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Using Dust Assessment Technology to Leverage Mine Site Manager-Worker Communication and Health Behavior: A Longitudinal Case Study

Emily J. Haas[1], Andrew B. Cecala[2], Cassandra L. Hoebbel[3]

[1]National Institute for Occupational Safety and Health, Pittsburgh, PA.
[2] National Institute for Occupational Safety and Health, Pittsburgh, PA.
[3] National Institute for Occupational Safety and Health, Pittsburgh, PA.

Abstract

Research continues to investigate barriers to managing occupational health and safety behaviors among the workforce. Recent literature argues that (1) there is a lack of consistent, multilevel communication and application of health and safety practices, and (2) social scientific methods are absent when determining how to manage injury prevention in the workplace. In response, the current study developed and tested a multilevel intervention case study at two industrial mineral mines to help managers and workers communicate about and reduce respirable silica dust exposures at their mine sites. A dust assessment technology, the Helmet-CAM, was used to identify and encourage communication about potential problem areas and tasks on site that contributed to elevated exposures. The intervention involved pre- and post-assessment field visits, four weeks apart that included multiple forms of data collection from workers and managers. Results revealed that mine management can utilize dust assessment technology as a risk communication tool to prompt and communicate about healthier behaviors with their workforce. Additionally, when workers were debriefed with the Helmet-CAM data through the device software, the dust exposure data can help improve the knowledge and awareness of workers, empowering them to change subtle behaviors that could reduce future elevated exposures to respirable silica dust. This case study demonstrates that incorporating social scientific methods into the application of health and safety management strategies, such as behavioral modification and technology integration, can leverage managers' communication practices with workers, subsequently improving health and safety behaviors.

Keywords; Health behavior; Health and safety management system; Helmet-CAM technology; Mine health and safety; Multilevel intervention; Mixed-methods design; Respirable silica dust; Safety climate; Wearable health monitoring.

1.0. Introduction

Health and safety management systems (HSMS) consist of interacting, strategic practices designed to achieve occupational health and safety goals (e.g. ANSI/AIHA/ASSE Z10-2012; OHSAS 18001; ILO-OSH-2001). HSMS have become a self-regulatory priority for many industrial organizations – mining in particular. The National Mining Association (NMA) developed an HSMS comprised of 20 elements and over 130 complementary practices needed to improve and maintain worker health and safety (CORESafety, 2012). Despite such guidance, however, the use of health and safety management practices is not fully integrated nor consistent across the industry.

Previous research asserts that the lack of HSMS consistency and application is primarily due to: (1) studying worker and manager perspectives separately, rather than focusing on their H&S interactions (Haas, 2014; Wachter & Yorio 2014; Joy 2004); and (2) the absence of integrated social scientific methods to help address problems in injury prevention and control (Trifiletti, Gielen, Sleet, & Hopkins, 2005). In response to these gaps, researchers from the

National Institute for Occupational Safety and Health (NIOSH) designed and implemented a multilevel intervention (MLI) case study, grounded in social science theory and methods. The intervention framework encouraged mineworkers and mine management to work together to solve a common problem – reducing elevated exposures to respirable silica dust. This case study is unique in that the intervention incorporated dust exposure assessment technology (i.e., Helmet-CAM, described later) to help bridge manager-worker health communication efforts. Results indicate that dust assessment technology has implications for developing leaders' H&S management practices as well as facilitating healthier behaviors among the workforce.

Before exploring the research questions and methodology relevant to this study, first we highlight mineworkers' elevated exposure to respirable silica dust to warrant the initial focus on this issue within health and safety (H&S) risk management.

2.0. Review of Literature

2.1. Exposure to Respirable Silica Dust

Mining environments generate large quantities of respirable dust. Exposure to dust containing crystalline silica is a serious health concern, making silica exposure a critical area of research (Laney, Petsonk, & Attfield, 2009). Overexposure to respirable silica dust for an extended period of time can lead to silicosis and other complications including pulmonary tuberculosis, autoimmune disorders, chronic renal disease, and other adverse health effects (NIOSH, 2002). The current silica compliance standard, as mandated by the Mine Health and Safety Administration (MSHA), is approximately based on 100 µg/m^3 SiO_2 level (30 CFR 56/57.5001). However, the Occupational Safety and Health Administration (OSHA) recently proposed to reduce the current respirable silica dust standard by 50 percent (Occupational Exposure to Respirable Crystalline Silica released 9-12-2013). If this legislation is adopted by MSHA, the mining industry faces a significant increase in the number of mineworkers whose dust exposure levels may exceed the allowable standard (as shown in Table 1).

Table 1. Silica exposure data for occupations at surface industrial mineral mines (MSHA, 2012).

