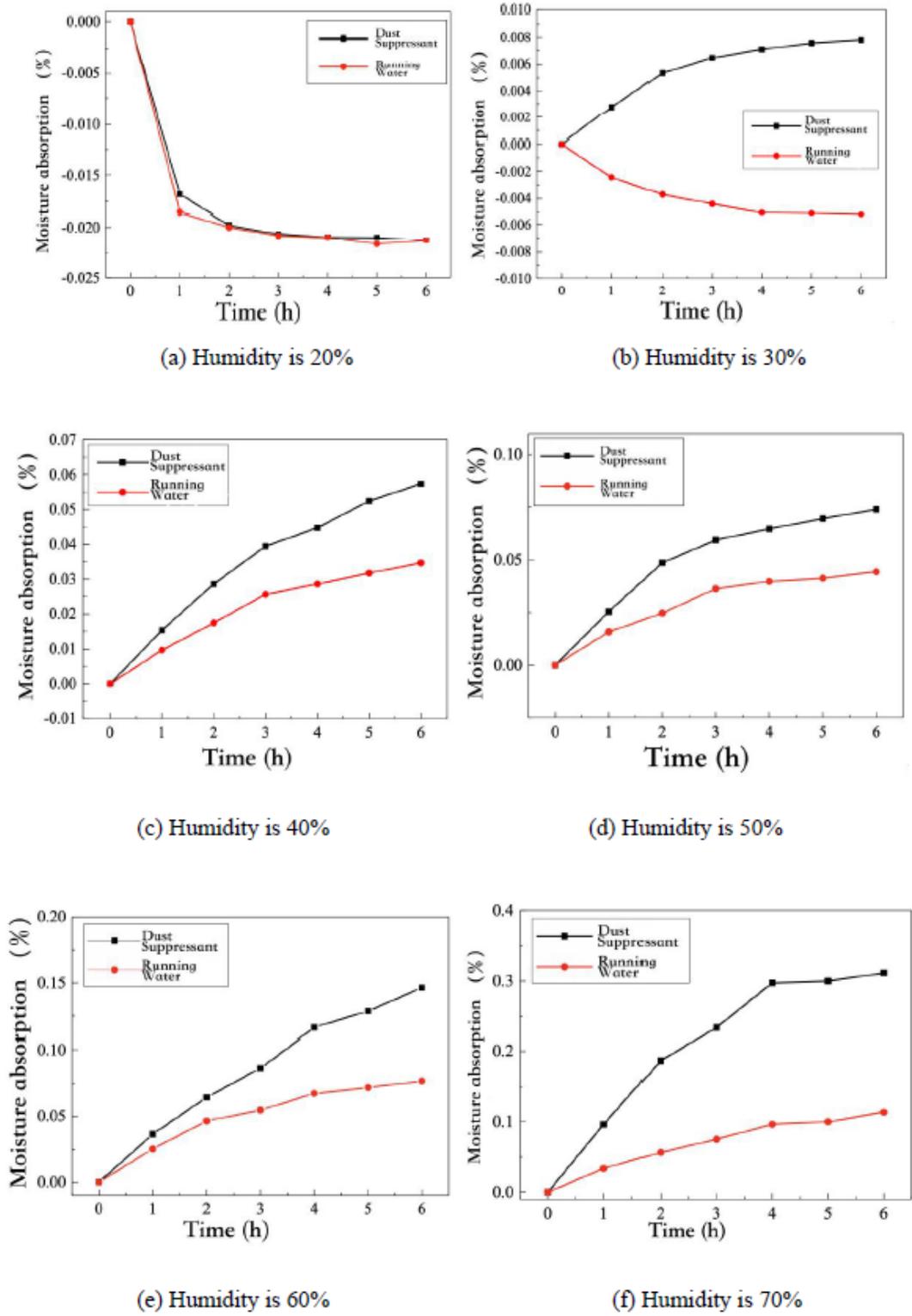


Figure 1

Hygroscopic rate under different humidity

