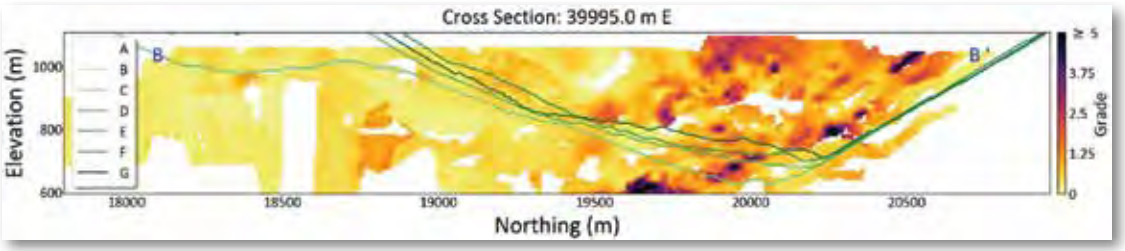

Fig. 3 East to west cross-section of the averaged grade model showing the outlines of each pit shell along the efficient frontier.

be used to apply risk management principals to the pit optimization process of an openpit mining project. ■

References

1. Hustrulid WA, Kuchta M (2013) Open pit mine, 3rd edn. Taylor and Francis, London
2. Rossi ME, Deutsch CV (2013) Mineral resource estimation, chap. 10, 12. Springer, Netherlands
3. Markowitz H (1952) Portfolio selection*. The Journal of Finance 7(1):77–91
4. Levy H (2016) Stochastic dominance: investment decision making under uncertainty, vol. 1, 3rd Edn Springer
5. Acorn T, Deutsch CV (2018) Optimizing pit shells in the presence of geologic uncertainty with a heuristic algorithm. Society for Mining, Metallurgy & Exploration Annual Transactions

Helmet-CAM: Strategically minimizing exposures to respirable dust through video exposure monitoring

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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

Exposure to respirable crystalline silica (RCS) remains a serious health hazard to the U.S. mining workforce who are potentially exposed to RCS [1,2] as various ore bodies are drilled, blasted, hauled by truck, crushed, screened/sized and transported to their destinations. To examine a method for assessing RCS exposure using a NIOSH-developed video exposure monitoring (VEM) technology (referred to as Helmet-CAM), video and respirable dust concentration data were collected on 80 miners across seven unique mining sites. The data were then collated and partitioned using a thresholding scheme to determine exposures that were in excess of 10 times the mean exposure for that worker. Focusing on these short-duration, high-magnitude exposures can provide insight into implementing controls and interventions that can dramatically lower the employee's overall average exposure. In 19 of the 80 cases analyzed, it was found that exposure could be significantly lowered by 20 percent or more by reducing exposures that occur during just 10 minutes of work per eight-hour shift. This approach provides a method to quickly analyze and determine which activities are creating the greatest health concerns. In most cases, once identified, focused control technologies or behavioral modifications can be applied to those tasks.

Background

Many mining operations conduct routine personal sampling with gravimetric (filter collection) methods. While full-shift gravimetric sampling does give an accurate time-weighted average (TWA) of respirable dust exposure, it is not able to pinpoint elevated exposure sources. Personal dust monitors that record continuous readings via optical light-scattering technologies are able to measure respirable dust levels on a second-by-second basis and therefore add additional discernment of dust profiles [3,4]. To identify a worker's specific task or activity during peak exposures, researchers at the National Institute for Occupational Safety and Health (NIOSH) developed a video exposure monitor-

ing system named Helmet-CAM (Fig. 1) [5,6] with an accompanying software package called EVADE, for enhanced video analysis of dust exposure. EVADE combines logged dust-monitor data with recorded video from wearable body cameras to determine the specific task, situation or activity at the times of elevated dust exposures [7]. While the process of collecting, reviewing and discussing the data is convenient for a limited number of workers (for example, through a one-day study at a single mine), it could become unmanageable and impractical for gathering larger datasets (for example, collecting data once a month across a dozen operations).

The objective of the analysis methodology described in this paper is to offer a technique for quickly determining if the exposures are coming from distinct events, where improved work practices or targeted engineering controls may lower exposures, or from overall high dust levels, where changes such as total structure ventilation or local exhaust ventilation systems may be needed. In this way, resources can be spent most efficiently on addressing those situations that create the highest potential for short-duration, elevated exposures. To accomplish this work, NIOSH researchers used the EVADE software in a series of behavioral/engineering cooperative interventions [8]. Workers were fitted with a person-wearable video camera and a real-time data-logging respirable dust monitor during part of their work shift while performing routine tasks.

