Miners' Views about Personal Dust Monitors

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ABSTRACT

Coal Workers Pneumoconiosis is the leading cause of death due to occupational illness among coal miners. This disease is caused by miners' exposure to respirable coal mine dust. A Personal Dust Monitor has recently been developed to provide near real time feedback to miners regarding the number of milligrams of respirable coal mine dust in the air they breathe. This paper was prepared by the National Institute for Occupational Safety and Health to document coal miners' reactions to this new device, and how they make use of the information it provides. Structured interviews were conducted with 30 coal miners at four mines. A four-stage conceptual model of miners' decision processes with respect to how they interpret and respond to the dust exposure numbers from their personal dust monitor is proposed. The stages are: Diagnosis, Action Planning and Intervention, Evaluation, and Institutionalization. The interview responses provide considerable support for the model. Most miners paid attention to Personal Dust Monitor feedback and made efforts to reduce their dust exposure. Their efforts included: changing where they positioned themselves, making ventilation system improvements, and using respirators more often. The 29 miners who reported having experience wearing both the old and new type of dust monitors were asked which dust sampling system they preferred. Eighteen (62%) preferred the new monitors, 7 (24%) preferred existing monitors, and 4 (14%) had no preference. The most frequently cited advantage of the new monitor is its ability to provide relatively quick feedback on dust exposure. Miners provided several suggestions for improving the design of the instrument.

Keywords: Black Lung disease, Coal mine dust, Underground mining, Pneumoconiosis, Exposure assessment, Effectiveness research, Respiratory disease, Work practices

INTRODUCTION

Although the most recent data on the prevalence of Coal Workers' Pneumoconiosis (CWP) in the United States indicates that it is declining, substantial numbers of CWP cases continue to be diagnosed (Antao et al. 2006; Antao et al. 2005; Pon et al. 2003). During the three year period, 2000 – 2002, CWP contributed to the deaths of 2,697 miners in the US (US Dept. of Health and Human Services, 2005). In 2004, Federal "Black Lung" benefits totaling more than $726 million were paid to approximately 93,000 beneficiaries [US Dept. of Labor, 2007]. Data from MSHA indicate that from the early 1980s to 2006 the underground coal mining industry experienced little change in level of exposure to respirable coal mine dust [US Dept. of Labor, Mine Safety and Health Administration, 1982-2006]. In 1982, the mean value based on 86,000 samples from mine operators was 1.0 mg. In 2006, the mean value based on 26,000 samples from operators was 0.9 mg. During the period 1995 to 2006, 12% (40,790) of operator-collected designated occupation samples (337,066) and 15% (7,039) of MSHA inspector samples (47,966) exceeded the applicable dust standard.

A Personal Dust Monitor (PDM) has recently been developed through a collaboration involving NIOSH, the Bituminous Coal Operators' Association, the United Mine Workers of America, the National

Mining Association, Thermo Fisher Scientific Inc. and the Mine Safety and Health Administration (Figures 1 and 2). This new device represents a major advance in the tools available for assessing coal miners' exposure to respirable dust levels.

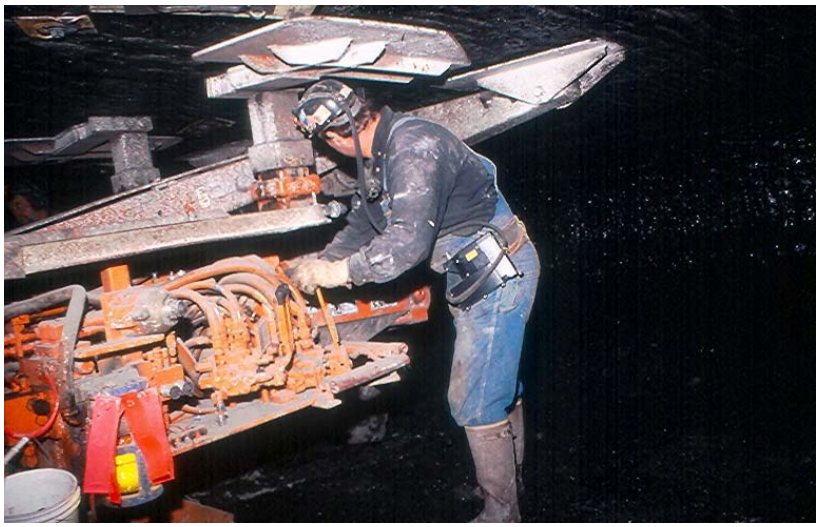

Figure 1. A miner wearing the PDM.

