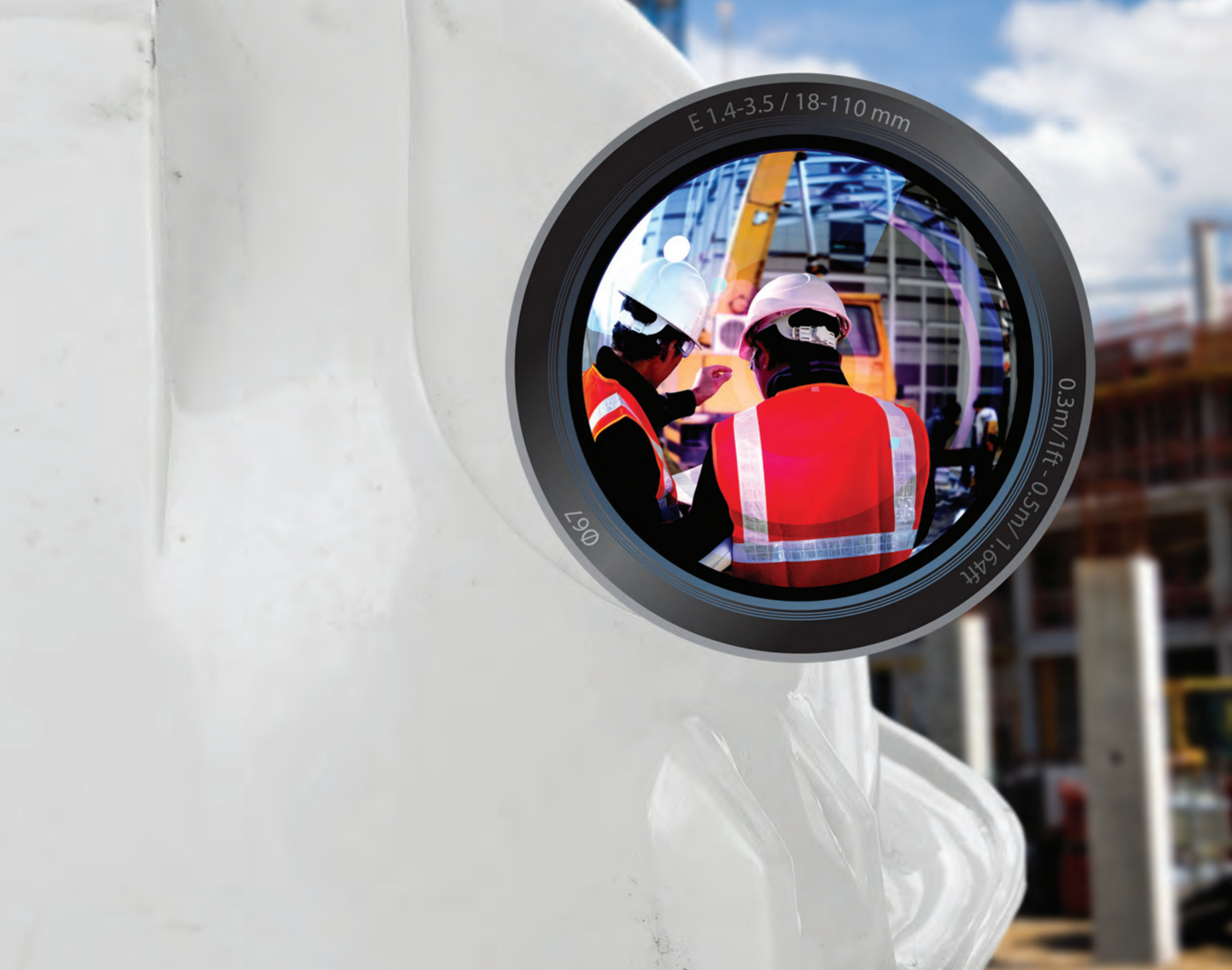
VEM Goes Mobile

"Helmet-cam" Allows Video Exposure Monitoring for Mobile Workers

BY GERALD JOY



Since the 1980s, video exposure monitoring (VEM)—a method that combines video monitoring with datalogging environmental instruments—has been used to evaluate exposures for workers during job activities that are performed in relatively fixed locations. Over the years, advances in video recorders, video file formats, exposure monitors, and software have increased VEM's viability as a monitoring method. However, one aspect of VEM has not changed: the restriction of its application to fixed work locations. The challenge of monitoring mobile workers—workers who do not have a fixed work location such as a plant or mill, or who do not work inside a cab with an effective air-cleaning system—persists.

