Respirable dust detection and optimization of dust prevention measures in fully mechanized face of coal mine

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Abstract. With the deepening of coal mining depth, mining scale and mechanization, the widespread use of high-power, high-performance automated coal mining equipment has increased the amount of dust generated in coal mines during various operations, which has seriously affected the coal mines normal mining and the health of miners. In order to study the harm of respirable dust in fully mechanized coal mining face and reduce the degree of dust hazard, individual sampling and fixed-point sampling method were used to detect the contact level of dust in different types of fully mechanized coal mining face in Shaanxi Province. The test results show that shearer drivers, stent workers and other five types of jobs are the most serious in fully mechanized coal mining face. Analyze the reasons for the excessive concentration of dust in different positions, put forward the optimization measures, so as to further improve the efficiency of mine dust control.

1. Introduction
China’s energy utilization structure is dominated by coal, and the whole process of coal production is accompanied by dust generation[1-2]. The fully mechanized mining face is the most important dust-producing site in the coal mine production process[3]. The dust production is large and the dust concentration is high. The dust generated by the coal mine accounts for 45%~80% of the total dust of the mine[4]. Dust enters the human body through the respiratory tract, damaging the human respiratory system, causing respiratory diseases and local irritation[5]. According to the statistics of the past ten years, the annual incidence rate of pneumoconiosis caused by respiratory dust accounts for more than 90% of the incidence of occupational diseases. The degree of harm to miners and the concentration of exposure dust, the length of time, the dispersion of dust, and the free silica content is closely related[6-8]. Scientific and reasonable optimization measures can effectively reduce the dust concentration and its dispersion. Therefore, analyzing the common problems in the dust control of some coal mines in Shaanxi Province, and proposing targeted treatment recommendations, so as to improve mine dust control efficiency is the key to reducing dust hazard.

2. Material and Methods
The time-weighted average concentration detection of dust uses an individual sampling method. According to the dust sampling measurement specification (GBZ/T192.1-2007, GBZ/T192.2-2007) in the workplace air to determine the number of samples of workers who exposed to dust in each type
of work, including workers with the highest concentration of exposed dust and the longest contact time, using the AKFC-92G individual dust sampler, install the small plastic sampling clip of the filter membrane and preseparator, and wear it on the upper part of the chest of the sampled object to collect 8 hours of air at a flow rate of 2 L/min. Continuous sample collection for 3 days, taking the highest concentration of \( C_{TWA} \) in three days.

The method of fixed point sampling is adopted for the excursion limits of dust. Choose AKFC - 92 type a dust sampler, selected representative sampling points, the dust sampling clamp of the filter will be installed at the highest concentration of dust in the air every day. Collecting 15 minutes of air sample at a flow rate of 20 L/min at the height of the breathing zone, continuous sample collection for 3 days, take the highest concentration value in the working day as short time exposure limit (\( C_{STEL} \)) of the dust at the working place, and calculate the excursion limit of the total dust at the working place. The selection and layout requirements for the measurement points of coal mining operations by Table 1.

| Category | The production process | The arrangement of dust spots |
|----------|------------------------|------------------------------|
| Coal face | Coal winning machine cutting coal, coal hydraulic support, scraper conveyor, transfer machine, crusher, belt conveyor transport, drilling, artificial coal and coal shovel. Multiple operations at the same time | 10m~15m on the return wind side, where the workers work. |
| Others | Roadway maintenance, transfer point, etc. | Working place |

Table 1. Selection and layout requirements of measuring points for coal mining operations.

The concentration of dust in the air and the contact time are the direct factors affecting the onset of pneumoconiosis. According to the relevant provisions of the “Regulations on Prevention and Control of Occupational Disease Hazards in Coal Mines”, dust exposure levels of coal mining operations in 20 coal mining enterprises in Shaanxi province were detected, analysis of the obtained data. During the dust measurement, the main works such as stopping, driving, underground transportation, mine ventilation system, etc. are basically in normal operation, the occupational disease protection facilities are open and functioning normally, and the tested objects are in normal working condition.