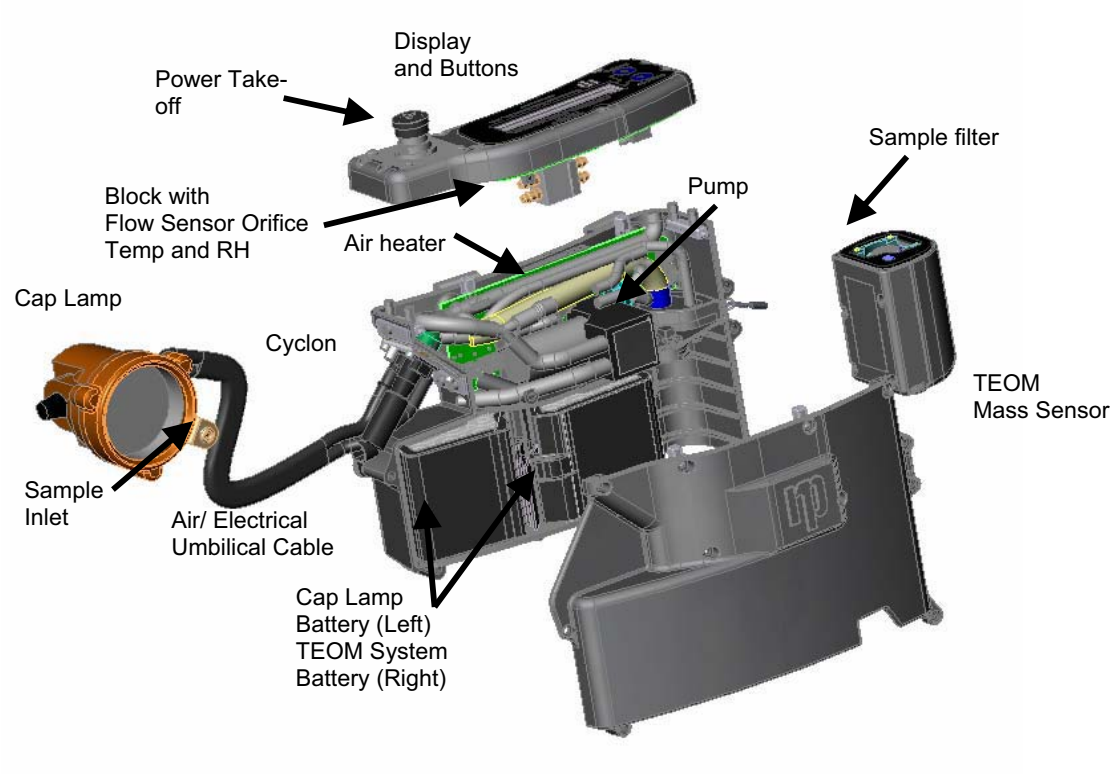

Figure 2. PDM internal components.

To date, the dust monitoring process has relied upon a coal mine dust personal sampler unit to collect a filter sample in the mine environment. The respirable dust-laden filter is then sent to a laboratory for analysis. Results are returned to the mine operators several days after the actual samples were taken. A major advantage of the new PDM is its ability to provide near-real-time dust exposure data. This feedback allows miners to better understand how their actions are related to variations in dust exposure, and tells management how actions and equipment affect each miner's dust exposure. The new PDM has been field tested at 10 mines, and found to be at least as accurate as samplers currently in use (Volkwein et al. 2006). As with the introduction of any new technology, it is very important to systematically document how workers react to it and make use of it. If miners know how to properly use the information PDMs are capable of providing, they may be able to make adjustments to their work place or work procedures that will reduce their exposure to respirable coal mine dust. There appears to be great potential. However, no one knows precisely how miners performing a wide variety of tasks and jobs are actually going to use this new information to reduce their exposure to dust.

By collecting and sharing information about how miners have begun to use PDMs, we hope to facilitate the effective use of this new technology to help prevent Black Lung disease. This paper provides examples of how miners used PDM information to diagnose the causes of exposure to high levels of respirable dust, and make changes to try to reduce their exposure. This paper also documents the opinions of a small number of mine safety directors and their staff, who maintained the equipment for four weeks. The findings from interviews with 30 miners and seven mine safety staff members are presented.