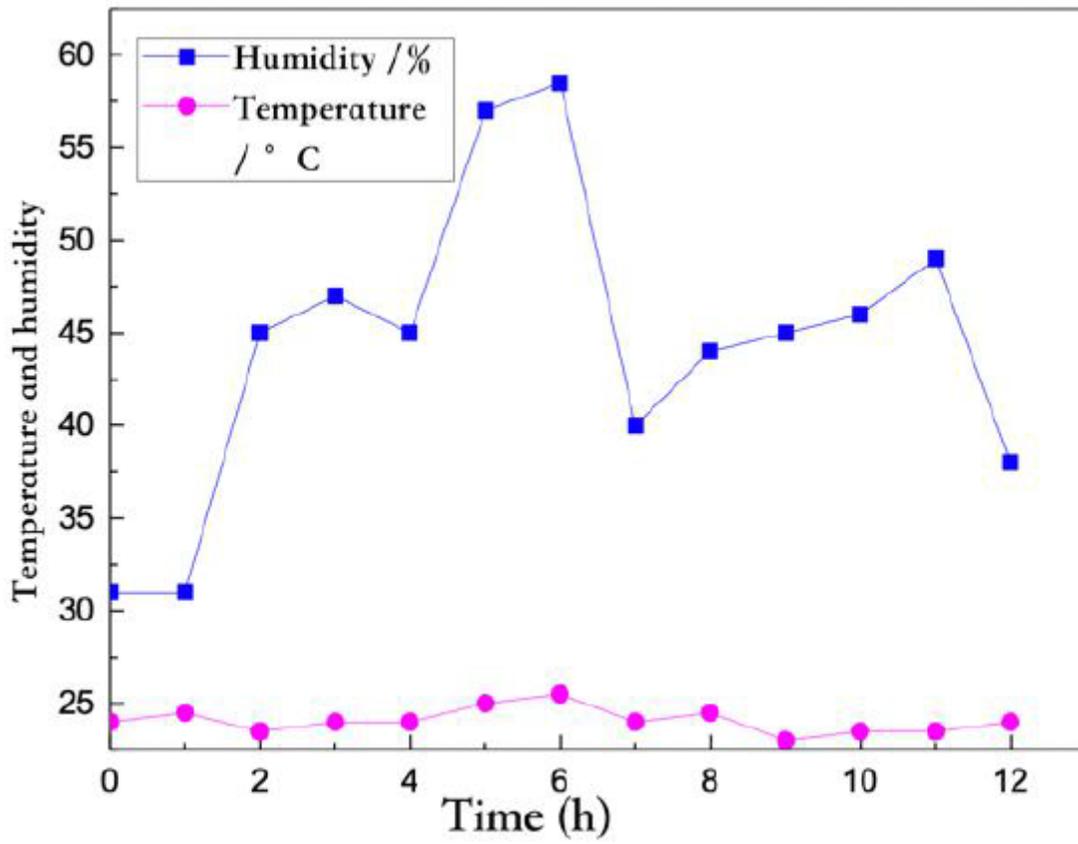


Figure 2

Environmental temperature

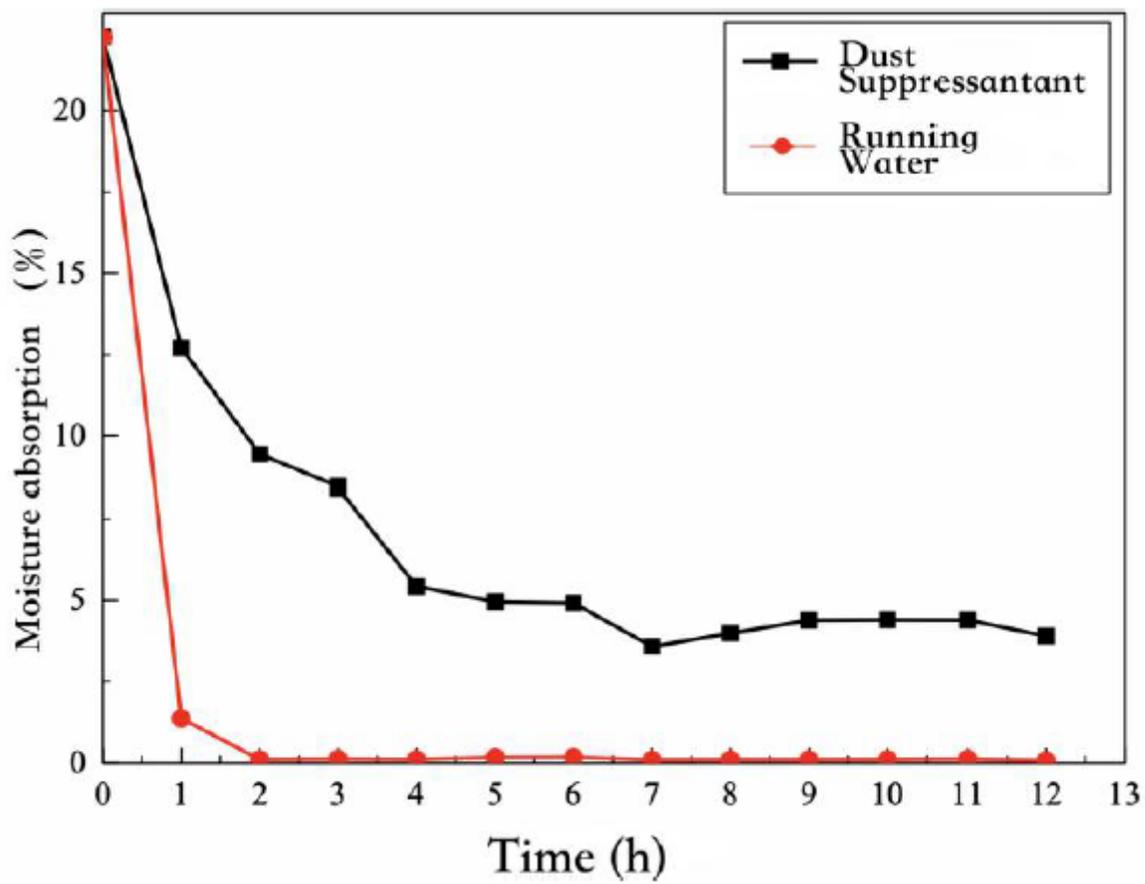