It can be difficult to identify source(s) of exposure for mobile workers, given the variety, number, and brevity of tasks that may be assigned; the multiple work locations involved; and transient effects from weather conditions and other nearby work activities. Traditional time-study methods provide the necessary information, but this approach is labor intensive. Worker self-evaluations may be used as an alternative, but this method requires supplemental training of the work force and careful analysis of the reports to control potential biases. The self-evaluation method also adds duties to workers who may already be overtaxed.

But now modern technology allows for VEM to "go mobile." Researchers from the NIOSH Office of Mine Safety and Health Research (OMSHR) are working on a potential solution to provide insight into the sources of exposures for mobile workers: mobile video exposure monitoring (M-VEM). M-VEM has already served as a useful tool in exposure monitoring for mobile workers. For example, elevated respirable crystalline silica (quartz) exposures have been identified among a group of surface mine workers, including mobile employees such as mechanics, laborers, and oiler/greasers, through traditional sampling methods. Using M-VEM, OEHS staff were able to pinpoint the sources of exposure—not possible with time-weighted average samples—and work to eliminate the hazard.

"Helmet-cam"

Researchers have casually labeled M-VEM "helmet-cam" because of the monitoring camera attached to the worker's hard hat. This method of exposure monitoring utilizes a small commercial off-the-shelf video camera/recorder and an appropriate datalogging exposure monitor to be worn by the worker being studied. Other than the initial deployment of the equipment and orientation of involved workers, little oversight is required to make use of M-VEM. Mobile workers are able to perform their normal activities with minimal interference while gathering video and exposure data simultaneously. One configuration of the personal video recorder and respirable dust exposure monitor being worn by a worker is displayed in Figures 1, 2, and 3.

A note about gathering video and exposure data simultaneously: one of the pioneering reports on the VEM method discussed an issue that the authors termed "system response time" or "transportation lag." This lag is the combination of the delays associated with movement of the contaminant from its source to the worker's breathing zone and the response time of the monitoring instrument. As a result, the concentration values reported by the monitoring instrument trail the activity displayed in the video image. The magnitude of this

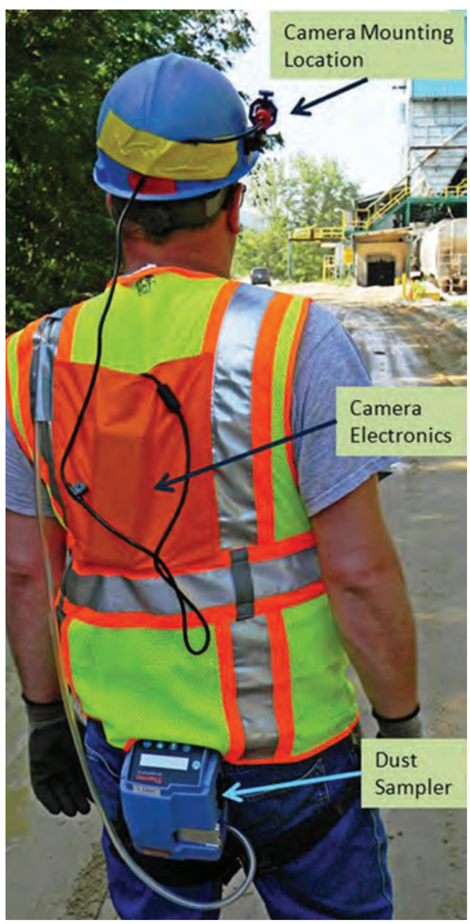


Figure 1. A worker equipped with a video recording camera and dust sampler.

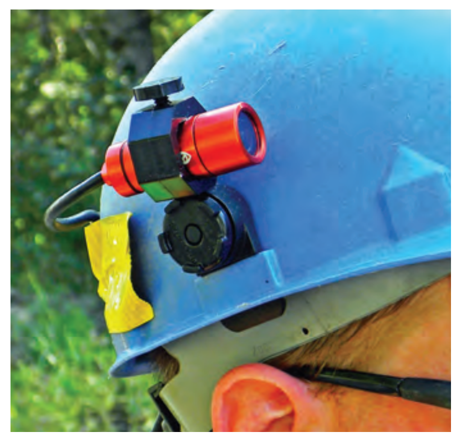


Figure 2. Detail of the camera mounted on a worker's hard hat.

