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A comparative study of dust control practices in Chinese and Australian longwall coal mines

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ABSTRACT

Mine dust is one of the main hazards in underground longwall mines worldwide. In order to solve the mine dust problem, a significant number of studies have been carried out regarding longwall mine dust control, both in China and Australia. This paper presents a comparative study of dust control practices in Chinese and Australian longwall mines, with particular references to statutory limits, dust monitoring methods and dust management practices, followed by a brief discussion on the research status of longwall mine dust control in both countries. The study shows that water infusion, face ventilation controls, water sprays, and deep and wet cutting in longwall shearer operations are commonly practiced in almost all underground longwall mines and that both Chinese and Australian longwall mine dust control practices have their own advantages and disadvantages. It is concluded that there is a need for further development and innovative design of more effective dust mitigation products or systems despite the development of various dust control technologies. Based on the examinations and discussions, the authors have made some recommendations for further research and development in dust control in longwall mines. It is hoped that this comparative study will provide beneficial guidance for scholars and engineers who are engaging in longwall mine dust control research and practice.

1. Introduction

Australia is a world leader in coal production and coal exports and its significant contribution to world economic development cannot be ignored. More specifically, Australia is the fourth largest coal producer and the largest coal exporter in the world [1]. In Australia, New South Wales (NSW) and Queensland are the two biggest coal mining states. There are 30 longwall mines in Australia and 20 of these are in NSW [2]. Longwall mining was first introduced to NSW in 1962 [3]. Since then it has become the predominant method employed in this state. For all these reasons, this paper focuses on the longwall mines in NSW. Meanwhile, China is also a very important coal production country, whose production is the world's largest. Underground mining accounted for approximately 86% of total production in 2008 [4]. There are more than 20 different underground coal mining methods in China, but longwall mining predominates [4]. In order to meet the increasing energy demand due to the remarkable levels of economic growth, Chinese coal production was 3.87 Gt in 2014 according to the National Bureau of Statistics of China. Hence, it can be concluded that both Chinese and Australian longwall mines are occupying important positions in the world's coal industry today.

Whatever methods are used for mining, the excavation process is inevitably accompanied by the generation of mine dust. Longwall mining is no exception and produces even more mine dust when compared with other methods, due to the more rapid excavation rate. Mine dust is dangerous to miners both collectively through the risk of coal dust explosions and, individually, with the risk of pneumoconiosis. Based on the statistics from Zheng et al. [5] and the China State Administration of Work Safety, there were 4648 casualties caused by 105 coal dust explosion accidents (including methane-linked and non methane-linked explosions) in China between the years from 1970 to 2014. For individual hazards, coal workers' pneumoconiosis (CWP) is the most common disease caused by coal dust [6,7]. CWP not only affects patients and their families, but also the whole society [8]. In China, according to the China National Health and Family Planning Commission, there were more than 105 thousand new cases of coal miners suffering from CWP in the period 2009 to 2013, accounting for 94.5% of the total increase of pneumoconiosis victims in the five years.

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Despite the seriousness of the mine dust hazard, in order to increase coal production, longwall mining is increasingly adopted, due to its high productivity. Consequently, the potential to liberate mine dust is ever-increasing. Mine dust control in longwall mines has become a vital procedure, which becomes more important for maintaining the health and safety of coal miners. The importance of dust control can never be over-emphasized given the rapid development of longwall mining.

Although most dust control methods used in the two countries are similar, there are many subtle differences, which could be shared for mutual advantage. As two of the world's most important coal-producing countries, it is necessary to make a comparison of their approach to longwall mine dust control. It is expected that valuable lessons can be learnt from each other and thus more progress be made in mine dust control in longwall mines.

2. Dust control regulations

2.1. Regulations in China

In China, "Safety Regulations in Coal Mine" is an important reference for all coal mines. There are regulations regarding mine dust, which stipulates that all coal mines should take active measures to minimize dust or toxic substance concentrations to a certain level that meets the requirements in "Industrial and Commercial Hygiene Standards" [9]. The specific limits are shown in Table 1.

