# Intelligent Explorations of Occupational Disease Prevention and Control in Coal Mine

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**Abstract:** Coal enterprises in high yield and high efficiency at the same time accompanied by a large number of occupational disease personnel, in order to continuously improve the operating environment of coal mining enterprises in each operation point, reduce occupational disease hazards, reduce the incidence of occupational diseases, to ensure the health and personal safety of operators, in recent years in China's coal industry occupational disease incidence and occupational health management department changes on the basis of the basis of intelligent mine construction theory and technology, combined with the production and distribution of occupational disease hazard factors in various coal mine work sites, Through the comprehensive use of optimization of the equipment start-up process, the real-time monitoring technology of occupational disease hazard factors and the linkage of key equipment, the excavation of the long pressure short pumping system of the working surface, the establishment of a centralized control room, the exploration of the use of positive pressure fully enclosed helmets, active sound reduction technology, noise reduction headphones and other intelligent technologies and means, from the source control, process elimination, terminal control of the three dimensions of dust concentration and noise value to the coal mine safety regulations limit value, thereby improving the operating environment, reducing the incidence of occupational diseases, Maximize the health of operators throughout their careers and help coal companies achieve sustainable development.

**Key words:** Coal mine; the work environment; occupational disease; prevention and cure; intelligent

## 1. Introduction

China has become the fastest-growing economy in the world during the country's 13th Five-Year Plan, and all industry in China is in an unprecedented booming age. As a rapid development of all industries, the coal industry is named the "industrial grain", playing a dominant role in the supply of energy for industrial production [1]. With the continuous maturing of automation and information [2] and the application of the Internet of Things [3] in coal mines, the coal industry in China has already entered the intelligence era [4]. Such intelligence promoted the development of the coal industry. In recent years, the death rate per million-ton of coal has come down every year [5], and the number of safe mines is also increasing, with high production and high efficiency [6]. The coal mining industry also attracts a growing number of highly educated talents [7]; however, lack of advanced managerial philosophies and technology for the prevention and control of occupational hazards. Such insufficiency has caused an increase in the number of occupational diseases suffers [8]. Wang et al. [9] found that more than 270000 people were diagnosed with occupational disease from 2009 to 2018 in China, based on the statistical analysis of morbidity, and pneumoconiosis accounts for 87.16%. Tang et al. [10] furthered this idea by the statistical analysis of occupational disease patients from 2010 to 2018. They found that occupational diseases mainly occur in coal mining, coal washing, and other industries, and pneumoconiosis accounts for 88.71%. The death toll of occupational disease surpasses those of other work-related accidents every year [11], and the number is increasing at a rate of roughly 20000 fatalities each year [12]. Although the coal mine has made great contributions to the development of industrial production, it nevertheless has brought unhealthy consequences to the works in the coal mining industry, such as occupational diseases [13]. The occupational disease has been one of the major adverse factors, causing fetter development of the coal mine and the malign social impact with economic and working day losses [14]. The CPC Central Committee and the State Council set a high value on the health of the workers and proposed the Healthy China initiative (2019-2030) [15] and the Tutorial for Outline of the Healthy China 2030 Plan [16]. Therefore, in the developing process of the coal-mine production intelligence, the way to effectively reduce the concentration of the factors of occupational disease hazards in the workplace, are urgent problems to be solved for the sustainable development of the coal enterprises. Such measures will help to improve the working environment, decrease the incidence of occupational disease, ensure the safety and health of employees, and improve the happiness quotient.

## 2. The development of occupational health in China

Since the founding of China, five administration changes in occupational health in China. It was managed by the Ministry of labor and the Ministry of health from 1949 to 1998. The Ministry of Health was responsible for occupational health for the three years from 1998 to 2003. It was managed by the health department and the safety supervision department from 2003 to 2010. The authority is the State Administration of Work Safety from 2010 to 2018, and the National Health Commission from 2018. The authorities of occupational health have changed many times, causing a severe shortage of professionals, inconsistency between laws and regulations, and other problems in occupational health. In 1957, China promulgated the regulation on the trial implementation of the "scope of occupational diseases and measures for the treatment of patients with occupational diseases", and the regulation listed 14 types of occupational disease. In 1987, the regulation of occupational disease scope and treatment method for occupational disease patients was introduced, and 99 kinds of occupational diseases were stipulated by laws as occupational diseases. The occupational disease prevention law (2002) listed 115 types of occupational disease. 132 occupational diseases were specified in the occupational disease prevention law amended in 2013.