3. Results
The 8h time-weighted average concentration(\( C_{TWA} \)) and short-time exposure limit(\( C_{STEL} \)) of different positions in coal mine fully mechanized mining face were tested. The on-site inspection results show that the proportion of flour dust concentration exceeding the standard work in coal mine comprehensive mining work is above 50%; all coal mining machine drivers, support workers, loader drivers, scraper drivers, and end workers in all fully mechanized mining face of the dust concentration is seriously exceeded.

![Figure 1. Detection results of dust concentration at driver's position of shearer.](image-url)
Figure 2. Dust concentration test results of support working level.

Figure 3. Dust concentration detection results of driver operating position of scraper.

Figure 4. Dust concentration test results of operating position of end support workers.
The table and diagrams show the dust concentration data for the different operating positions and discuss the implications of these findings. The analysis highlights the critical role of dust control measures in ensuring worker safety and meeting regulatory standards.
handling and cleaning support, and secondary dust caused by ventilation. Now the specific reasons for dust production are analyzed as follows:

During the coal cutting process of coal mining machine, the coal rock is intercepted and fractured by the cutting teeth. The coal rock crushing produces a large amount of dust. In this process, the dust production accounts for more than 80% of the total dust in the mine. Under the requirements of national laws, regulations and standards, all coal mining machines in fully mechanized mining face are equipped with dust-proof devices such as internal and external sprays. However, due to the high coal cutting strength of the coal mining machine, the dust generated cannot be completely suppressed. In addition, some mines use hydrostatic water supply, no spray pump, insufficient water supply, internal and external sprays are blocked; some mines use the reused water after mine drainage treatment as a dust-proof water source, poor water quality, suspended solids, carbonate, the hardness is high, resulting in poor spray effect inside, outside and between shelves. The shearer drivers and the bracket workers are exposed to dust exceeding the standard because the workers in the position are exposed to a high concentration of dust for a long time and are close to the dust source.

During the process of coal block slumping, loading and transportation, the collision between the coal blocks and between the coal blocks and the machine and the ground, and the friction and crushing effect all produce more dust. In the actual production process, due to the surface tension of water for dust prevention, the ability of combining water with coal dust and the infiltration effect of water on coal dust are poor. Transfer machine, scraper, vibrating screen, coal conveyor belt, etc. due to the reasons of production process, complete sealing cannot be achieved during the operation, and workers in this operation are extremely vulnerable to dust hazards.

The dust deposited on the working face is raised again during the coal mining, transportation operation or ventilation process, that is the secondary dust, and because the operation position is on the leeward side, it is susceptible to the secondary dust caused by ventilation or machine operation. A small part of the dust generated by the influence of geological effects, such as coal dust (rock dust) existing in the gap between coal, rock mass dislocation or fracture, such dust is easily exposed under the influence of mining, thereby increasing the dust concentration.

4.2. Optimization of dust-proof facilities in fully mechanized mining face

4.2.1. Optimize shearer parameters. Working flour dust mainly comes from the coal crusher crushing coal body, developing dust reduction coal mining machinery, changing the crushing mechanism of coal rock mass and increasing the particle size of dust particles, which is the basis for optimization of dustproof facilities[10][9]. The cutting teeth of the drum shearer are divided into two categories: knife ruler and pick tooth. The cutting process of the knife ruler is dominated by shear force. Pick tooth because of its coal cutting resistance along the axis direction of the line will be firmly pressed on the cutting teeth in the tooth seat, the bending moment is small, the tooth loss is low, and pick teeth can rotate around its axis, with its own sharpening function. Combined with the comparison and analysis of dust exposure level in fully mechanized mining face of coal mine, it is found that with the same type of coal mining machine, the level of dust exposure is higher and the dust damage is more serious. Therefore, in order to meet the coal mining requirements of the working face, as far as possible to choose pick cutter teeth.