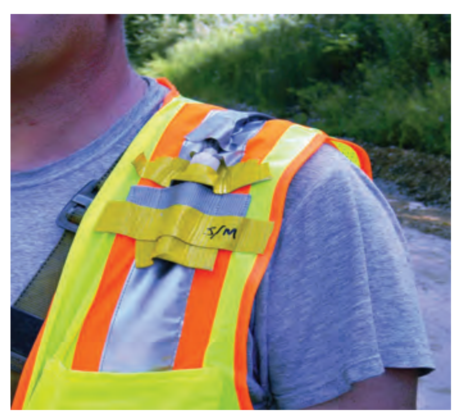


Figure 3. Detail of dust sampler inlet location (10-mm Dorr-Oliver nylon cyclone).

delay must be recognized, particularly if the activity under study exhibits periodic emissions peaks, or in the case of M-VEM, if the worker moves through multiple exposure environments.

Integrating Software

As with fixed VEM systems, the video and exposure data files must be combined to create a usable product. In the OMSHR M-VEM system, integration of the collected information is accomplished through a Windows-based software application called Enhanced Video Analysis of Dust Exposure, or EVADE. EVADE combines the exposure data file and the video file, performs some basic analysis, and facilitates further analysis of the information through graphic representation of exposure data and the synchronized video file.

Figure 4 is a screenshot that depicts a full view of the EVADE dust application. The video window occupies the largest portion of the screen and a line graph of exposure concentration vs. time is at the bottom of the screen. The exposure concentration is presented on the Y-axis in user-selectable units of µg/m^3 or mg/m^3. The formatted horizontal lines on the graph are optional user-defined criteria (action level, exposure limit, etc.). The concentration shown next to the word “Reading” is the value corresponding with the video image.

The upper left portion of the screen in Figure 4 contains information and command functions arranged in tabs. The “Active Bookmarks” tab is open and the vertical red lines on the graph below mark the bookmark locations. EVADE automatically bookmarks the five highest concentration peaks. The user can add up to 45 additional bookmarks, which allow for rapid navigation through the data. Selecting a bookmark moves the both video and concentration files to that point in time, facilitating quick analysis.

The respirable dust version of the EVADE software application and supporting user’s manual are available for free download on the NIOSH website at www.cdc.gov/niosh.

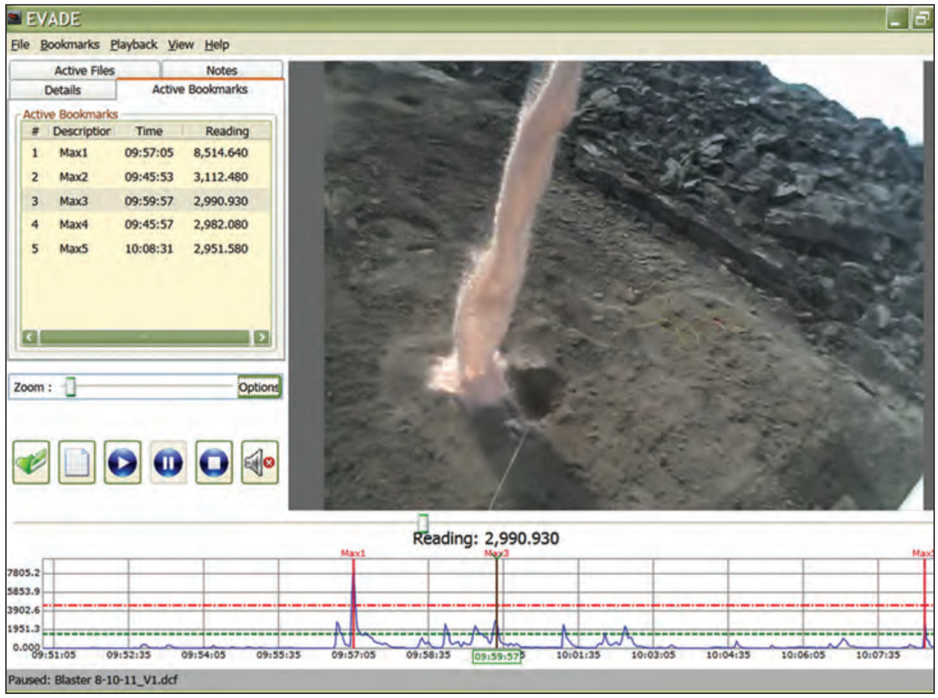


Figure 4. Screenshot from the EVADE software application.