## 3. Current occupational hazards in the coal mine

Major occupational hazards in the coal industry included dust, noise, vibration, and other harmful gases. Dust is a widely occupational hazard harmful to humans in the coal industry. Dust is the leading cause of suffering from pneumoconiosis (e.g., anthracosis, silicosis, and anthracosilicosis). Pneumoconiosis suffers accounts for about 90% of occupational disease patients. Note that, in recent years, the number of patients with noise-induced hearing loss is also increasing sharply in the coal industry. This paper thus focused on the dust and the noise.

### 3.1 The dust

As the coal production and transportation, it produces lots of dust. Such dust suspended in the air flows to the lungs through the respiratory, and the small dust goes deeply into the human body. If workers inhale dust for a long time and it stays in the lungs, it will lead to pneumoconiosis [17]. In coal production, dust account for roughly 3% of the total output, suspended in the atmosphere of the coal mining face and roadways [18]. A mine with high production thus produces a lot of dust harmful to the workers [19]. The coal mine safety regulations lay down rules on the limit value of dust concentration when the content of free $SiO_2$ is less than 10%. The time-weighted average allowable concentration of total dust should not be higher than 4mg/m3 in the workplace air; however, is about 100mg/m3 in production at the coal mining face, exceeding the limit value. Dust from coal production moves in a current of air. Most of them will be removed by dedusting devices, and the rest will flow with air to the return airway. Therefore, most pneumoconiosis patients are the coal miners and the driving workers in the coal industry. Dust affects visibility of the workplace, leading to misoperation and other human errors, in addition to the threat to human health. Such an impact poses a certain threat to the personal safety of operators.

The noise

With the rapid development of mechanization in the coal industry, mining and transportation equipment are widely applied in coal production. Although the production is increasing, such application nevertheless causes severe noise harmful to health [20]. The noise in the coal industry can be classified according to its sources. It includes the mechanical noise (e.g., the sound of breaking coal, drilling, and the sound of belt operation, friction), the fluid-dynamic noise (e.g., the sound of air compressor, and mine local fan ventilation, and explosions), the voltage conducting (e.g., the sound of the transformer). The coal mine safety regulations lay down rules on the limit value of the noise when the continuous exposure time of operators to noise every day is over 8 hours. The noise level should not be higher than 85 dB in the workplace; however, is 90-150 dB at the coal mining face, the local ventilation facilities, and other sites with noise. In an environment with exceeding noise for a long time, the hearing of workers losses. The noise can also cause endocrine disorders, insomnia, neurasthenia syndrome, eye pain and fatigue, visual loss, dazzled, stomach disorders, and other symptoms.

## 4. Intelligent explorations of the dust prevention and control

### 4.1 The dust at the coal mining face

#### *4.1.1 Optimization of the coal mining face equipment start-up process*

The current start-up process contains the start-up order of each production equipment; however, lacks those for dedusting devices. Workers then turn the dedusting facilities on and off during production. Such a process can thus be incorporated into the start-up process, as shown in Figure.1. The optimized one is an all-in-one process. Start-up processes are as follows. The first step is opening the belt, and the next is the shearer, the scraper conveyor, and the hydraulic support. Note that the next is turning on the dedusting facilities to clean the dust. After that, it is that opening the cutting coal machine. As each coal production equipment stops running, the final step is turning off the dust removal facilities.

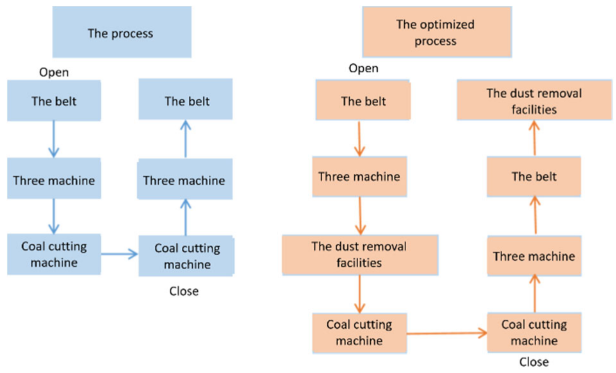


**Fig.1** Optimization diagram of coal mining face equipment start-up process

#### *4.1.2 Intelligent purification of the airflow on coal mining face*

The fresh air is continually polluted because of the long distance between the coal mining face and the air inlet. Therefore, the dust sensors are installed at the air inlet of the coal mining face. Such sensors monitor the dust concentration in the air, usually used with the full-section spray valve. When the dust concentration of the inlet air reaches 0.5mg/m3, the sensor transmits a first-level signal to the full-section spray valve gate. The spraying is then provided and maintains the opening pressure. When the dust concentration rises to 1.0mg/m3, the sensor transmits a second-level signal, and the pressure rises to its maximum, as shown in Figure.2. The method of the real-time adjustment of the pressure avoids the waste of water and the excessive humidity of the coal mining face according to the dust concentration. This method can also be used for the dust flowing to the vitiated air on the coal mining face, produced by coal mining. These facilities can also be used for the vitiated air on the coal mining face to minimize the dust concentration.