METHODS

PDMs and training materials were delivered to the mine's safety director at least 10 days before miners began wearing PDMs. After becoming familiar with the dust monitoring system and the instructional materials, the safety director provided training to a crew of miners. The 30 minute training session consisted of showing a six minute training video, followed by a period of questions and answers. At the end of the class, miners were asked to complete a short questionnaire to evaluate their understanding and retention of information about PDMs. Miners then wore their PDMs each shift for four weeks. Researchers returned at the end of the fourth week to interview the miners and the persons in the safety department who had maintained the PDM equipment and kept records of the dust exposure data.

The interview questions were intended to yield the following types of information: (1) descriptions of incidents in which miners tried to use their PDM to reduce their dust exposure; (2) problems or difficulties encountered by miners while wearing the PDMs; (3) problems or difficulties encountered with maintaining the PDMs and the data they provide; and (4) evidence regarding the validity of a conceptual model proposed to explain how PDM feedback leads to changes in miners' behavior and to reduced dust exposure.

All miners who wore a PDM during the preceding month, and who were present on the day that the interviewers visited the mine, were asked to participate in an interview. All interviews were conducted in private, usually at a dinner area near the miner's work site. All participants were assured that their responses would be held in confidence and were told that their participation was completely voluntary. No one refused to participate in the interviews. Each interview lasted approximately 20 to 30 minutes. All interview questions had been reviewed and approved by the NIOSH Human Subjects Review Board and the Office of Management and Budget (OMB). The complete list of interview questions can be found in Appendix A and a NIOSH Information Circular Report (Peters et al. 2008).

Data were collected from September 2006 to May 2007. A total of 30 miners from four underground coal mines participated in the interviews. The mines were selected jointly by NIOSH and by the coal company officials who participate in a PDM research partnership committee. Table I presents information about each of the four mines including: the number of miners interviewed, the number of underground employees, the location, the seam height, and whether or not miners were represented by a union. The sample is composed primarily of large mines operating in relatively high seams. The mines were located in Utah and West Virginia.

Table I. Sample Mine Characteristics

Mine	Number of miners interviewed	Number of underground employees	Location	Seam height (in)	Union
A	5	255	Utah	102	Yes
B	6	439	North WV	72-84	Yes
C	10	81	South WV	66-76	No
D	9	125	South WV	54	No

Half of the mines were represented by a union and half were non-union. Mine C used only continuous mining machinery to extract the coal. The other mines were using longwall mining equipment in addition to continuous mining machines. The crews in mines C and D were operating a “supersection” i.e., two continuous mining machines (rather than one) were being used in the section where miners were wearing the PDMs.

RESULTS AND DISCUSSION

Characteristics of miners’ interviewed. Miners were asked what job they currently performed, and how much mining experience they had. Table II lists their jobs.

Table II. Breakdown of Mine Employees Interviewed, by Job Title

	Number
Shuttle car operator	5
Continuous miner operator	5
Longwall shearer operator	2
Longwall jack setter	3
Roof bolter operator	8
Mechanic	2
Electrician	1
Scoop operator	1
Section foreman	2
Face man	1
Total	**30**

Most miners had substantial experience working as a coal miner. Nineteen had more than 10 years of experience. Only one had less than 2 years of experience. All but three miners had worked in their present job category for more than a year. Miners' ages were distributed as follows:

Age (yrs)	N
Less than 30	6
30 – 39	6
40 – 49	12
50 and over	6

The sample consists of miners with considerable mining experience, and who represent all the major categories of jobs performed in face areas of underground coal mines in the United States.

Miners' Interpretation and Response to PDM Feedback

Figure 3 proposes a four-stage conceptual model of miners' decision processes with respect to how they interpret and respond to the dust exposure numbers from their PDM. The model is based on a few different lines of psychological research including the health belief model (Janz and Becker, 1984; Janz et al. 2002), self-efficacy (Bandura, 1977; 2004) and studies on feedback interventions (Kluger and DeNisi, 1996). The four stages of the model are: Diagnosis, Action Planning and Intervention, Evaluation, and Institutionalization. Each stage is described below, and miners' responses to interview questions relating to Stages 1, 2 and 3 are summarized.