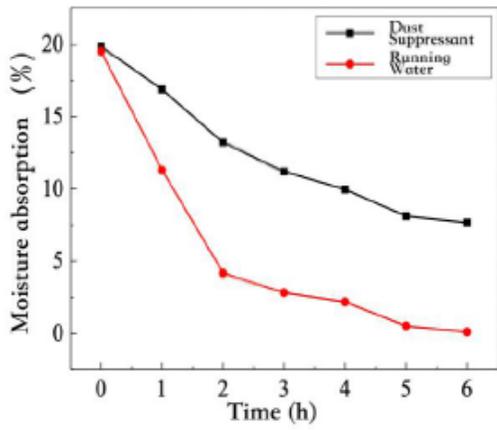
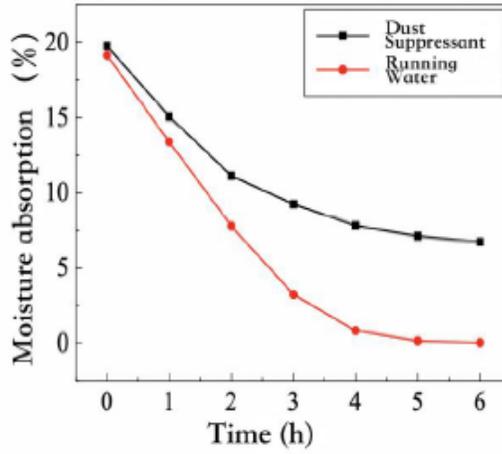