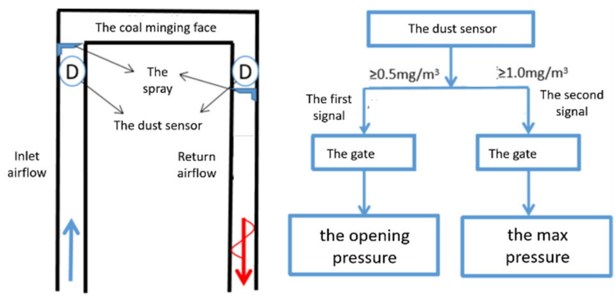


**Fig.2** Schematic diagram of intelligent purification of airflow on coal mining face

#### *4.1.3 Intelligent dust prevention and control technology for the coal mining working surfaces*

The dust sensors are installed at every certain distance on the coal mining face. These sensors are used to monitor the dust concentration in the air and are also usually used with other production equipment, such as the cutting coal machine. When the dust concentration in the air exceeds the limit value, the sensor transmits a multi-signal, as shown in Figure.3. The first signal is sent to the main module of the cutting coal machine. The cutting velocity is often in inverse proportion to the dust concentration. After receiving the signal, the cutting velocity can be reduced by adjusting the current of the machine until the machine stops running. The second signal is sent to the spray valve of the machine body. The pressure of the spray valve gate is often in the direct ratio to the dust concentration. After receiving the signal, the pressure of the machine increases, minimizing the dust concentration. The third signal is sent to the spray valve of the frame. The pressure of the spray valve gate is often in the direct ratio to the dust concentration. How it works is the same as those for the spray valve of the machine body to minimize the dust concentration at the operators between frames. The fourth signal is sent to the dedusting facilities installed on the work surface. After receiving the signal, the facilities are turned on immediately. This multi-pronged approach plays a vital role in accurately cleaning the dust with high efficiency. A series of problems have been solved when various spraying is opened for a long time. Such issues include the waste of water resources, a decrease in coal quality, the excessive humidity of the working face, the failure to associate the spray pressure with the actual concentration of dust, and other problems.