Occupation in MSHA database	% samples over 100 µg/m^3 SiO_2 (2009-2012)	% samples over 50 µg/m^3 SiO_2 (2009-2012)
Bagging operator	26	74
Dry screen plant operator	15	46
Clean-up worker	20	36
Laborer	12	42
Lab technician	30	40
Truck loader	22	78
Crusher operator	11	31

Fortunately, overexposure to respirable silica dust is preventable, with control technologies having a critical role in proactively identifying and mitigating sources of respirable dust at mine sites.

2.2. The Role of Technology in Reducing Exposure to Respirable Silica Dust

To date, several engineering control technologies have significantly reduced respirable dust liberations at surface mines (for a review of technologies, see Cecala et al., 2012). In addition to control technologies, assessment technologies can be used to identify and manage new respirable dust sources. This study focused on the application of Helmet-CAM dust assessment technology to help managers and workers address this health issue.

2.3. Overview of Helmet-CAM Assessment Technology

A joint partnership formed several years ago by a mining organization and the National Institute for Occupational Safety and Health (NIOSH) resulted in the development of an assessment technology now known as Helmet-CAM (see Cecala & O'Brien, 2014; Cecala et al., 2013). Helmet-CAM technology (Figure 1) helps identify how, when, and where mineworkers are being exposed to respirable silica dust, allowing for a tailored focus on the tasks and activities that can increase periods of elevated exposure.

Figure 1. (from left to right) Video camera attached to helmet, dust monitor and video monitor, and safety vest to hold instrumentation.

The Helmet-CAM system includes a lightweight video camera on the worker's hardhat and an instantaneous dust monitor on the worker's belt/backpack. Workers perform their job tasks as usual while video and dust exposure data are collected every two seconds via the dust monitor. Video footage and dust data then are downloaded to the Enhanced Video Analysis of Dust Exposure (EVADE) software (NIOSH, 2014). This software merges the video footage and dust concentration data to produce a graphical, time based representation of the worker's POV and simultaneous respirable dust exposure (Figure 2). The Helmet-CAM currently is utilized at a number of mine sites to identify higher sources of respirable dust. For a more detailed history and background of the Helmet-CAM and EVADE software, see Cecala and O'Brien (2014) and NIOSH (2014).

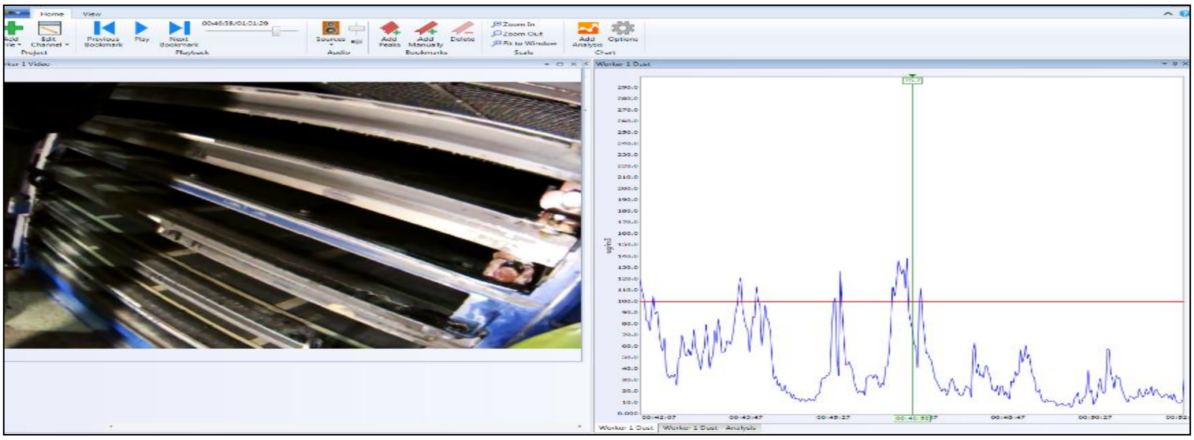

Figure 2. The beta version of the EVADE 2.0 software showing a graph representing the worker's respirable dust exposure (right) and the job task being completed (left).

From the Helmet-CAM data, mineworkers' exposures have been lowered through the implementation of control technologies, interventions, and changes to work practices. However, current data shows that surface workers still experience periods of elevated exposure. Therefore, further determination of how to make optimal use of this technology was deemed necessary to improve workers' long-term health.