Figure 3

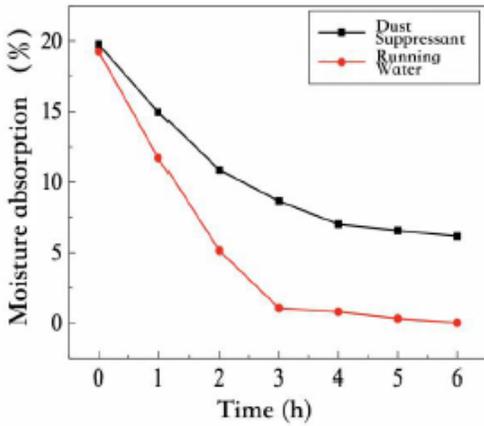
Change of moisture



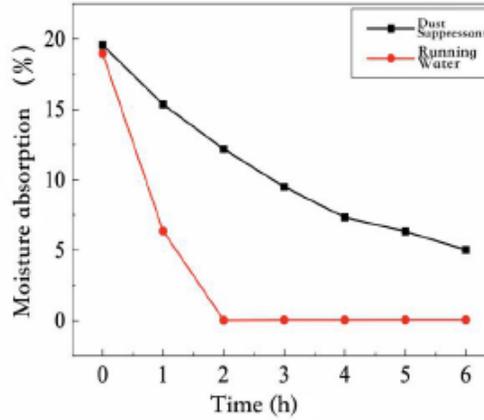
(a) Temperature is 30 °C



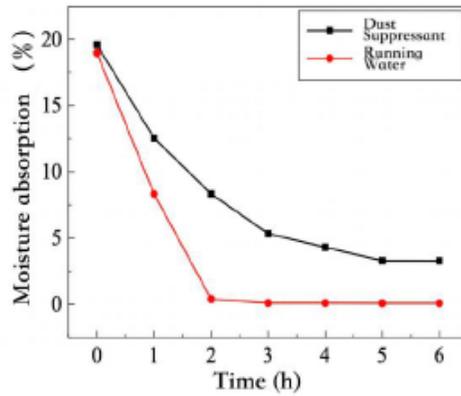
(b) Temperature is 40 °C



(c) Temperature is 50 °C



(d) Temperature is 60 °C



(e) Temperature is 70 °C

**Figure 4**

Moisture content at different temperatures