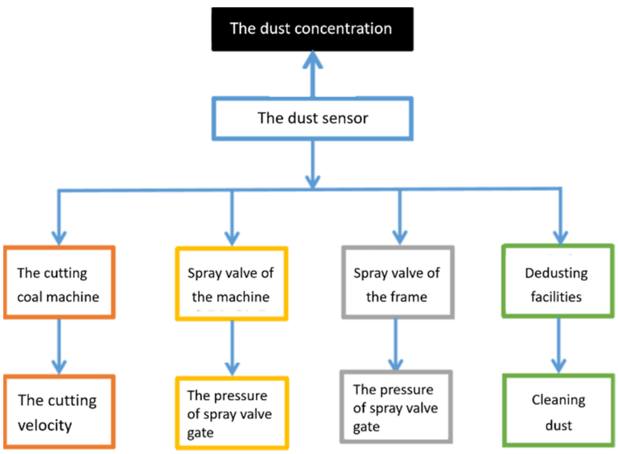


**Fig.3** Schematic diagram of intelligent dust prevention and control technology for coal mining working surfaces

### 4.2 The dust at the tunneling face

Install the dust removal system, including the forced local fan ventilation and the exhaustion dust removal fan at the tunneling face. Forced local fan ventilation is installed to supply fresh air to the tunneling face for a long distance. An exhaustion dust removal fan (Frequency-modulated fan) is also installed to clean the dust generated by excavation at the tunneling face for a short distance, as shown in Figure.4. The dust sensor is also installed at the tail of the tunnel boring machine. When the dust concentration in the tunneling face exceeds the limit value, the sensor transmits a multi-signal. The first signal is sent to the converter module of the dust removal fan. The air volume of the fan is often in the direct ratio to the dust concentration. After receiving the signal, the air volume can be increased. The second signal is sent to the main module of the tunnel boring machine. The cutting velocity is often in inverse proportion to the dust concentration. After receiving the signal, the cutting velocity can be reduced until the machine stops running. The third signal is sent to the spray valve of the machine body. The pressure of the spray valve gate is often in the direct ratio to the dust concentration. After receiving the signal, the pressure of the machine increases, minimizing the dust concentration at the tunneling site. The fourth signal is sent to the spray valve of the tunnel boring machine. How it works is the same as those for the spray valve of the machine body. At the tunneling face, the start-up process is set as follows: turn on the dust removal fan, open the tunnel boring machine, turn off the machine, and close the dust removal fan. It can be seen that if the dust removal fan fails to start, the tunnel boring machine also fails to start.

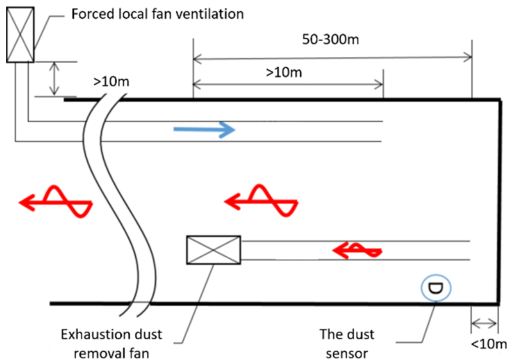


**Fig.4** Schematic diagram of intelligent dust removal for long pressure and short pumping of the boring working surface

### 4.3 The dust in belt conveyor roadways

The dust sensors are installed at every certain distance (200) on the coal mining face. These sensors are used to monitor the dust concentration in the air and are also usually used with the belt conveyor, as shown in Figure.5. When the dust concentration in the air exceeds the limit value, the sensor transmits a multi-signal. The first signal is sent to the controlling module of the belt conveyor. The velocity of the conveyor is often in inverse proportion to the dust concentration. After receiving the signal, the velocity can be reduced by adjusting the current of the machine until the conveyer stops running. The second signal is sent to the spray valve of the belt conveyor. The pressure of the spray valve gate is often in the direct ratio to the dust concentration. After receiving the signal, the pressure of the belt conveyor roadway increases, minimizing the dust concentration in the roadways.

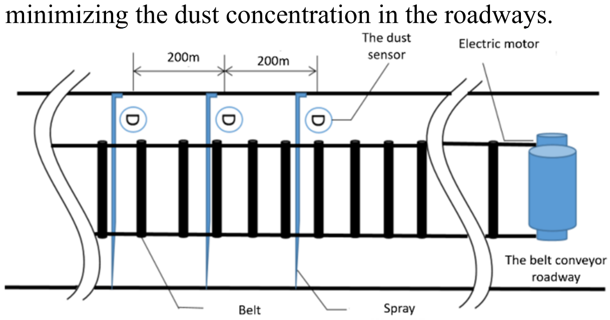


**Fig.5** Belt conveyor lane intelligent dust reduction schematic diagram

### 4.4 The automatic early warning of the exceeded dust concentration

The dust sensors can be used with the personnel positioning and communication systems to realize the automatic early warning of the exceeded dust concentration. When the dust concentration in the air exceeds the limit value, the workers will receive early warning information from the positioner or the explosion-proof mobile phone. The broadcasting system will also send the relevant message to remind workers that the dust concentration exceeds the limit value. When receiving such messages, workers should immediately wear masks and clean the dust in the air. In addition, according to the real-time and historical data on the dust concentration, the number of operators can be controlled in places where dust concentration exceeds the limit value. The Roadways dust cleaning plan can also be formulated or adjusted, and the managerial philosophies and technology can be improved to prevent and control the dust.

### 4.5 Using the positive pressure fully enclosed helmet

The dust masks are the last line of defense against the dust. The filtering effect of the dust is closely related to the type of the mask, the way to wear and other factors. Wearing masks may also cause poor breathing, difficulty in intensive physical work, and other problems. A Positive pressure fully-enclosed helmet is developed to solve the problem, which integrates the helmet and goggles according to the design principle of the spacesuit. He also carries an air cylinder strapped to his waist. A hose feeds the cylinder with fresh air, and the exhaled air is expelled when wearing a helmet. With the helmet, the respiratory system of the workers is completely isolated from the dust in the air. It also meets the actual needs of underground workers engaged in the high-intensity physical operation.