2.4. Incorporating Technology into Multilevel Interventions to Encourage Manager-Worker Health Communication

Multilevel interventions (MLIs) support a systematic approach to social science research, as they are designed to target an audience on, within, and between two or more levels (e.g., individual worker, work group, etc.) to encourage and sustain behavior (Haas, 2014). Smedley and Syme (2000) argued that behavioral MLIs offer promise to reduce morbidity and mortality; however, their potential to improve H&S has not been adequately explored in applied practice. If multiple levels (i.e., managers and workers) of health and safety experiences are studied together, communicating about and tailoring H&S efforts may be easier to manage within the organization (DeJoy, 2005; Robson et al., 2007; Wachter & Yorio, 2014). The current study encouraged multilevel, collaborative efforts, using the dust assessment technology, to identify and increase awareness of respirable silica dust sources.

2.5. Management Health and Safety Communication Practices

One role of management is to guide and support workers' H&S behaviors (Mearns et al., 1998; Michael, Guo, Wiedenbeck, & Ray, 2006; Rubin, Bommer, & Bachrach, 2010). Previous research demonstrates that workers are more likely to engage in self-protective behaviors after receiving specific feedback about their exposure to and performance around workplace hazards (e.g., Zohar & Polachek, 2014; Kluger & DeNisi, 1996). These findings suggest that management commitment and support for H&S (relative to production demands) can substantially influence workers' tendency to engage in risky behaviors (Weyman, Clarke, & Cox, 1999). However, managers' perceptions of the organizational climate can be highly inaccurate (Mezias & Starbuck, 2003). Therefore, it is important to also assess workers' interpretations of management HSMS practices to help align actionable knowledge and behavior (Bettis & Prahalad, 1995).

Research suggests that when codified management practices are consistently carried out, the H&S behaviors of workers are also more consistent and disciplined (Denison, 1996). Health and safety managers and front-line supervisors play a critical role in identifying potentially risky practices, taking action to mitigate hazards, and enforcing policies and procedures (Kouabenan, Ngueutsa, & Mbaye, 2015; Schneider & Rentsch, 1988). Thus, these managers are in a unique position to influence the behavior and attitudes of workers by way of multi-level communication practices. Because the likelihood of miscommunication in the workplace is great, consistent practices, as communicated by management, are even more important to encourage workers' desired behavioral execution (Keyton, 2011; Wold & Laumann, 2015). In response, applied research is needed to inform the industry what HSMS practices are important and how those practices can be maintained overtime. Use of the Helmet-CAM can enhance this research area by identifying common vantage points from which managers and workers can address their H&S concerns.

2.6. Research Questions

With increasing frequency, social science research has begun to integrate technology as a mechanism to influence H&S behaviors over time. For this case study, we saw an opportunity to enhance social science research methodology by using dust exposure assessment technology as a bridge to effective health communication between managers and workers to support HSMS practices. The following questions guided the intervention study:

- What data does the Helmet-CAM provide that are used as manager-worker discussion points to reduce future dust liberations?
- What impact does a four-week intervention have on workers' perceived levels of health and safety (1) proactivity and (2) compliance?
- What H&S communication practices, as perceived by (1) managers and (2) mineworkers, influence participating workers to engage in behaviors that reduce respirable silica dust sources?

3.0. Methodology

A case study MLI design was deemed appropriate to allow for an initial and re-assessment of miners' work practices within the mine environment as well as management's communication practices revolving around dust exposure (George & Bennett, 2004). Traditionally, case studies provide important information from the viewpoint of participants by using multiple sources of data (Tellis, 1997). Repeated-measures quantitative and qualitative data were collected from managers and workers while the Helmet-CAM technology provided detailed scenarios that were reviewed with participants.

3.1. Description of Helmet-CAM Technology Multilevel Intervention

Researchers designed an MLI based on principles of behavioral science and health theory, specifically in crafting the data collection instruments (Trifiletti et al., 2005; Gielen & Sleet, 2003; DeJoy, 1996; Yorio, Willmer, & Moore, 2015; McLeroy, Bibeau, Steckler, & Glanz, 1988; Janz & Becker, 1984; Yorio & Willmer, 2015). In any type of longitudinal research, multiple methods in the form of pre- and post-test surveys, interviews, and/or focus groups are common (Anisimova & Thomson, 2012). The Helmet-CAM was used as a communication medium to help initiate and enhance conversations about workers' risks and occurrences of respirable silica dust exposures.

3.2. Recruitment, Data Collection Instruments, Intervention Design

Human subjects research approval was obtained from the NIOSH Institutional Review Board. Subsequently, a convenience, purposive sampling strategy was used to recruit mines (Given, 2016; Yin, 2011). This sampling strategy helped target mines that were familiar with or currently using the Helmet-CAM to allow more focus on manager-worker communication practices and less on the use of new a technology (Denzin & Lincoln, 1994). Familiarity with the technology allowed for more in-depth discussions about H&S communication issues and less apprehension around participation in the study.