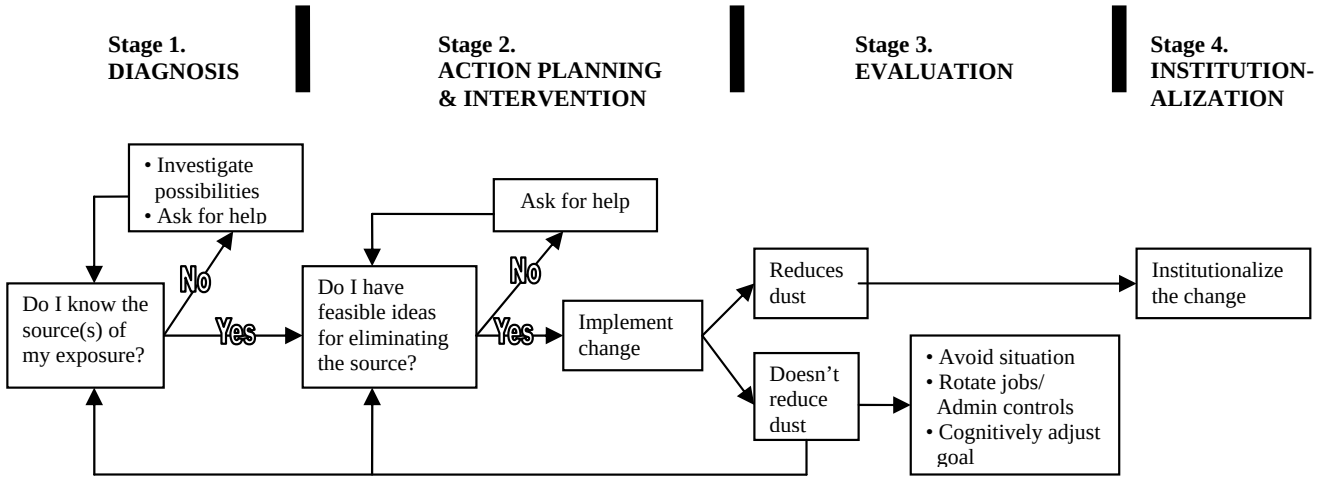

Figure 3. Conceptual model of how miners use PDM information.

Stage I. Diagnosis

The model starts with the assumption that the person wearing the PDM notices a number that is high enough to cause concern. The concept of cues that trigger action has been discussed in various early formulations of the Health Belief Model. Hochbaum (1958), for example, thought that readiness to take action (perceived susceptibility and perceived benefits) could only be potentiated by other factors, particularly by cues to instigate action, such as bodily events, or by environmental events, such as media publicity.

Until now, miners' cues to action relative to preventing CWP may have included: information from chest x-rays, advice or warnings from one's doctor, physical discomfort in one's lungs, coughing, shortness of breath, report of a high dust level from a previous days sampling, or a perception of high levels of dust in the mine air. CWP is an insidious health problem. It often takes years to develop, and miners may not receive any cues to warn them that respirable dust is damaging their lungs. Miners may not experience any physical symptoms to warn them that they are developing CWP until the later stages of the disease. Also, since the dust particles that cause CWP are invisible to the human eye, miners may sometimes be unaware that they are in the air they are breathing.

The information from PDMs should serve as a very important cue to action. Wearing a PDM allows miners to see how their dust exposure varies throughout the course of their workday. They should soon learn what circumstances expose them to high dust. For example, once people who work on longwall crews begin wearing PDMs, they may realize that whenever they spend time inby the shearer, they are being exposed to respirable dust levels that are very high relative to being outby the shearer. Receiving near-real-time feedback about what causes high respirable dust exposure should help miners to become more cognizant of when they are in an unhealthy situation, and hopefully, to think about how they can reduce the amount of time they spend in those situations.

Miners' responses to interview questions pertaining to the Diagnosis Stage

Miners were asked, "During a typical shift, how many times do you look at the numbers on your PDM?" Twenty-five miners gave numerical estimates ranging from 1 – 20. The median numerical estimate was 6 times. Five miners said they looked at it "frequently" or "several times".