Benefits of M-VEM

During development testing, M-VEM was able to provide useful information on the sources of exposures to mobile workers, and even helped to identify sources of unexpected exposures. In one case, M-VEM identified an exposure to respirable dust in a facility’s breakroom, even though the room was frequently cleaned and no apparent dust source was present. When the facility investigated the situation, it was determined that cloth-upholstered chairs in the breakroom had become reservoirs of respirable dust following years of use and that the dust was aerosolized when workers occupied the chairs. The facility replaced the chairs with non-upholstered furniture, and added cleaning the chairs to the maintenance of the room. Subsequent respirable dust sampling reported elimination of the issue. In a setting that would not typically be monitored and that would probably not be included in a time study or self-reporting protocol, M-VEM’s ability to identify the presence of an exposure source demonstrates one of its most important advantages.

Beyond exposure source characterization, M-VEM offers the opportunity to use exposure data collected via EVADE as a training tool, both for new workers and for reinforcing desired behavior in current workers. Together, the video and exposure concentration data effectively demonstrate the effect of a worker’s actions and location on exposures. Using M-VEM and EVADE, OEHS professionals can clearly illustrate the consequences of work techniques, such as dry sweeping vs. vacuuming, and even workers’ positioning with regard to a contaminant source.

Limitations

M-VEM has its limitations, some of which may be subject to technical improvement going forward. One key issue is that the operation of the camera and the exposure monitor must be synchronized to ensure that the video image closely matches the collected exposure data. Currently, the only way to accomplish this synchronization is to manually start the two devices as close to the same time as possible. Improved options to address this issue are being investigated, but the variation in how the available devices operate is a barrier.

The video camera presents several issues as well, including large file sizes that exceed 0.5 gigabytes/hour, battery life that is realistically less than two hours, *Little oversight is required to make use of M-VEM. Mobile workers are able to perform their normal activities with minimal interference.*

and multiple video file formats. EVADE currently supports .avi and .mp4 file formats, although the user may need to install additional video codecs (software that permits video files to be played). File format is selected by the camera manufacturer and is usually not variable. File format converters are available that may be able to generate a usable file, but compatibility should be verified before purchasing any equipment.

Limited battery life is a consequence of the small size and low weight that is a major consideration for the typical user of these cameras. They are normally intended to be worn by people engaged in sporting activities such as skiing, surfing or biking. Exposure assessment is an unforeseen use of these cameras, but their small size and low weight are advantages for this application as well. Researchers have found one camera model that will reliably record for four hours—a reasonable time frame for conducting exposure assessments, but it is a larger two-piece device that uses disposable batteries. Future design advances in these cameras may address this barrier for camera use in exposure assessment.

Future Work

Because the initial focus was the identification of respirable dust exposure sources, the current helmet-cam method uses a data-logging nephelometer as the exposure monitor. Work is underway within OMSHR to expand the EVADE application to work with other instruments, including noise dosimeters and elemental carbon monitors (surrogate for diesel engine emissions). Any instrument that can export a file that can be imported into spreadsheet format can potentially be used in M-VEM.
The EVADE software needs to "know" where the time and exposure data values (concentration, noise level, etc.) are located—row and column in spreadsheet terminology. This location is affected by headers and other identifying data added by the exposure instrument software. In most cases, custom functions can be coded to parse the spreadsheet file for use in EVADE. Unit of measure is another variable applicable to the contaminant being measured, but this is also straightforward to modify.

Researchers are looking into the possibility of incorporating non-invasive biological monitoring, such as heart rate and skin temperature. This has been demonstrated in VEM systems, and should be feasible for M-VEM as well.

Wireless communication of the video and exposure data to a base location may be another consideration for the future. The mining industry is adopting two-way communication systems that allow for contact between individual underground miners and control centers, both underground and on the surface, for routine and emergency purposes. It may be possible to adapt these technologies to the M-VEM model.

M-VEM ultimately allows OEHS staff to identify and quantify exposures of mobile workers in a time-resolved manner without significantly interfering with the workers' activities, or requiring staff to shadow mobile workers. Although it is not fully developed, M-VEM shows promise as a useful new tool for exposure assessment.

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About OMSHR: The mission of the NIOSH Office of Mine Safety and Health Research (OMSHR) is to eliminate mining fatalities, injuries, and illnesses through research and prevention. A primary objective established under this mission is the reduction of pneumoconiosis and silicosis among mine workers.

Readings

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