We contacted an H&S leader of an industrial minerals mining corporation who volunteered two Midwestern sites, both familiar with the technology, to participate. We held conference calls with the H&S site-level managers to discuss the logistics of the MLI, purposes of each data collection effort, and schedule field visits. Upon arrival, the H&S managers explained to workers, "We are utilizing Helmet-CAM technology to help provide educational information that we can discuss and use to help identify and lower exposures to respirable silica dust." Individual recruitment involved the same convenience, purposive sampling strategy in that we engaged individuals who were easily accessible and willing to participate while we were present at the mine (Given, 2016; Yin, 2011). Additionally, management was asked to identify any specific areas that were a concern regarding respirable dust levels and recruited individuals who were working in "dustier" areas. Nevertheless, we represented a variety of jobs and tasks (e.g., dry maintenance operations, lab technician, screen house maintenance, mobile equipment operators, etc.) to help avoid bias (Kuzel, 1992; Yin, 2011).

The intervention involved wearing the Helmet-CAM while completing routine work tasks during two separate visits. The pre-assessment visit included a sample of 12 mineworkers who agreed to participate. The post-assessment included 8 of the original 12 workers (the other 4 were absent during our second visit due to vacation, sick leave, and/or a schedule change). Additionally, 15 H&S managers or site leaders participated during the pre- and/or post-focus group discussions. The intervention timeline is visually depicted in Figure 3.

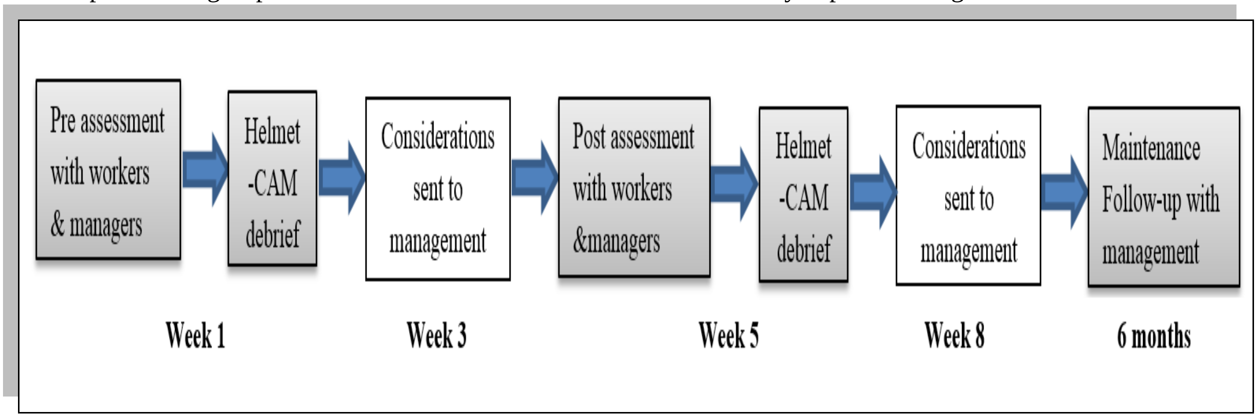

Figure 3. Intervention timeline.

3.3. Mineworker Pre and Post Survey Assessments

A subjective pre- and post-assessment was used to gauge participants' perceptions of the organization's climate and their own H&S proactivity and compliance (Grant, Parker, & Collins, 2009; Thompson, 2005; Crant, 2000, 1995). The survey consisted of scales to assess changes in workers' perceived proactivity, compliance, their supervisors' safety communication/support, the organization's safety communication/support, their personal tendency to take risks, and personal H&S knowledge and motivation. A 6-point (strongly disagree to strongly agree) response format was used and each scale was tested for internal consistency using Cronbach's alpha to measure its reliability, each scale rendering an acceptable coefficient (Cronbach, 1951; Nunnaly, 1978).

3.4. Mineworker Interviews

After completing the survey, short interviews were conducted with participants in designated office rooms to protect workers' confidentiality. Theoretical constructs within the Health Belief Model (Janz & Becker, 1984), Protection Motivation Theory (Rogers, 1975), and the Precaution Adoption Process Model (Weinstein, 1988) were used to devise questions about mineworkers' risk perceptions, susceptibility/severity, knowledge/motivation, and protective behaviors. Additional questions prompted participants to discuss common hazards they watch for on the job, tasks which expose them to the most respirable silica dust, and behaviors they engage in to prevent elevated exposures.