## 5. Intelligent explorations of the noise prevention and control

### 5.1 Establish the centralized control center for devices

A centralized control room is installed in a place far from the high noise, according to the principle that the noise value will decrease with the propagation distance. The room is isolated from external noise with the sound-absorbing material. In this closed room, some tasks can be achieved using remote-control technology, which should be carried out in a high-noise operating environment. It can prevent workers in a high-noise working environment for a long time and avoid inhaling too much dust.

https://doi.org/10.1051/e3sconf/202235203041


**Fig.6** Centralized control center for devices

### 5.2 Using active noise reduction facilities

The theory of the active noise reduction facility is that two waves of the same wave type but in opposite directions cancel each other out when superimposed, as shown in Figure.7. A facility collects and analyzes the characteristics of noise wave patterns of the equipment, which produces the noise, and calculates the reverse wave patterns by processing chips. The loudspeaker emits reverse waveform noise. The noise has been sharply reduced, produced by the equipment. Installing the facilities near high-noise equipment can reduce or eliminate noise from the source.

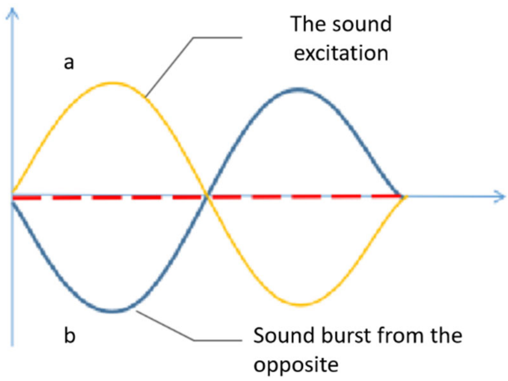


**Fig.7** Waveforms in the same direction opposite superimpose extinction schematic

### 5.3 Using noise-filtering headphones

The traditional earplugs work on a barrier principle, used by coal enterprises. Although it reduces the noise of the outside and protects the hearing of workers, it nevertheless affects the communication between workers to some extent. All sounds comprise a certain spectrum. The spectrum of a worker's sound speech differs from that of the equipment. An audio processor can thus be installed inside the earplugs to identify the frequency spectrum of the worker's voice. The Audio Processor can filter the voices of non-workers and reduce the noise precisely without affecting communication between the workers.

## 6. The effect of intelligent prevention and control of occupational hazards

The Bulianta Coal Mine has carried the above techniques through engineering actualize and get a well effect. Such application of the above technology has a solid guarantee for the health and safety of the workers.

### 6.1 Analysis of dust intelligent control effect

These intelligent technologies associate the dust concentration in the air with the production equipment, the belt conveyor, and other dust sources. Such technology achieved the goal of intelligently monitoring, analysis, warning, and disposal. With these technologies, the dust concentration of the dust source is significantly reduced. For example, the dust concentration in the coal mining face decreased from 100 mg/m3 to a value below 4 $mg/m^3$.

### 6.2 Analysis of intelligent noise control effect

After applying intelligent noise prevention technology, the number of operators can be reduced in places where noise exceeds the limit value. The noise after reduction is 83dB in the workplace. That of the centralized control room is about 60 dB. Such technology plays an important role in protecting workers' hearing and preventing employees from hearing loss.

## 7. Conclusion

With coal mining, it produces a high concentration of dust, high-intensity noise, high-frequency vibration, toxic and harmful gases, and other occupational hazards. Such a disease poses a threat to workers' health. The dust and noise are the two main factors causing the occupational diseases of the coal mine workers.

Optimized the start-up process and the use of sensors and the fully-enclosed helmet, achieving the goal of the monitoring, the analysis, the warning, and the disposal intelligently. The sensors are used to monitor the dust concentration in the air and are usually used with other production equipment, such as the cutting coal machine, the dedusting facilities, and the dust removal system. Such intelligent technology can effectively reduce the dust concentration and reduce the incidence of pneumoconiosis.

Established the centralized control center and used the active noise reduction facilities and the noise-filtering headphones, achieving the goal of noise reduction intelligently. The noise is controlled from the three dimensions of the source, the dissemination process of the noise, and the terminal. Such intelligent technology can effectively reduce the noise and reduce the incidence of noise-induced hearing loss.

With the continuous development of intelligent construction of the mine, the number of mines with serious occupational hazards is decreasing. The goal of unmanned operation will be achieved with the wide application of the new technologies, the new materials, and the new facilities. These techniques can also be combined to get a better effect. The application of these new technologies will contribute to the prevention and control of occupational disease in the coal mine industry.

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