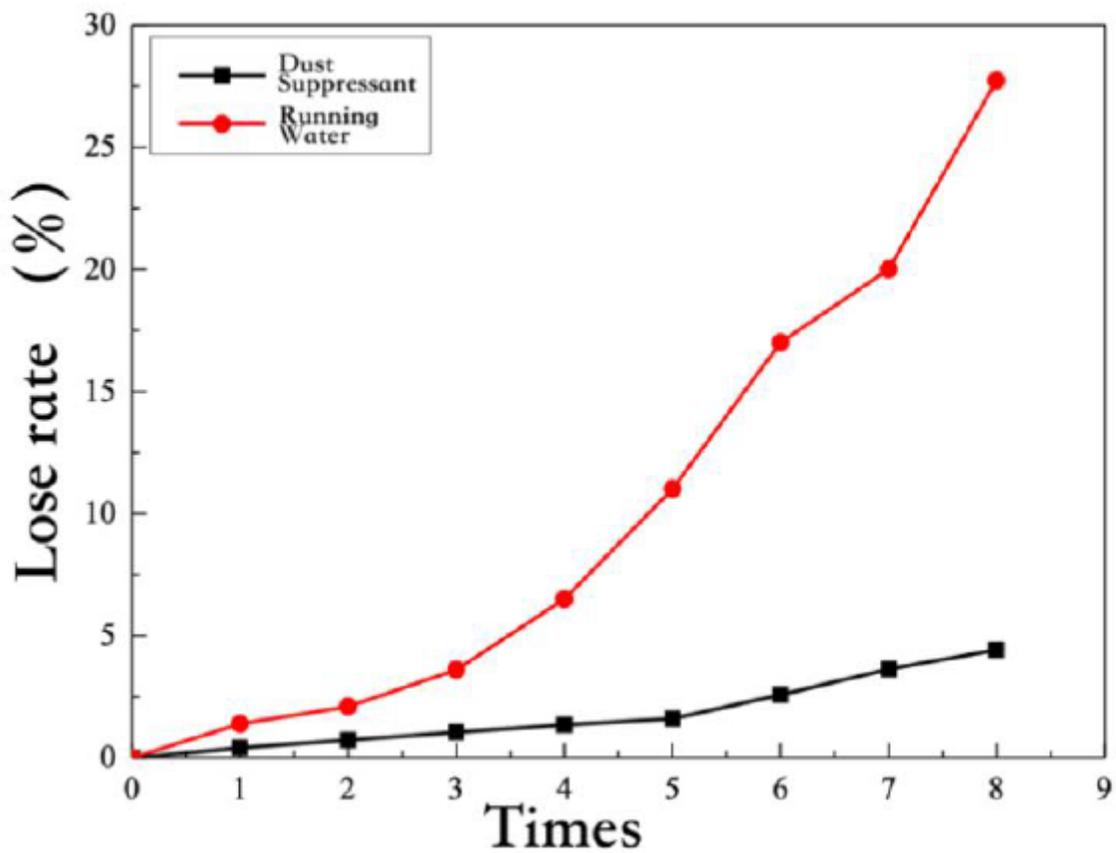


Figure 5

Water erosion resistance results

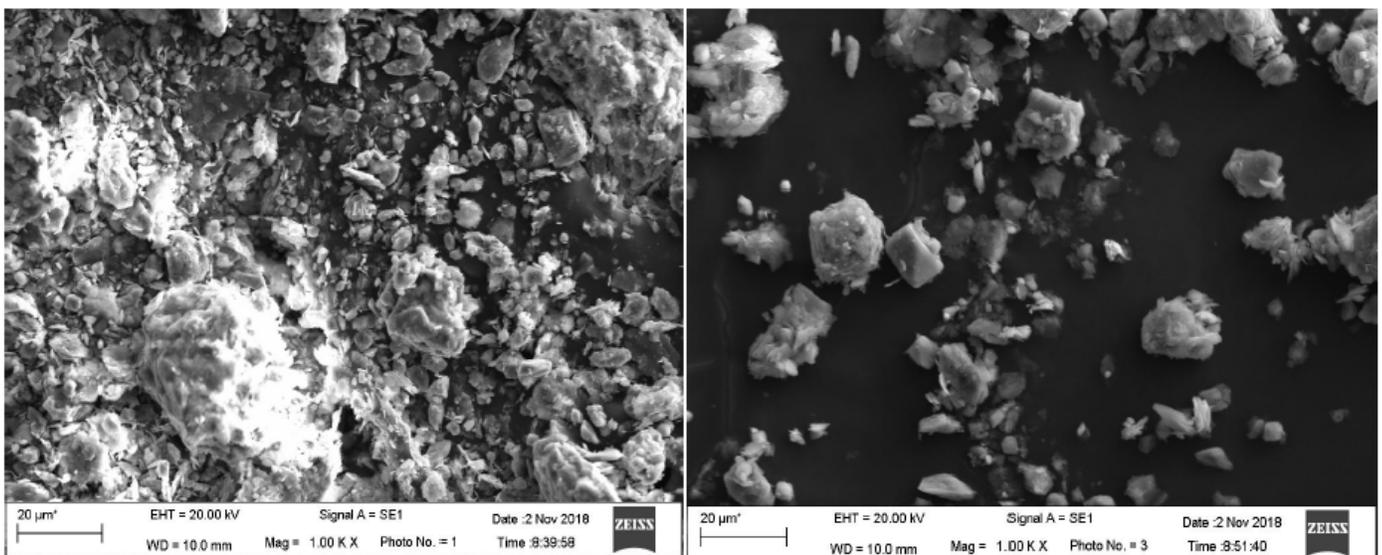


Figure 6

Microscopic changes in the surface of the dust sample sprayed with a dust suppressant (left) and the dust sample sprayed with tap water (right) (Huang et al. 2021)