Miners were given a response card and asked to select one of four options to answer the question: "Which option best describes how often you looked at your dust exposure number before you turned in your PDM at the end of the day?" Most miners said they looked at this number every day. The distribution of responses is as follows:

Response	Distribution
every day	20
most days	8
a few days	1
never	1

Miners were reminded that their PDM has a few different screens with information about dust concentrations. The initial screen has values for MC0, CUM0 and PROJ. MC0 is the miner's average respirable dust exposure during the past 30 minutes (expressed as number of milligrams per cubic meter). CUM0 is the miner's cumulative respirable dust exposure since the shift began. Mathematically, CUM0 is the mass divided by volume sampled to the present point in time. The PROJ is the miner's projected exposure for the whole shift. Mathematically, PROJ is the mass divided by the volume to be sampled for the entire shift. PROJ starts out as a very low number and steadily progresses to the true end of shift concentration. If CUM0 exceeds the permissible exposure limit, steps can be taken to reduce the miner's exposure to stay within the permissible exposure limit before the end of the shift. However, once the limit (PROJ) is exceeded, it becomes impossible to meet the permissible exposure limit.

Miners were given a response card and asked to select one of four options to answer the question: "How often did you look at this initial screen?" The distribution of responses is as follows:

Response	Distribution
more than 3 times per day	20
at least once per day	9
a few times per week	0
less than once per week	0

Miners were next reminded that another screen on their PDM shows a bar chart. Each bar represents the average dust concentration for 30 minutes intervals since the beginning of the shift. Miners

were given a response card and asked to select one of four options to answer the question: “How often did you look at the bar chart screen?” The distribution of responses is as follows:

Response Distribution	
more than 3 times per day	20
at least once per day	6
a few times per week	3
less than once per week	1

Miners were asked, “Did you notice whether your numbers tended to fluctuate throughout the day?” Twenty-seven of 30 miners said “Yes”. Those who said “Yes” were next asked if it was usually clear to them what was making the numbers go up and down. All said “Yes”. Miners were asked, “Were you ever surprised or concerned by what the numbers on the PDM display were telling you?” Seventeen of 30 said “Yes”. Those who said Yes were asked to recall the most recent time this happened, and to explain what they were doing when they noticed the unusual reading. The types of activities they mentioned were:

Returning from tailgate on longwall
Cutting coal with continuous miner
Cutting rock with continuous miner
Operating shields on longwall
Riding the man trip
Operating scoop in return
Roof bolting

All but one of these 17 miners said that they were surprised by how high the numbers on their PDM were. One miner who was cutting rock with a continuous mining machine said he was surprised because the numbers were not as high as he thought they would be. Given that miners will sometimes become aware that the level of respirable dust in their work environment is high, the conceptual model assumes that some are apt to start thinking about what is causing it. If they do not know what is causing the high respirable dust, they may investigate. For example, some of the miners in this study reported checking to see if the necessary ventilation controls were working properly. Perhaps water sprays on coal cutting machinery are not working or ventilation curtains are not properly installed. If they cannot find a plausible explanation, miners may ask others if they know why the respirable dust level is so high.

Stage II. Action planning & intervention.

Once miners think they have a plausible explanation for the high respirable dust, some are apt to start thinking about how to eliminate exposure to the source. If they think they can correct the problem on their own, they will hopefully take care of it. If they do not know how to eliminate the source, they may ask for help. If they do not have the time or resources needed to fix the problem, they may inform their supervisor.

Miners’ responses to interview questions about Action Planning & Intervention Stage

Miners were asked if they had tried to do anything to reduce their dust exposure. The following twenty-seven actions were reported:

15 changed position
3 changed ventilation
4 changed both position and ventilation
1 wore his respirator more often

Position. Continuous miner and longwall operators said they stood a few feet farther away from the dust. Roof bolter operators said they waited for the continuous miner to finish cutting before bolting. Shuttle car operators reported that they stayed behind the ventilation curtain in intake air longer.

Ventilation. Miners reported keeping the ventilation curtains up closer to the face and keeping them tighter.

Respirators. One of the miners on the longwall said he began wearing a respirator during certain phases of his job. At a super section, the crew was told to wear respirators until air flow into the section could be increased.

Stage III. Evaluation

The next stage of the conceptual model is Evaluation. After making a change to try to reduce their exposure, miners may try to evaluate whether the change helped. One good way to do that would be to check the numbers on their PDM to see if they went down.

If the change does not initially reduce respirable dust, they may try the same approach but more vigorously, or they may conclude that they really did not know the true source of the dust, or that a different type of countermeasure is needed. They may try to investigate other possible sources or countermeasures, or may seek help or advice from others.