Participating workers also discussed various messages that impact their H&S decisions so we could better understand the current communication mechanisms in place on site. For instance, participants were asked how often their supervisors talk with them about silica dust, behaviors they discuss that can reduce exposure, and their preferred method of communication. The discussions took anywhere from 15-35 minutes, depending on time constraints and openness of each participant. Researchers took handwritten notes during each interview that were later typed. The same survey and interview occurred during the initial part of the first visit and before concluding the follow-up visit, four weeks later.

3.5. Helmet-CAM Use and Results Debrief with Mineworkers

After completing the survey and interview, participants wore the Helmet-CAM, equipped with a real-time data-logging respirable dust monitor, during part of their normal work shift. The information was downloaded into the EVADE software, which synchronized the video footage and respirable dust exposure data to allow for quick and easy review with each participant. By some participants' request and/or consent, a H&S manager was present as well. The information revealed possible work practices that could reduce future dust liberations and potential engineering controls and interventions to consider. These discussions were conducted to identify target behaviors that workers wanted to change. Subsequent interviews and debriefs regarding these behaviors to assess what corrective actions, if any, were taken during the intervening period.

3.6. Management Focus Groups

Members of management participated in focus groups to discuss ways they engage employees to be accountable and proactive in protecting their personal health. These focus groups lasted about one hour and contained 4-7 leaders during any given discussion – ideal for sharing knowledge in an open forum (Krueger & Casey, 2009). Because focus groups generally cover broad topics, these leaders were asked to share specifically what efforts were made to ensure consistent site-wide communication. Questions focused on the top-ranked HSMS elements (i.e., leadership development; accountability; knowledge, skills, and abilities development; system coordination; culture enhancement; behavior optimization; and risk management) to help understand how these elements assist with H&S communication (Bowen & Ostroff, 2004; Yorio & Willmer, 2015). Researchers who facilitated the focus groups took handwritten notes to capture participants' opinions throughout the discussion. The data allowed us to glean more insight into the organizational climate, which was helpful when reviewing the Helmet-CAM footage with participants and brainstorming possible solutions to reduce elevated exposures on site.

3.7. Helmet-CAM Results Debrief and Considerations with Management

Throughout the duration of the MLI, feedback was provided to participating members of management via e-mail, phone, or in person about elevated exposure areas, issues associated with elevated exposures, and considerations to possibly reduce respirable dust sources. During this process, management was encouraged to explore new communication messages with workers about behaviors that may further protect their health on the job. The range of data collection efforts and participants is documented in Table 2.

Table 2. Intervention timeline and participant sample.

Timeline	Group	Data Collection Effort	Field Work Participants
Pre-assessment	Mineworkers	• Survey pre-test; wearing Helmet-CAM; interview and debrief	Site 1: 7 workers Site 2: 5 workers
	Site Leadership	• H&S management focus groups	Site 1: 7 managers Site 2: 4 managers
Results and considerations	Site Leadership	• Considerations that could be discussed with workers to mitigate elevated exposures	Site 1: 2 managers Site 2: 1 manager
Post-assessment	Mineworkers	• Survey post-test; wearing Helmet-CAM; interview and debrief	Site 1: 4 workers Site 2: 4 workers
	Site Leadership	• Post-discussion and close-out meeting	Site 1: 9 managers Site 2: 6 managers
Results and considerations	Site Leadership	• Considerations that could be discussed with workers to mitigate elevated exposures	Site 1: 2 managers Site 2: 1 manager
Maintenance Follow-up	Site Leadership	• Checklist indicating what considerations provided have been implemented and maintained by management and workers	Site 1: 2 managers Site 2: 1 manager

4.0. Data Analysis

4.1. Quantitative Data

After each visit the survey results were input into an SPSS data file. Because this case study sample was not large enough to complete a paired-samples t-test with acceptable confidence, we could not determine whether the MLI significantly affected workers' proactive behaviors. However, basic descriptives were used to compare changes in mean scores for workers' perceived proactivity and compliance and perceptions of organizational values.

4.2. Qualitative Data

We analyzed the data from a deductive perspective, using the survey scales as an organizing framework (i.e. proactivity/compliance, organizational and supervisor H&S support, H&S knowledge and motivation, risk propensity, and engagement). Initial coding as the data was collected, transcribed, and debriefed allowed us to quickly identify general themes and topics that were emerging from both worker and manager levels. Additionally, discussions while viewing the Helmet-CAM footage provided supplemental information regarding varying or similar perceptions on site.

After initial coding, we engaged in a more focused effort to identify codes under respective themes from both the worker and manager perspective to organize a file of the joint results (Boyatzis, 1998; Charmaz, 2006; Patton, 2002). Once the worker and manager data was organized, the themes, codes, and examples that supported the codes were compared to the theoretical constructs used to develop the data collection instruments (Haas & Mattson, 2015). This allowed us to better understand the forces driving certain perceptions and decisions of workers and management.

