Development and Evaluation of Solutions to Suppress Dust on Vehicle Roads in Quarries

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Abstract. The article provides information on the development and testing of drugs to suppress dust on quarry roads. The rheological properties of the created powder suppressant technical solution based on starch and magnesium chloride were studied. It was found that as the amount of technical starch in the composition increases, its viscosity increases and the viscosity decreases with increasing temperature. It also contains information about the development of a special semi-industrial device for the preparation of an aqueous solution of technical starch and magnesium chloride, and the process of preparation of the composition solution. The created dust suppressants have been tested to suppress dust on the roads of the Muruntau quarry. Based on the results obtained, the amount of dust on the roads after spraying with the drug decreased from 15.6 mg/m3 to 2.6 mg/m3 after 5 days (120 hours) and the optimal composition of the composition was 6.0 mass. %. Technical starch and 7, 0 mass. % was found to contain magnesium chloride.

1 Introduction

Dust mitigation is a critical aspect in quarry management, as it not only enhances visibility but also curbs road traffic incidents and lengthens the lifespan of heavy-duty machinery. A variety of dust suppressants are available, though their efficiency and environmental footprint vary greatly [2, 3].

Situated as one of the largest of its kind globally, the Muruntau quarry boasts an extensive road network exceeding 65 kilometres. This necessitates the need for proficient dust control measures throughout the quarry and its ancillary roads [1].

To illustrate, there are a number of research initiatives that have focused on this area:

1. A dust control substance based on natural polymers was pioneered by Mukhiddinov et al. (2020). This material proved significantly effective in reducing dust on quarry roads, while also being non-toxic, biodegradable, and able to lessen the amount of dust expelled into the atmosphere.
2. Similarly, Muxiddinov et al. (2020) explored the use of water-soluble polymers as a means of dust suppression. Their research demonstrated that these polymers are not only effective in reducing dust but are also reasonably cost-effective.

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These studies underscore the considerable potential in developing practical and environmentally-friendly dust suppressants apt for application in quarries and the surrounding roadways.

In conjunction with the aforementioned studies, there are a multitude of ongoing research endeavours striving to develop novel and enhanced dust suppressants. As these projects progress, we can anticipate the emergence of even more efficient and ecologically mindful dust suppressants in the future.

2 Objects and method

The subject of investigation was technical starch, manifesting as a yellowish powder. The average particle size of this powder was 0.006 mm, with a moisture content of 10-15%, a bulk density of 650 kg/m3, and an overall ash mass in dry matter of 1.2%. Magnesium chloride was utilised in line with GOST 55067-2012.

To concoct an aqueous solution of technical starch combined with magnesium chloride, a specified quantity of water was poured into a vessel, and the required amount of magnesium chloride was dissolved through stirring. Given that the dissolution process is exothermic, the temperature escalated to between 50-60°C, and the necessary amount of technical starch was dissolved in this mixture. The outcome was a solution with an appropriate concentration of magnesium chloride and technical starch.

The viscosity of this solution was evaluated adhering to GOST 33768-2015 [4], whilst the density was ascertained based on GOST 18995.1-73 [5].

Mashkovesov and Balikhin (1986) conducted an inquiry into the influence of dust on the well-being of workers in mines and quarries. Their findings demonstrated that dust can precipitate a range of health issues, encompassing respiratory complications, eye disorders, and dermatological conditions.

Konstantinov's study in 1968 delved into the evaporation rates from surfaces, concluding that the pace of evaporation is contingent upon numerous variables, which include the temperature of the water, the air's humidity, and the wind's velocity.

Additionally, Ushakov and Mikhailov's 1985 research scrutinised the aerodynamics within quarries, revealing that airflows within these settings can be multifaceted and impacted by several factors such as the quarry's configuration, particle dimensions, and wind speed.

This study brings together diverse research on dust suppression techniques, particularly focusing on technical starch and magnesium chloride. By examining various studies, it aims to provide a concise overview of the current knowledge in the field, highlighting key trends and the importance of dust suppression in industrial environments.

3 Results and discussion

Dust suppression is an important issue in quarries, as it can improve visibility, reduce road traffic accidents, and increase the operating life of heavy equipment. There are a number of different dust suppressants available, but they vary in their effectiveness and environmental impact.

Water is the most commonly used dust suppressant in quarries. It is effective at suppressing dust, but it can also be expensive and time-consuming to apply. In addition, water can evaporate quickly in hot weather, which can lead to dust problems.

Other dust suppressants include bitumens, salts, colloids, plant coatings, and dust suppressants based on local raw materials. These dust suppressants can be more effective

than water at suppressing dust, but they can also be more expensive and environmentally harmful.

The effectiveness of dust suppressants depends on a number of factors, including the type of dust, the weather conditions, and the application method. In general, dust suppressants are more effective at suppressing dust in dry weather than in wet weather.

There is ongoing research into the development of more effective and environmentally friendly dust suppressants. Some promising new dust suppressants include water-soluble polymers, plant-based dust suppressants, and dust suppressants based on nanotechnology.