Miners may not always be able to maintain acceptable levels of dust exposure. Changes that are beyond their control may be needed, i.e., mine wide ventilation system changes. At one mine, several changes were attempted during the first two weeks of the field test, but dust levels were still too high. The safety director said the PDM data helped him convince mine managers that they must increase the volume of air flowing to this section of the mine. Thus PDM data can be a very useful decision tool for mine safety directors, managers and engineers, as well as for the miners.

When high dust levels persist, miners may simply learn to avoid being in certain locations at certain times when they know respirable dust will be high. Or, it may be possible to reduce an individual's daily exposure through administrative controls, such as having miners perform a different job for part of the day, i.e. one that does not expose them to as much dust as their primary job.

Another way miners might respond to feedback about high respirable dust exposure is to cognitively adjust (upward) the perceived level of respirable dust they think they need to be concerned about. This will be discussed in greater detail below. After repeated failures, some miners may experience "learned helplessness", and give up trying. Learned helplessness is "the experience of uncontrollable failure to solve a problem originally perceived as solvable." (Mikulincer, 1994, p. 13).

Taylor's (1983) cognitive adaptation theory maintains that disconfirmation of efforts to control one's health often do not produce the emotional upset or inactivity that one might expect based on reactance or learned helplessness theories. Rather, there are many things that can potentially be controlled, and if one's need to control a situation is great, one will control what one can and give up attempting to control what one cannot. When a particular plan is thwarted, some alternative plan is often substituted to try to accomplish the same goal. This suggests that if a miner is truly concerned about contracting CWP, he or she is apt to try *several* different approaches to reducing respirable dust exposure before giving up.

Until now, miners have never had quick access to information about their personal dust exposure. Therefore, it might have been easier for them to assume that the amount of respirable dust they were breathing was nothing to worry about. Because PDMs provide miners with relatively quick and objective evidence about their respirable dust exposure, miners may be less likely to harbor false illusions, i.e., that the air they are breathing is harmless when in fact it contains high levels of respirable dust.

Miners' responses to interview questions pertaining to Evaluation Stage

Whenever miners reported making any changes to reduce their dust exposure, they were asked, "Did you look at the numbers on your PDM to see if they went down after you made this change?" In 22 cases, miners said "Yes". In all but two of these cases, the miner reported seeing the numbers go down following the change. In one case, the miner said that the change caused his numbers to stop rising. In

another case, the miner said that the change did not seem to affect his numbers, but he thought that the change had helped reduce his coworker's exposure, i.e., the continuous miner operator.

For miners to be motivated to take precautionary measures to protect their health, the Health Belief Model suggests that they must believe the preventive actions will be effective in reducing their exposure to the hazard. To assess miners' perceptions of the magnitude of the effect of their changes, they were asked to choose one of four options on a response card to answer the question, "Which option best describes how much you think this change will reduce your overall exposure to dust?"
The distribution of responses is as follows:

Response	Distribution
None	0
Small	4
Moderate	16
Large	4

This suggests that most of the miners believed the changes they made were efficacious in reducing their dust exposure. There is also some limited objective evidence that dust exposures declined following the introduction of PDMs. One of the mines that participated in the study allowed NIOSH access to the dust exposure data collected during the four weeks that their miners wore the PDMs. Analysis of the data confirmed that this mining crew's exposure steadily declined throughout the month they were wearing PDMs. By the end of the test, their exposure had declined by about 60%.

Second Samples. PDMs are designed to allow miners to quickly determine whether changes are effective in reducing respirable dust. By pressing two buttons on the PDM, miners can initiate a new "second sample" at any point in their work day. They will start to receive feedback within 15 minutes regarding whether or not the change they just made is reducing respirable dust. Miners can start/stop a second sample as often as they want. Starting a second sample does not affect the initially programmed sampling for the entire shift.

During the interviews, miners were reminded that their PDM allows them to start taking a new "second sample" at any point during their shift. They were asked, "Did you ever try out the Second Sample feature on your PDM?" Relatively few miners (11 of 30) reported trying to use this feature. Of the 11 who tried, most said they used it only once or twice. Miners may need additional instruction or encouragement to take advantage of the second sample capability.