Loading [MathJax]/jax/output/CommonHTML/jax.js

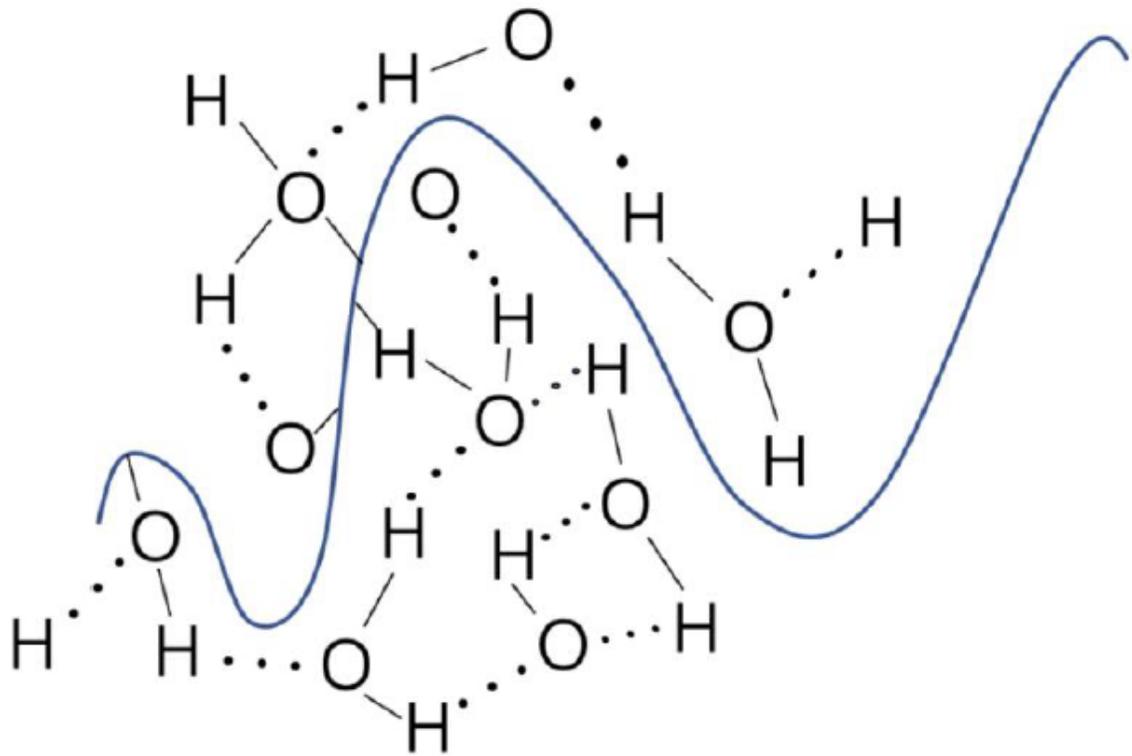


Figure 7

Hydrogen bond network

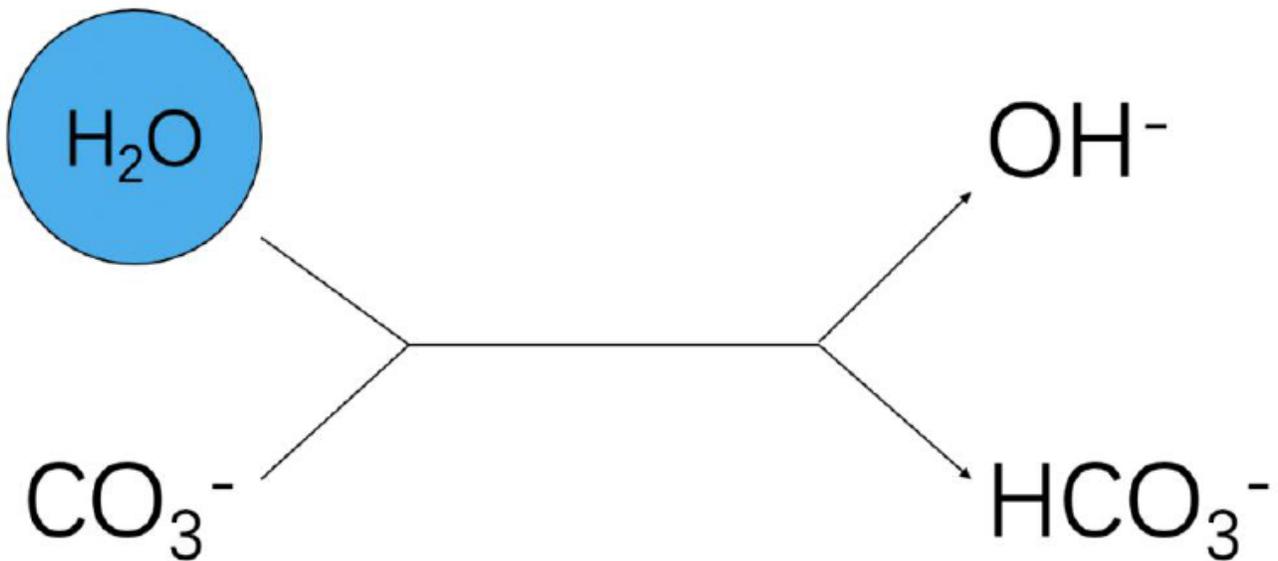


Figure 8

Carbonate to bicarbonate