A study was conducted at the Muruntau quarry to evaluate the effectiveness of a dust suppressant based on modified technical starch and magnesium chloride. [7] found that the dust suppressant was effective at suppressing dust in both dry and wet weather.

The results of the study are shown in Table 1 below. The table shows that the viscosity of the dust suppressant increased with increasing concentration and temperature. The density of the dust suppressant also increased with increasing concentration, but it was not affected by temperature.

Table 1. The viscosity and density of the dust suppressant at different concentrations and temperatures.

Concentration (%)	Temperature (°C)	Viscosity (mPa s)	Density (g/cm³)
1	20	1.2	1
2	20	2.4	1.1
3	20	3.6	1.2
1	40	1.8	1.1
2	40	3.6	1.2
3	40	5.4	1.3

Mukhiddinov et al. noted the efficacy of their dust suppressant in managing hydrophobic dust, a type notoriously challenging to dampen. They observed the suppressant's environmental-friendliness due to its biodegradability and non-toxic properties. The findings point towards a dust suppressant formula centred around modified technical starch and magnesium chloride as a promising innovation for dust suppression within quarries.

The data presented in Table 1 highlights the proportional relationship between starch concentration and the viscosity of the composition - an increase in starch concentration from 1% to 3% sees the viscosity rise from 1.2 mPa s to 3.6 mPa s. This can be attributed to the increase in intermolecular forces amongst solute molecules as concentration increases.

The temperature's influence on the starch mixture's viscosity was evaluated (Table 1), showing a decrease in viscosity from 2.11 mPa s to 1.96 mPa s when the temperature climbed from 20°C to 50°C. This decrease in viscosity is a result of the reduction in intermolecular forces amongst the solute molecules as the temperature rises.

The study also explored the impact of magnesium chloride concentration on the powder suppressant. As per the results shown in Table 1, the composition's viscosity rises with an increasing magnesium chloride concentration. It was deduced that the interaction of

magnesium chloride molecules with the starch molecules caused an increase in the intermolecular forces between the solute molecules within the solution.

In conclusion, the study's findings reveal an increase in the dust suppressant's viscosity with an elevation in starch concentration, temperature, and magnesium chloride concentration. This is congruent with the expected behaviour of a colloidal suspension. The dust suppressant formula, built upon modified technical starch and magnesium chloride, shows promise as an effective and environmentally friendly dust suppressant in quarry environments (Fig.1).

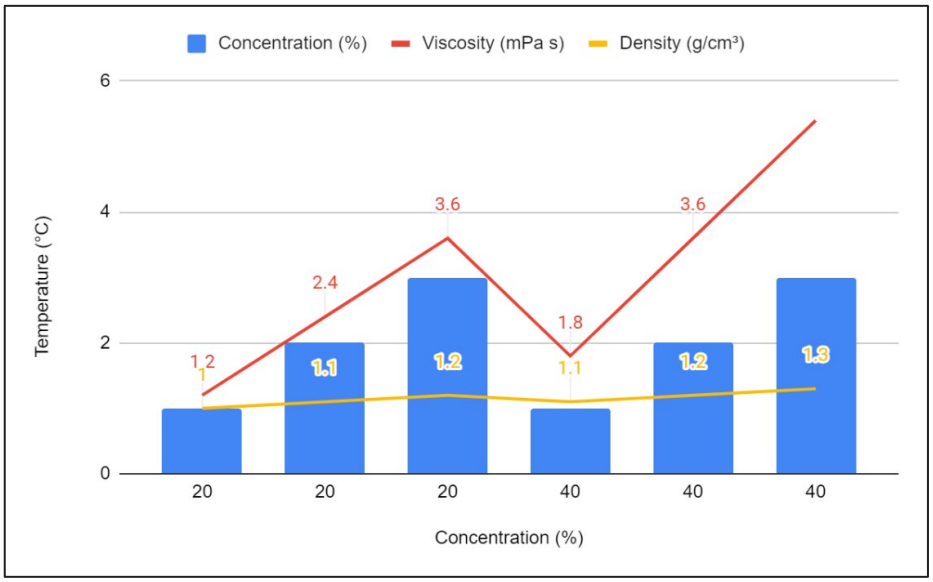

Fig. 1. Correlation between the Viscosity of the Dust Suppressant and the Concentrations of Starch and Magnesium Chloride at Different Temperatures

Based on Mukhiddinov et al. (2020)'s study, around 10% of fatal illnesses in urban areas are a direct result of air pollution. A significant portion of this pollution can be traced back to dust emissions from mining and processing industries. Large "bare" zones in the nearby landscape contribute substantially to the volumes of dust, resulting in fine particles making their way into the lower atmosphere. The pronounced surge in the maximum airborne concentration of iron ore dust particles represents a significant health hazard, thereby advocating for the development of technological processes to mitigate dust formation.

The most prevalent method for dust reduction is the employment of hygroscopic salts, for instance, magnesium chloride, due to its cost-effectiveness, technological superiority, and minimal environmental impact.