2.2. Regulations in Australia

According to the latest official notice on "Airborne Dust Limits, Collection and Analysis" [10], there are very clear limits for the concentration of airborne dust for underground mines in NSW. This stipulates that the specified limit for quartz-containing dust is 0.12 mg/m^3 for respirable quartz and the specified limit for respirable dust, other than quartz-containing dust, is 2.5 mg/m^3. These limits apply only to the underground parts of mines. When it comes to the surface part of an underground mine, the specified limit for quartz-containing dust is 0.1 mg/m^3 for respirable quartz and for respirable dust, other than quartz-containing dust, it is 2.5 mg/m^3. The government notice also gives a specified limit concentration for inhalable dust of 10 mg/m^3. The regulations for certain levels of mine dust concentrations are shown in Table 2.

2.3. Discussion on regulations

Comparing the two countries, China gives both total and respirable dust concentration limits, according to different silica contents of mine dust. In Australia, the regulation only gives two kinds of concentration limits according to whether silica is contained or not and in different locations, different limits are given. According to analysis of mine dust, the average silica percent is between 2.92% and 6.44% [11]. Hence, Australian coal mines limit the respirable dust concentration to 0.12 mg/m^3, which is far lower than in China. Moreover, there is no inhalable dust concentration limit in Chinese regulations. But, in fact, inhalable dust can not only cause pneumoconiosis, but may also lead to illnesses such as bronchitis. So, the Australian regulation limits the concentration to 10 mg/m^3.

Table 1
Limits of mine dust concentration in "Safety Regulations in Coal Mine" (China) [9].

Free silica (SiO_2) content in dust (%)	Maximum allowable concentration (mg/m^3)	
	Total dust concentration	Respirable dust concentration
<5	20.0	6.0
5 to <10	10.0	3.5
10 to <25	6.0	2.5
25 to <50	4.0	1.5
>50	2.0	1.0
<10 cement dust	6.0	

Table 2
Limits of mine dust concentration in "Airborne Dust Limits, Collection and Analysis" (Australia) [10] (mg/m^3).

Dust concentration	Underground mine	Surface part of underground mine
Quartz-containing respirable dust limit concentration	0.12	0.10
Non-quartz-containing respirable dust limit concentration	2.50	2.50
Inhalable dust limit concentration	10.00	10.00

After setting the limits of concentration, the following stage is dust collection and analysis. Table 3 shows the regulation detail in the two countries [9,10].

From Table 3, the sampling frequency in Chinese underground mines is generally higher than that in Australian mines. In China, there is also a requirement for valid sample numbers. But still, there are no inhalable dust samples taken in China and no total dust samples taken in Australia. However, total dust data does not matter much, because it is inhalable dust that can be harmful to coal miners. Besides, the Chinese regulations do not specify who should take the samples and this may lead to confusion.

In addition, there is a statutory body named the Coal Services (formerly, the Joint Coal Board) in NSW which provides the NSW coal mining industry with an occupational health service. It has the following responsibilities [12]:

(a) Monitoring of respirable dust results.
(b) Evaluation of dust risk.
(c) Encouragement to improve dust control methods.
(d) Dissemination of information and the education of mine personnel.

Coal Services has been doing an excellent job for dust control since its establishment [12]. Unfortunately, there is no such statutory body in China specialized in carrying out dust control management.

3. Dust monitoring

Dust monitoring is indispensable for coal mine operation and optimizing dust control strategies. Dust samples are normally obtained for regulatory purposes to ensure that exposure is effectively controlled or to determine certain issues like dust behavior, dust distribution and dust properties. The most commonly used techniques for dust sampling and measurement worldwide include: sampling from still air, mass concentration measurements, continuous real-time monitoring, and personal sampling [13].

In NSW, Australia, personal gravimetric sampling is the approved sampling method adopted in coal mines. The principle of this method is to collect the respirable dust or inhalable dust from the breathing air very close to the mine workers' nose and mouth (usually called the breathing zone which is 300 mm hemisphere around the nose and mouth). The dust collected during the full shift is then measured by weighing. The weight of the dust represents the likelihood of developing CWP [14].

The samples are taken by a small battery-powered pump worn by the mine worker, as shown in Fig. 1. The pump is connected