Fig. 1 Video exposure monitoring equipment (Helmet-CAM) worn by a miner with a mobile camera (right shoulder) and cyclone inlet (left lapel)

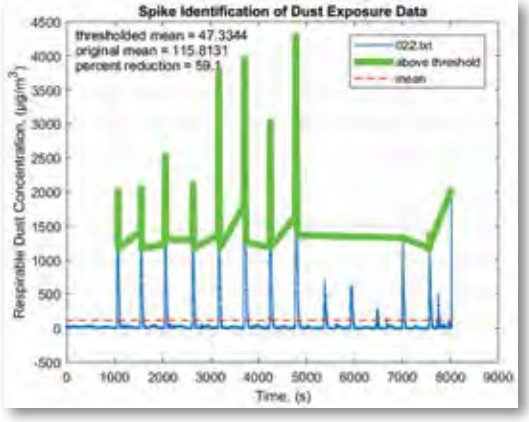

Fig. 2 Example of spike identification of dust exposure levels.

Methodology

NIOSH researchers aggregated the respirable dust exposure data and associated video footage of 80 mine workers at seven unique sites. Respirable dust data (time histories) used for the analysis was processed in several high-level steps: collation, thresholding, peak identification and evaluation of potential to substantially decrease mean exposures. The result of those procedures was a list of datasets, with one dataset per miner, classified as having the possibility of significant exposure reduction with the removal of specific, individual peaks. This refined dataset was then evaluated with EVADE to identify the work task, location and work practices at the time of the exposure.

Scripts written in Matlab (Mathworks, Natick, MA) were developed that read the *.txt files, allowing the data to be processed. Each dataset is individually analyzed to determine if short-duration exposures had a major impact on the miner's average exposure. Metrics are then calculated, such as the mean, maximum and length of each dataset. A threshold of 10X the mean was chosen to determine which points in the file are greater than that limit. Those points greater than the threshold limit are flagged, and a new mean is calculated with those points having been removed (Fig. 2). To determine if a dataset should be set aside for further analysis, the mean dust exposures are compared with and without point removal. If the mean exposure level is decreased by 20 percent or more, the dataset is flagged and studied further. Computationally, this is a simple task, and the entire process takes less than 7 seconds for the more than 225,000 data points collected in total for all 80 datasets.

Results and discussion

The data gathered during the Helmet-CAM studies represent more than 144 hours of miners engaged in various work tasks and included the following workers: maintenance personnel, bagging operators, skid-steer drivers and general laborers. The mean dataset length was 108 minutes with a

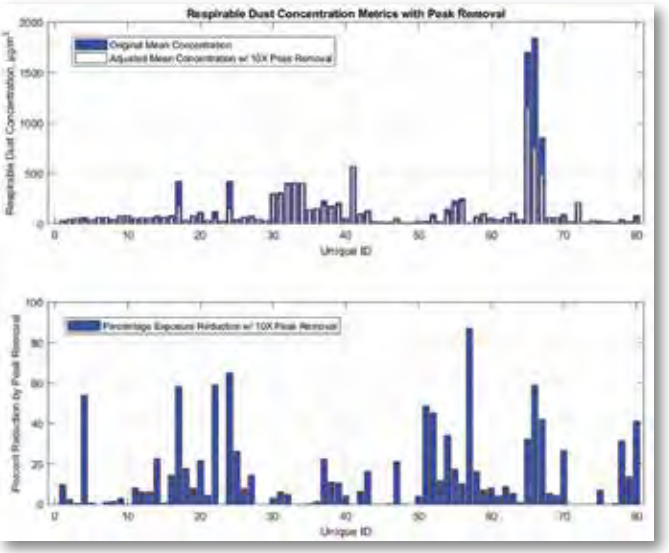

Fig. 3 Original mean dust concentration (top chart, blue) and mean concentration if peaks greater than 10X mean are removed (top chart, white). Percentage dust exposure reduction realized by peak removal (bottom chart, blue).

mean exposure of 159 µg/m³. The standard error is then 2.17 µg/m³, which with 95 percent confidence intervals would estimate the mean to fall between 155 and 163 µg/m³.

When the data were processed with the thresholding scheme described previously, 19 of the 80 datasets met the thresholding criteria — that is, the mean exposure would decrease by 20 percent or greater if peaks larger than 10X the original mean exposure were removed. Five of those 19 criteria-matching datasets would have their exposure reduced by greater than 50 percent with this analysis (Fig. 3, bottom chart). The average "over threshold" time was just 112 seconds per mine worker, which means that the peaks identified occupy just 1.7 percent of the time sampled, equating to roughly 10 minutes in an eight-hour shift. To highlight the types of activities occurring during the peak exposures, two datasets are discussed below.

In the first dataset of interest (number 022), a haul-truck driver is delivering screened sand between a load-out station and a stockpile. The algorithm found 11 peaks that are in excess of the threshold criteria (greater than 10X the mean). Using EVADE to analyze the data, it was found that these peaks correlate to when the truck was backing up to the stockpile. Because the truck was older and lacked an effective filtration and pressurization system with air conditioning, the truck driver relied on natural ventilation (windows down), which allowed the dust cloud stirred up by the truck to flow into the cab. The original mean exposure was 116 µg/m³, and the removal of these peaks would reduce his exposure by 59.1 percent. Further, analysis with EVADE revealed that about 83 minutes into the recording, this dust source was reduced by about 54 percent when the video showed a haul water truck being used, thus pointing to the effectiveness of watering haul roads and heavily trafficked areas.

