layer and hence improve the kinetics of leaching. Additionally, antimony precipitation tests should be conducted in further studies for producing special antimony compounds such as antimony trioxide (Sb_2O_3) and sodium antimony(III) oxide tartrate ($Na_2(SbO)_2C_8H_4O_{10}$). ■

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The impact of black lung and a methodology for controlling respirable dust

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Coal workers' pneumoconiosis (CWP), commonly known as black lung, is caused by the inhalation of respirable coal mine dust and is a disabling and potentially fatal lung disease with no cure. Historically, CWP has taken a tremendous human and financial toll on the U.S. coal mining industry. Recent health surveillance data indicate that CWP continues to occur at elevated levels. Respirable coal dust exposure must be controlled to prevent the development of CWP. The Pittsburgh Mining Research Division of the U.S. National Institute for Occupational Safety and Health (NIOSH) conducts laboratory and mine-site research to identify control technologies that can be used to successfully reduce respirable dust levels. Various technologies, using multiple methods of control, can be applied to reduce dust levels. An overview of CWP's impact and a general methodology for controlling respirable dust in underground coal mines are discussed in this paper.

Coal workers' pneumoconiosis

During the mining, transport and processing of coal, respirable-sized dust (less than 10 µm in diameter) can be released into the ambient mine air. Inhalation of this respirable coal mine dust can lead to the development of CWP. CWP is a disabling and potentially fatal lung disease that occurs in simple and complicated form, known as progressive massive fibrosis (PMF). The severity of CWP is determined through chest radiograph standards established by the International Labour Office (ILO).

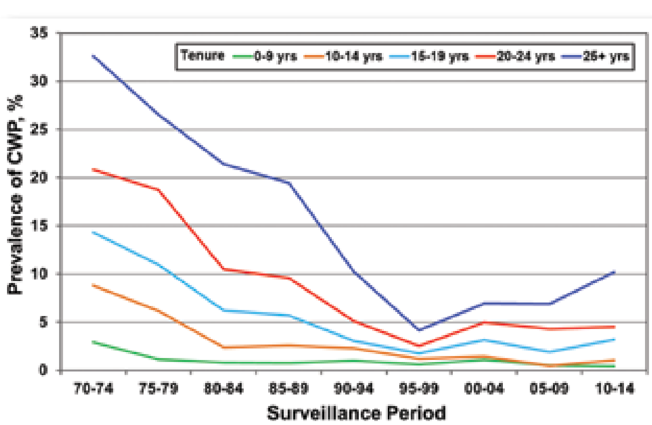

Fig. 1 Percentage of examined miners with CWP category 1 or greater by tenure in coal mining.

NIOSH has administered the Coal Workers' Health Surveillance Program since 1970 to monitor respiratory disease in miners. In this surveillance program, each miner is required to have a chest radiograph at the beginning of their mining employment and can then volunteer to have subsequent radiographs in approximately five-year intervals. Figure 1 illustrates CWP prevalence data summarized over five-year surveillance intervals for miners with different lengths of service. During the 1970-1974 surveillance period, approximately one out of every three examined miners with 25 or more years of work experience was diagnosed with CWP category 1 or greater. The prevalence of CWP in subsequent five-year surveillance intervals dropped dramatically, reaching less than 5 percent for the longest-tenured miners in the 1995-1999 period. However, since that time, the prevalence for the longest-tenured miners has increased so that it is above 10 percent for the last five-year surveillance period for which complete information was available. Even more disturbing is the prevalence of PMF that is being found in the mining workforce. For those miners filing for benefits under the federal Black Lung Benefits program, the percentage of these miners that are found to have PMF has increased more than five-fold since the 1970s.

Data are also available that summarize coal miners' deaths with CWP as the underlying or contributing cause. From 1970 through 2016, 75,178 deaths are attributed to CWP. From a financial perspective, federal benefits, including monthly compensation payments and medical expenses,

Fig. 2 (a) Directional spray system on longwall shearer with venturi sprays mounted on the splitter arm and hollow-cone sprays on shearer body, and (b) tailgate-side sprays.

paid through the Black Lung Benefits program, were more than $250 million in 2018, with a total of $46.9 billion in payments made from 1971 through 2018.

Dust control methodology

The damage caused to the lungs by CWP is irreversible and can continue to progress even after dust exposure ceases, so the goal is to reduce respirable dust exposure to prevent initial development of the disease. Research has identified numerous control technologies that can successfully reduce respirable dust levels in continuous and longwall mining operations. A general methodology on how to approach controlling respirable dust by utilizing different types of controls is presented:

1. Minimize the quantity of respirable dust generated by employing efficient cutting. Efficient cutting is obtained through proper drum design for the mining conditions, appropriate bit selection, maintaining sharp cutting bits and having effective cutting techniques.
2. Prevent respirable dust from getting into the ventilating air by wetting the dust at the generation point and enclosing dust sources. Appropriate spray types located close to the dust generation source should provide full coverage of the area where coal breakage is occurring. Dust generation sources, such as stageloader/crushers on longwalls and belt transfer points, can also be enclosed to physically prevent the generated dust from reaching the ambient ventilating airstream.
3. Remove respirable dust from the ventilating air through the use of powered dust collectors and water sprays. Flooded-bed scrubbers on continuous miners and vacuum systems on roof bolters have effectively reduced dust levels, while hollow-cone water sprays are commonly used for airborne dust capture.
4. Dilute the remaining airborne dust by maximizing the quantity of ventilating air available. Also, increasing the distance between the dust source and workers allows greater opportunity for the dust to mix and dilute with the ventilating air.
5. Prevent respirable dust from reaching the breathing zones of workers by increasing ventilation velocity, using water sprays to direct dust away from workers, and providing physical barriers between the dust and workers. Water sprays induce airflow and can be used to direct dust-laden air away from workers. A successful example is a directional spray system used on longwall shearers. Hollow-cone or venturi sprays are mounted on a splitter arm with additional spray manifolds mounted along the length of the face side of the shearer body (Fig. 2a). Additional sprays are mounted at the tailgate end of the shearer to help control dust generated by the tailgate drum (Fig. 2b). All of these sprays have a downwind orientation and are designed to hold dust generated by the shearer near the face until the dust is downwind of the shearer operators. A key component of the splitter arm is belting that is hung from the arm down into the face conveyor. This belting provides a physical barrier that prevents dust released by coal landing in the face conveyor from moving into the walkway.
6. Regular maintenance of dust controls must be a required part of the mining operation and culture, with adequate time and supplies allotted by the mine operator to complete this maintenance. NIOSH studies have shown that the filter panels of flooded-bed scrubbers can quickly become clogged after one cut and result in a reduction in scrubber airflow of up to 35 percent, substantially reducing scrubber effectiveness without regular maintenance being provided.

Silica dust

A related issue of great concern is mine workers' exposure to respirable crystalline silica (RCS) dust. Inhalation of RCS can lead to silicosis, another disabling and potentially fatal lung disease with no cure. Medical evidence suggests that miners in Kentucky, Virginia and West Virginia have increasingly been exposed to silica dust over the last several decades. When increased levels of silica are present in the mining environment, diligent application of dust control technologies, potentially at elevated levels — such as increased airflow, water quantity — is even more critical as silica has greater toxicity to lung tissue than coal dust. ■

Disclaimer

The findings and conclusions in this report are those of the author and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company name, product, or software does not constitute endorsement by NIOSH.

References

A list of all references is available in the full-text paper.

Haul-road monitoring in openpit mines using unmanned aerial vehicles: A case study at Bald Mountain Mine site

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Improved haul-road conditions can have a positive impact on mine operations, resulting in heightened safety, productivity gains, longer tire life and lower maintenance costs. For these reasons, a monitoring program is required to ensure the operational efficiency of the haul roads. Currently, at Bald Mountain Mine, monthly site severity studies, ad hoc inspections by frontline supervisors or operator feedback reporting are used to assess road conditions. These methods are subjective and provide low temporal resolution data. This case study presents novel unmanned aerial vehicle (UAV) technologies, applied on a critical section of haul road at Bald Mountain, to showcase the potential for monitoring haul roads. The results show that orthophotos and digital elevation models can be used to assess the road smoothness condition and to check the road design compliance. Moreover, the aerial mapping allows detection of surface water, rock spillage and potholes on the road that can be quickly repaired/removed by the dedicated road maintenance team.

Introduction

Road quality has a significant impact on mining operations and is therefore identified as an area for improvement. Roads require constant monitoring because they are prone to defects caused by the daily wear and tear from heavy machinery and rough weather conditions. Insufficient or inadequate vigilance over the design and maintenance of haul roads can have detrimental consequences and negative impacts on productivity, costs and safety. In addition, maintenance issues that arise due to poor road conditions can increase costs and requirements for manhours, which could be used more effectively. Conversely, good road conditions can improve safety, raise equipment efficiency, lower fuel consumption, increase tire life and reduce maintenance requirements. To this end, continuous haul-road monitoring and optimization efforts are required to improve operational efficiency at mine sites.

Thompson et al. [1] discussed the methods available for addressing deteriorating road conditions, which can involve routine maintenance, resurfacing, rehabilitation and betterment. Some of the methods are simple, such as shallow blading and dust control. Other more complex tasks include ripping, regraveling and geometric improvements (betterment). Some of the common issues with haul roads in openpit mines are spilled material or boulders on the road, potholes, rough and uneven surfaces, and super-elevation. To ensure that the appropriate repairs are performed, the road conditions must be continuously monitored and assessed.

Method

The experiment was conducted at Kinross Gold Corp.'s Bald Mountain Mine, an openpit mine complex located in Nevada in the United States. Due to the large mining area, there is a complex road network at the site, which makes monitoring the roads both challenging and critical for efficient operations. The section of road selected for the experiment was approximately 1.2 km long and 40 m wide, and it was selected because it was one of the most utilized roads at the mine.

The UAV system used was a DJI Inspire 2. For this experiment, two parallel flight lines on either side of the road centerline were used to collect 601 images. Front and side image overlaps of 60 and 80 percent, respectively, were used. The flight height was considered to be 100 m above the road, resulting in ground-sampling distance of 10 cm/pixel. The images were processed in an open-source software package, called OpenDroneMap [2], to generate an orthophoto and digital elevation model (DEM) of the road.

Figure 1a presents the slope model of the road, and Fig. 1b shows the instantaneous gradient of the road along 1,200 m of the road centerline. This can be an indication of the road smoothness/undulating condition. Areas with high frequency of sharp peaks are more undulated than the rest of the road. In addition, the 3D model can be used to lo-