Saturation of the data occurred when a specific code had ample supporting content from both the worker and management perspective (Corbin & Strauss, 2008). If both groups did not agree or provide support regarding a specific topic, then a code was not identified and rather, the disparate views were mentioned in the closing report to the mine. Overall, this joint codebook displayed the communication themes and practices evident on site, and the HSMS practices that were effective. In addition to this codebook, a Helmet-CAM document was compiled that displayed all of the procedural and environmental situations where respirable silica dust exposure was higher, behaviors that helped reduce dust, and possible dust reduction strategies of engineering control and interventions when behavioral modifications were not deemed to be effective or appropriate.

5.0. Case Study Results

The results highlight observed changes in workers' knowledge, awareness, and behavior toward respirable silica exposure and ways to reduce future elevated exposures. Additionally, documented changes in knowledge, awareness, and behavior from the first to second visit were found based on feedback provided by management and information learned via the Helmet-CAM debriefs with workers. More insight into managements' perspectives and behaviors are described during the discussion, to provide support for the positive intervention results.

5.1. Pre-assessment: Reported Respirable Silica Dust Exposure Awareness

5.2. Initial Awareness and Knowledge

The participating mineworkers were asked to share potential risks and hazards related to respirable silica dust exposure prior to and after wearing the Helmet-CAM. During the first visit, several workers had few concerns about their exposure and the associated long-term consequences, illustrating a low sense of perceived susceptibility. For example, one worker said, "I know that I'm exposed but I don't think I'm overexposed. So, I tend to not worry about it." Particularly, younger workers often said that they think about exposure but not necessarily overexposure because dust is well-controlled on their site. The following excerpt illustrates this attitude: "I think about dust exposure and trying to reduce it but I generally don't worry about it being a problem in the future in terms of my health. I don't think that because people have worked here for 35+ years and they're fine." Workers also tended to say that the probability of long-term health consequences is minimal because their exposure time is likely very limited. These initial reports align with workers initially underestimating a negative event happening to them as a result of routine tasks (Zohar & Erev, 2007).

Alternatively, the few workers with more experience mentioned varying levels of concern about their personal exposure based on the number of years they had been working in the mining industry, not the fault of any particular plant site. Participants with more experience were well aware of long-term health consequences associated with respirable silica dust exposure. One worker said, "I think it's [the dust] in the back of everyone's mind. The dust is definitely there." He also acknowledged that his co-workers need to be attentive to these exposures throughout their mining careers. These variations in feedback from mineworkers were consistent with findings among surface mineworkers in previous research (e.g., blinded for review, 2015).

5.3. Initial Behaviors

After the initial interview we reviewed individual Helmet-CAM footage with participants. After showing participants how the EVADE software works, we encouraged them to interact with the software to locate their highest respirable dust exposures. Participants were able to ask questions about their exposures and associated tasks while going over their personalized dust data. Generally, they were surprised at the magnitude of very brief dust exposures they experienced as they walked through certain areas of the facility, or the significant effects of something they did personally to raise their exposure. Examples of instances that resulted in brief elevations included: rubbing/clapping hands together and on clothes; forgetting to use ventilation measures already in place (i.e. fans) to circulate air; limited housekeeping in mobile equipment; and work processes for obtaining a sample for lab analysis.

5.4. Initial Feedback to Management

The Helmet-CAM footage was reviewed again when we returned to our research facility to ensure we did not overlook any critical scenarios of elevated exposure. Based on our review of the footage and discussions with participants, considerations were provided to management after the first site visit. These considerations primarily consisted of things management could do to support workers' health (e.g., purchase leather gloves that absorb less dust for workers to wear, encourage housekeeping in shared equipment, and provide additional tools such as plastic storage totes and vacuums for workers to use so less dust is liberated when performing job tasks). A similar feedback document was provided after the post-assessment as well.

5.5. Observed Changes in Workers' Respirable Dust Exposure Awareness and Behavior

5.6. Changes in Awareness and Motivation

During the second visit, participating workers completed the same survey and interview, and wore the Helmet-CAM again. Contrary to the first visit, participants' motivation to learn about respirable silica dust exposure and its consequences was much more evident through their eagerness in asking specific questions about respirable silica dust. Workers asked us questions such as, "What is the silica standard?," "How much [respirable silica] is too much before it affects you?," and "If you're exposed to the exposure limit your whole life will you get silicosis?" Additionally, participants asked to wear the Helmet-CAM in specific areas where they thought dust concentrations might be higher, because they were curious what could be done differently to reduce exposure levels. This observation of associates' increased interest indicates that perhaps "seeing," by means of the Helmet-CAM technology, what can't visibly be detected during the workday, is critical to establishing a sense of personal accountability to reduce sources of respirable silica dust.