In addition to the influence of the shape of shearer drum cutting teeth on the amount of dust, the appropriate number of cutting teeth and cutting depth are also conducive to reduce the generation of dust. Different number of truncated teeth and different installation mode will affect the effective working space of truncated teeth. If there are too many truncated teeth, some truncated teeth will produce a lot of dust due to the shallows of truncated teeth, and some truncated teeth will lead to vibration and idling along the track of previous truncated teeth. Therefore, it is an effective way to reduce dust generation to select a reasonable number of truncated teeth, increase the tooth spacing appropriately and ensure the effective working space of each truncated tooth.
4.2.2. **Optimize the quality of dust-proof water to ensure the reliability of dust-proof facilities.** Before coal seam mining, pressure water is injected into coal seam by drilling to wet the coal in advance, so as to improve coal moisture content and dust particle adhesion, which can reduce the amount of dust produced and help coal dust coalescence. In addition, spray dust removal is the main measure of dust control on working face. Therefore, the quality and pressure of dust-proof water are the main factors affecting these two measures.

According to regulations on prevention and control of occupational hazards in coal mine operation sites (State Administration of Safety Supervision Order No.73), the internal spray pressure of comprehensive mechanized coal shearer shall not be less than 2MPa, and the external spray pressure shall not be less than 4MPa. When the internal spray device cannot be used normally, the external spray pressure must be above 8MPa to ensure that the internal and external spray device of coal shearer can fully play its role. For this reason, the coal shearer must be equipped with spray pumps, and the number of spray pumps shall not be less than the number specified in “technical specifications for comprehensive dust control in underground coal mines”.

Strictly control the quality of dustproof water, the suspended solid content does not exceed 30mg/L, the suspended matter particle size is not more than 0.3mm, the PH value is between 6~9, and the carbonate hardness does not exceed 3mmol/L, ensuring the inside of the shearer, the spray nozzle between the outer spray and the hydraulic bracket is not blocked.

4.2.3. **Add wetting agent to reduce dust.** Under the same conditions, the addition of a wetting agent to the dustproof water can significantly improve the physical properties of the dust, enhance the ability of the dust to combine with water, and significantly enhance the sedimentation efficiency of the dust. Combined with previous experiments on the sedimentation of coal dust by surfactants, it is recommended to add a surfactant to the dustproof water to enhance the binding ability of water and coal dust to improve the dust reduction effect. For example, the fast penetrant T(0.05%) is main material and the alkyl glycoside (0.01%) compounding the wetting agent, combined with the dust removal fan to reduce dust, the dust reduction efficiency can be increased to about 75%[10]. In the field application, the process of adding a certain proportion of the wetting agent compounding solution in the dustproof water often causes problems such as large concentration error and untimely supply due to the process and human factors. For this, designed a smart water tank for the combination of spray dust and humectant, which solves the above problems well. The structure diagram is shown in Figure 7.

![Figure 7. Schematic diagram of intelligent water tank structure.](image)

1. Feeding box  2. Feeding tube  3. First solenoid valve  4. Add water pipe  5. The tank body  6. Level sensor  7. Concentration sensor  8. Outlet pipe  9. Second solenoid valve  10. Third solenoid valve  11. Agitator

The main components of the smart water tank for spray dust humectant compound include the water tank main body, the feeding box and the water supply pipe. A liquid level sensor for detecting the liquid level in the water tank main body and a concentration sensor for monitoring the liquid
concentration in the water tank main body are disposed in the main body of the water tank. At the bottom of the feeding box, there is a feeding pipe in contact with the feeding box. At the bottom of the side wall of the main body of the water tank, there is an outlet pipe. Explosion-proof solenoid valves are installed on the feeding pipe, the feeding pipe and the outlet pipe. By setting the liquid level sensor and concentration sensor, the liquid level and liquid concentration in the water tank can be monitored in real time. By controlling the opening and closing of the solenoid valve, water and wetting agent can be added to the water tank to improve the dust settling efficiency.

5. Conclusions
After individual sampling and fixed-point sampling and monitoring, the dust concentration of the five positions such as shearer drivers, support workers and scraper drivers seriously exceeds the standard, which are the key positions of dust hazard prevention and control.

The shearer drivers' position of the coal mining machine in the fully mechanized mining face is the closest to the dust source, and the concentration of the respirable dust is over 100%, which is the most serious damage. Therefore, the key part of the dust prevention and control is at the dust source.

The coal mine should select the appropriate coal mining machine parameters, strictly control the dustproof water quality and pressure, and install a smart water tank for the spray dusting and wetting agent to improve the dust reduction efficiency of the coal mine.

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