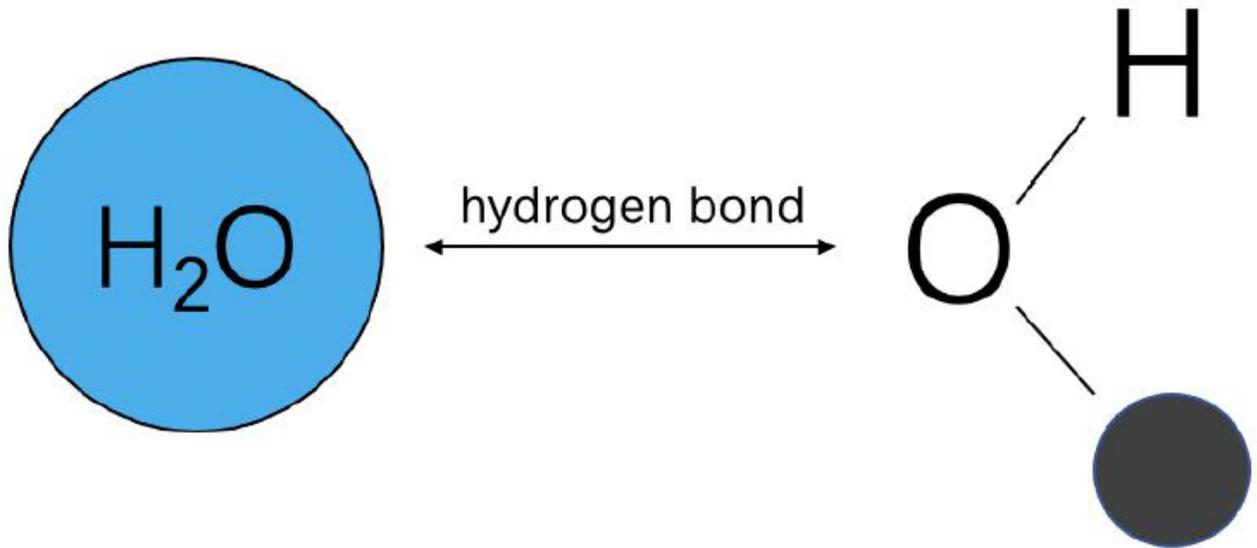


Figure 9

Polyethylene glycol moisture absorption principle

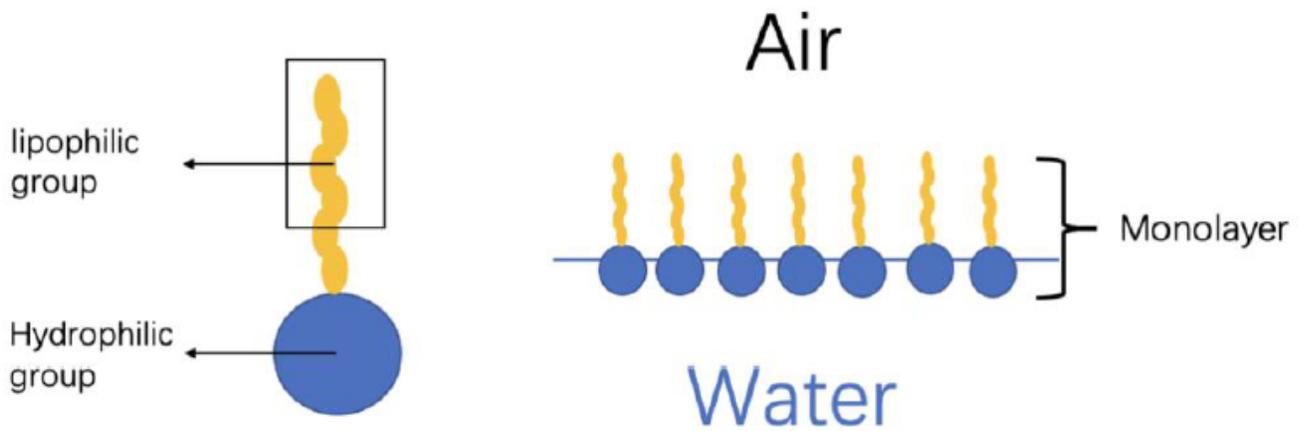


Figure 10

Surfactant schematic