5.7. Changes in Perceptions and Behaviors via the Survey Assessment

Although significance cannot be statistically determined due to the small sample, the survey results show a slight increase in averages, indicating a possible intervention effect on H&S outcomes. Table 3 lists scale averages that were measured within the pre- and post-survey items. A higher score is associated with positive H&S behaviors and perceptions of organizational support and leadership.

Table 3. Worker health and safety perceptions pre and post the Helmet-CAM intervention.

Workers' self-reported attitudes and behaviors	Pre Helmet-CAM assessment (Average on 6-point scale)	4-week Post Helmet-CAM assessment (Average on 6-point scale)
H&S Proactivity	4.6	4.7
H&S Compliance	4.8	5.6
Supervisor's Safety Support	3.9	4.3
Organization's Safety Support	5.5	5.5
Personal Risk Tendency	4.8	5.7
Personal H&S Knowledge	5.7	5.7
Personal H&S Motivation	5.8	6.0

As the pre-assessment results indicate, participants already held their own behaviors as well as their organizations' values and support for H&S to be high; so even minor increases during the post-assessment are promising. Particularly, participants' likelihood of maintaining compliance with H&S rules and policies, such as the silica standard, greatly improved, as well as their likelihood to take fewer risks on the job. The survey results also demonstrate that participants' perception of their supervisors' H&S support increased.

In addition to the survey results, the post-discussions with participants as well as corrective actions revealed in the Helmet-CAM footage show that mineworkers made a conscious effort to modify certain work tasks and behaviors to reduce personal exposures. For example, at follow-up, participants more regularly used clothes cleaning technology to remove dust from dirty/soiled clothes (Cecala et al., 2008); installed a switch to easily turn on a fan when entering the sampling splitter room to better ventilate the area; and changed a pre-established process for gathering lab analysis samples so that less fugitive dust is emitted near personal breathing zones. All of these behaviors would considerably reduce their exposure to respirable silica dust.

6.0. Discussion

The case study results revealed key information that was exchanged between workers and managers to help reduce respirable dust liberations. Examples included housekeeping and cleanliness, and potential changes to certain buildings to increase ventilation. Additionally, results provided insight into workers' reported proactivity and compliance. Importantly, the pilot case study results indicate that after mineworkers wear the Helmet-CAM and review their personal footage, they are likely to better recognize instances in which they experience brief elevations. More specifically, reviewing the footage with participants seemed to positively impact their level of awareness on the job, including potential hazards that may be a source of respirable silica dust. After reviewing the dust data and modifying certain decisions or controls, participants were able to quickly see if these changes lowered their risks, instilling internal knowledge and personal motivation.

The last question of interest in the current study was what HSMS practices, as perceived by managers and workers, effectively influence workers' H&S decisions. The subsequent discussion answers this question, drawing on the focus group and interview data provided by managers and workers throughout the case study.

6.1. Health and Safety Practices that Support H&S Performance

Managers shared which H&S practices they engage in on site and how, which was compared with feedback provided by mineworkers. Workers cited several of the same examples provided by their managers, indicating consistent interpretations across the facility. The multilevel results show that mine management consciously engage with workers to provide information and support health and safety as a priority for the organization.

6.2. Engagement Practices: Communication and Joint Decision Making

Worker engagement practices were discussed as a way to foster responsibility and accountability, particularly in terms of identifying and solving an H&S problem. Several practices were in place that facilitated consistent communication and problem-solving efforts between these two groups. For example, managers indicated that establishing cross-functional teams has developed workers' leadership skills, problem-solving capabilities, and more equally shared responsibilities. Another unique example discussed was engaging workforce members in the hiring process within their work group allowing employees to communicate potential concerns. However, despite the various efforts managers discussed to enhance consistency, one manager said, "As a group we need to work on consistent communication so every job function is receiving the same information," indicating awareness that there can always be areas to improve in relation to H&S management.

Additionally, workers are invited to leadership meetings to provide ideas to prevent re-occurring H&S incidents. For example, one manager said, "We let workers determine things that need to be improved because then they are involved in coming up with solutions to problems." Previous research has argued that in order to mitigate risks and endorse H&S behaviors, individuals must be involved in the discussion of problematic hazards, behaviors, and how they can be changed (Gielen & Sleet, 2003; Tong, Rasiah, Tong, & Lai, 2015). Therefore, engaging workers through direct involvement and decision making efforts during the Helmet-CAM intervention may have contributed to workers' increased H&S proactivity, knowledge, and motivation.