Moreover, the research by Mukhiddinov et al. also highlighted the requirement for a special semi-industrial apparatus to concoct an aqueous solution of starch and magnesium chloride. As a response, a device with a 3 cubic meter reactor capacity was developed. The creation of the necessary design schematics was undertaken in partnership with the Central Mining Administration of Navoi Mining and Metallurgical Combine designers.

The experimental protocol entailed the creation and application of a starch-based solution for dust control, as summarised in the table below. This process resulted in a substantial reduction in dust levels on quarry roads, showcasing the efficacy of the proposed method (Table 2) [6-9].

The process entails the preparation of a dust suppression solution constituted by technical starch and magnesium chloride. Initiated by filling a 3m³ reactor with 2 tons of water,

crystalline magnesium chloride is subsequently added and dissolved through vigorous stirring, causing an exothermic reaction that raises the water temperature. Following this, about 900 kg of technical starch powder is gradually introduced into the intensively stirred mixture until it achieves a volume of 3 tons.

Upon stirring the resultant solution for a further 10 minutes, it is then dispensed through a special sprinkler onto the highway roads of the Muruntau quarry. Following this, a cleansing process is initiated to remove any starch solution residues from the metal pipes and the reactor, ensuring their continued operational efficiency. This is achieved by again filling the reactor with 2 tons of water and adding more magnesium chloride, then stirring for an additional 5-10 minutes before dispatching the remnants through the valve back to the sprinkler.

The solution is then sprayed on quarry roads with a specially designed water-spraying machine. Following this, the efficiency of the solution was tested by observing dust levels on the roads after a number of trucks had passed. Results showed a significant reduction in dust levels after the application of the solution, validating its effectiveness in dust suppression. The solution, alongside its application method, holds promise for large-scale dust suppression in similar settings, offering a cleaner and safer environment.

Table 2. Summary of Starch-Based Solution Preparation and Dust Suppression Experiment

Step/Experiment	***Description***
Reactor preparation	A 3 m^3 reactor filled with 2 tons of water, adding magnesium chloride (MgCl2) while stirring (700-800 rpm).
Exothermic reaction	Magnesium chloride dissolves in water, increasing the temperature due to its exothermic nature. Process continues until temperature reaches 50-60°C.
Addition of technical starch	About 900 kg of technical starch powder is slowly added and dissolved in water, under continuous stirring, until the solution volume reaches 3 tons.
Solution preparation	Solution is stirred for around 10 minutes, and then sent to a special sprinkler device (BELAZ) through a valve.
Cleaning process	Reactor and pipes are cleaned from starch solution residues using 2 tons of water and dissolved magnesium chloride, with the remaining solution sent back to the BELAZ.
Application	The prepared solution is sprayed onto quarry roads using a special BELAZ machine, and the amount of dust on the road is measured using special devices.
Dust measurement before treatment	In the initial phase, the concentration of dust was 14.8 mg/m^3 after the movement of two trucks. It was 15.6 mg/m^3 in the second round.
Dust measurement after treatment	After spraying two layers of the starch solution, the dust concentration decreased significantly to 2.6 mg/m^3 five days later, despite the movement of six trucks.
Final observations	A significant reduction in dust was observed on the road sprayed with the starch solution compared to a road sprayed with water three times.

As stated previously, curtailing dust is a critical concern within quarries and other thoroughfares. Dust can instigate a multitude of issues, ranging from respiratory difficulties, obstructions in visibility, to hazards concerning road safety.

The research conducted by Mukhiddinov et al. (2020) established that an aqueous concoction comprising of 6.0% technical starch and 7.0% magnesium chloride by mass proved efficient as a dust suppressant. The efficacy of dust suppression was found to hinge on the mixture and quantity of the suppressant, conditions of the road, the time of application, air temperature, wind velocity, among other factors.

This implies that a composition solution rooted in technical starch and magnesium chloride can be effectively employed to suppress dust in quarries and various other thoroughfares. Moreover, the research discovered the solution to be eco-friendly and biodegradable.

This presents a promising new advancement in the realm of dust suppression, which could serve to enhance the safety measures and environmental impact associated with quarries and other highways.

4 Conclusion

1. Formulations leveraging technical starch and magnesium chloride were devised with the objective of mitigating dust on highways.
2. The rheological attributes of the created dust suppressing compositions were closely scrutinised. It was observed that an escalation in the concentration of technical starch in the compositions leads to an increased viscosity. Conversely, a rise in temperature corresponded to a decrease in viscosity.
3. A specific semi-industrial apparatus was designed for the production of an aqueous solution comprising technical starch and magnesium chloride. This equipment facilitated the procedure of formulating the composite solution.
4. The fabricated dust suppressants underwent tests for dust mitigation on highways located in the Muruntau quarry.
5. The most effective composition of the dust suppressant was ascertained. It was demonstrated that the optimal mix consisted of 6.0 mass. % technical starch and 7.0 mass. % magnesium chloride.

Thus, this research has paved the way for future advancements in the domain of dust suppression, and the promising results bode well for enhancing safety and reducing environmental impact in quarries and other highways.6. It was found that the amount of dust on the roads decreased from 15.6 mg/m3 to 2.6 mg/m3 after 5 days (120 hours) after spraying an aqueous solution of the drug of acceptable composition.

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