In the second example, the algorithm found 12 peaks on a mobile bagger responsible for the filling, tying (Fig. 4) and warehousing of flexible intermediate bulk containers, or bulk bags. Upon review of the EVADE session, the dust peaks coincided with the worker's approach to the bag following each filling. By removing this short-duration exposure that occurred in just 110 seconds (just 1.6 percent of the measurement session), the worker's exposure would have been reduced by more than 65 percent. This example demonstrates that short-duration exposures can occur during specific work tasks such as bagging, which operators can address by such practices as exploring local exhaust ventilation options for bagging stations, training employees on best practices of tying bag collars away from their breathing zone and encouraging the use of respirators where appropriate.

Conclusions

The Helmet-CAM assessment technology and EVADE software have proven to be a useful combination in quickly identifying the sources of elevated respirable dust exposures at mine sites. This combination can be part of a larger multilevel intervention effort to systematically reduce worker exposure through increased awareness and control of dust exposures. In an effort to further reduce dust exposures over longer time scales, mine operators may wish to conduct more frequent Helmet-CAM assessments.

This paper has described a method of data post-processing accomplished with computer algorithms, which could be used to "screen" the data and identify those exposure tasks that are short in duration, yet substantial enough that their correction would lead to significant reductions in worker exposure. After an appreciation for the use of the technology has been developed, this or a similar technique could be used to identify, track and ultimately reduce the personal exposure to health hazards by mobile workers. ■

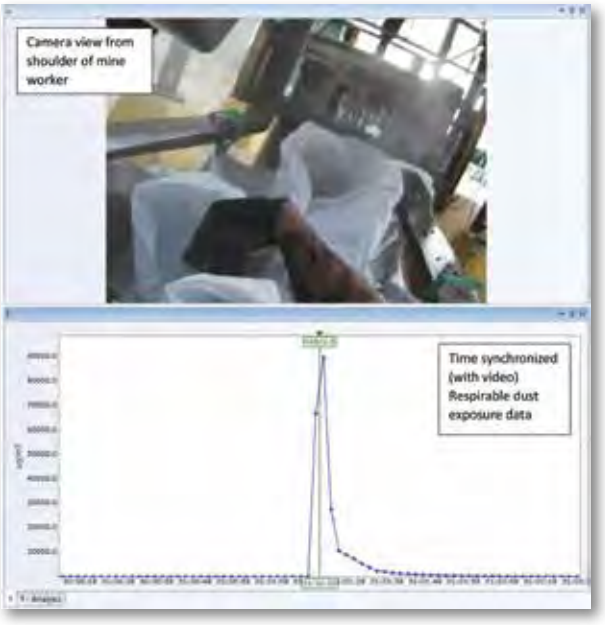

Fig. 4 Use of EVADE software in the case of a bulk bagger, linking the activity (worker approaching bulk bag after filling to begin tying the bag) to the dust exposure peak.

Disclaimer

The findings and conclusions in this paper are those of the authors 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 or product does not constitute endorsement by NIOSH.

References

1. MSHA (2017). MSHA Data Sets; Personal Health Samples
2. Cecala AB, O'Brien AD, Schall J et al (2012) Dust control handbook for industrial minerals mining and processing. In: Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Research, Office of Mine Safety and Health
3. ThermoFisher Scientific (2019). Personal dataram™ pdr-1500 aerosol monitor
4. Patts JR, Tuchman DP, Rubinstein EN, Cauda EG, Cecala AB (2019) Performance comparison of real-time light scattering dust monitors across dust types and humidity levels. Mining, Metallurgy & Exploration 36(4):741–749
5. Cecala AB, Reed WR, Joy GJ, Westmoreland SC, O'Brien AD (2013) Helmet-Cam: tool for assessing miners' respirable dust exposure. Min Eng 65(9):78
6. Cecala AB, Haas EJ, Patts J, Azman A, Cole GP (2017) Helmet-CAM: An innovative tool for exposure assessment of respirable dust and other contaminants. In Proceedings of the 16th North American Mine Ventilation Symposium, Boulder, CO
7. Reed WR, Kwitowski AJ, Helfrich WJ, Cecala AB, Joy GJ (2014) Guidelines for performing a helmet-CAM Respirable dust survey and conducting subsequent analysis with the enhanced video analysis of dust exposures (EVADE) software. Pittsburgh, PA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2014-133, RI 9696
8. Haas EJ, Cecala AB, Hoebbel CL (2016) Using dust assessment technology to leverage mine site manager-worker communication and health behavior: a longitudinal case study. J Progress Res Soc Sci 3(1):154–167