A substantial body of research argues that employee involvement is a predictor of safety-related outcomes, meaning that if employees perceive the outcomes of their evaluations to be fair, they are more likely to perform in a way that benefits the organization (Hystad, Mearns, & Eid, 2014; Carmeli, Reiter-Palmon, & Ziv, 2010). Pertaining to the current study, one practice management discussed that encouraged involvement and fairness is the ability for workers to annually evaluate managers just as managers evaluate workers. Similarly, workers continually emphasized their autonomy in solving problems. For example, one worker said, "They [management] don't push us to do any one thing in a certain direction. The managers don't do the job we do. So it is really about us making decisions together as a team and what's best for us." Management indicated that more work has to be done to encourage peer-to-peer intervention to promote health and safety, but they are trying to develop more ways for peers to evaluate and encourage each other. Therefore, not only involvement, but support emerged as being an important H&S practice.

6.3. H&S Support: Building Relationships Builds Trust

Supportive communication has been shown to enhance employee participation in H&S decision making (Casey & Krauss, 2013; Hofmann & Morgeson, 1999). The results of the current study support this point, particularly that engaging the workforce by way of Helmet-CAM showcased managements' interest in maintaining and even improving their employees' personal health. By allowing workers to wear the Helmet-CAM and subsequently discuss the feedback in a non-punitive way, managers helped foster a supportive environment that may enable future health and safety behaviors. With active participation from managers – meaning they encourage using the Helmet-CAM, discuss the footage with workers, and try to mitigate potential risks – the Helmet-CAM may be used as a tool to bridge communication efforts with workers and as a result, build relationships on site.

Also, managers discussed the importance of gaining their employees' trust as a way to enhance their one-on-one discussions. Participants appreciated when their managers would check in during a work task and provide tailored feedback. The Helmet-CAM provided opportunities for workers and managers to come together and discuss potential hazards that may be increasing elevated respirable dust exposures as well as discuss other general concerns – such as improved ways to clean equipment or complete a work procedure or task. Also, the Helmet-CAM can be used as a medium to communicate issues across workers, across different shifts, ensuring consistency of the messaging. Several participants said that consistent communication and trust helps increase site-wide production, so any tools to further establish H&S support are beneficial.

6.4. H&S Training: Continuous and Various Trainings Build Knowledge

Several managers and workers discussed the variety of H&S training that they are provided on site. Health and safety training is designed to increase worker knowledge and awareness of hazards, including certain behaviors necessary to avoid injury and illness. Research indicates that as worker behavior becomes more reliably safe through effective training, trust among the collective workforce is also enhanced (Evans & Davis, 2005; Zacharatos, Barling, & Iverson, 2005). In this study, several practices emerged about effective trainings on site. For example, managers discussed their site-specific orientation training as having a substantial impact on employee knowledge and trust in the organization because the training is tailored to the company's core values. One manager explained, "We spend a lot of time with individuals to make sure they have any skills needed to do something different as far as gaining experience and opportunities." As the survey results indicate, workers perceived H&S training adequacy to be extremely high, aligning with HSMS training practices.

Additional H&S practices that pertained to training included equipping everyone on site with the same, critical H&S skills. For example, managers said that they train every person in emergency response in case medics are not accessible at the time of an incident. This way everyone is prepared to step in and help if needed. Also, there is specific task training and approvals for every job, machine, piece of equipment, etc. The organization solicits an experienced person who agrees to provide task training for others. However, an H&S manager signs off on all completed trainings. Consistent with the previous H&S practices, managers said that their trainings engage various leaders and workers on site.

7.0. Conclusion

The initial results of this case study show promise that the use of a social scientific framework, particularly applying mixed methods, to simultaneously engage managers and workers is useful to identify and assess essential H&S practices to manage workplace risks. Additionally, the Helmet-CAM assessment technology can be used as an intervention data collection tool to help tailor and apply some of these H&S practices such as enhanced, targeted communication, joint committees, and coordinated training efforts. Despite the positive implications of the current study, additional MLIs with the Helmet-CAM are necessary to help provide more substantial, generalized guidance both about the social scientific framework, methods, and tangible HSMS practices. However, initial results and observations suggest positive outcomes for not only improved H&S via personal accountability, but improved communication practices between mineworkers and managers. As the MLI efforts are expanded, mine health and safety management are invited to utilize the empirically-validated HSMS practices found to be useful in managing H&S risks.

8.0. List of Abbreviations

- Health and safety (H&S).
- Health and safety management system (HSMS).
- Multilevel Intervention (MLI).

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