Stage IV. Institutionalization

The final stage in the model is Institutionalization. When interventions appear to be effective in reducing respirable dust, miners and mine managers should tell others about their experience so that those who work in similar circumstances can benefit. Some further testing and refinements of successful interventions may occur. But once it is verified as an effective and feasible means of reducing an important source of respirable dust, the intervention will hopefully become institutionalized, i.e., become part of the mine's routine operations. It may be especially helpful if someone is designated to champion successful approaches to dust reduction. This person should seek out good approaches, provide positive recognition to those who identify them, and ensure that the ideas get disseminated throughout the company. The period of the field tests for this study—four weeks—was too short to be able to assess the extent to which changes would become institutionalized at the companies that tried using the PDMs. As PDMs come into more widespread use, it may be possible to perform additional research focusing on the extent to which this new technology brings about lasting changes, and the extent to which these changes become adopted throughout the coal industry.

How Much Dust is Viewed as Too Much?

How will miners judge the acceptability of respirable dust concentrations? Hundreds of studies have been conducted by social scientists on the effects feedback has on human performance. Kluger and

DeNisi (1996) provide an excellent review of this considerable body of research. They have tried to synthesize the findings into a theory containing several propositions about how feedback affects performance. Kluger and DeNisi's theory contains several propositions about how people react to feedback that tells them where their performance lies relative to a goal. If a miner's perceived standard or goal for acceptable dust exposure is known, it should become easier to predict how they will react to feedback from their PDM.

Kluger and DeNisi's theory suggests that, when people know they are failing to achieve their goal, they will usually be motivated to try to improve. They argue that people may first simply try putting more effort into doing the same things they are already doing to try to achieve their goal i.e., working harder. However, if they still find that they are failing to meet their goal, they may try to think of new and different strategies. They argue that if, after trying new strategies they still fail to achieve their goal, people may cognitively adjust their view of what constitutes an acceptable goal. People may adjust their perceived goal to one that is more easily achievable. For example, miners might start out disliking the idea of ever working in higher concentrations of respirable dust, but later on conclude that these levels are acceptable for short periods of time or when doing certain nonroutine tasks. Miners might try to spend less time doing tasks that involve exposure to high respirable dust or increase their use of respirators. But if that is not feasible, they might try asking others for help or ideas. Or, they might decide that it is an impossible situation, and give up, i.e., "learned helplessness".

On the other hand, if miners find that they are exceeding their goals for keeping their respirable dust exposure below a particular value, and it takes extra time or effort to avoid dust, Kluger and DiNisi's theory suggests that some miners may relax their efforts to avoid dust. This is an interesting scenario that bears careful watch. If some miners' respirable dust exposures *increase* following the introduction of PDMs, it may be necessary to remind them of the harmful effects respirable dust has on their lungs.

Understanding how miners select goals for judging their dust exposure may help us understand how they will react to PDM feedback. There are at least three possible goals they might adopt.

1) Government standards. Miners could adopt the government's mandated upper exposure limit. MSHA has established 2.0 mg/m^3 as the upper limit for each miner's average exposure during an 8-hour shift. MSHA's permissible exposure value for coal mine dust becomes lower with increasing concentrations of silica dust. In order for miners to be able to put the numbers they see on their PDM into proper perspective, it is important that they have a benchmark or frame of reference. As part of an assessment of miners' retention of information presented to them in a training video, the miners in our sample were asked, "According to MSHA, what is the maximum average number of mg of coal mine dust per cubic meter that miners should be exposed to during an 8 hour shift, assuming no silica is present?" Only 20 of 30 miners could recall that MSHA's limit for respirable coal mine dust exposure is 2 mg. This suggests that several of the miners may not have had a good frame of reference for evaluating the numbers they saw on their PDM. Additional efforts are needed to ensure that miners remember this fact from the training they are given. Perhaps the number 2 could be associated with the number of lungs a person has. Since the maximum exposure value for each section of the mine can vary depending on the amount of silica that may also be present in the air, the best approach to reminding miners of their upper exposure limit might be to print out the number and tape it on each miners' PDM. Posters or stickers might also serve as effective reminders.

2) Comparisons to co-workers' dust exposures. Miners' judgments about the acceptability of their dust exposure level might also be influenced by comparisons to co-workers who do the same job they do. For example, if a continuous miner operator sees that other miner operators' exposures are consistently lower than his, he might begin to search for an explanation.

3) Comparisons to past dust exposures. Miners' judgments about the acceptability of their dust exposure level might also be influenced by comparing how their current dust exposure level compares to their prior levels (while doing the same particular task). If they observe that current levels are higher than past levels, they may be motivated to search for a reason.

Since PDMs provide feedback on a variety of different dust concentration measures (CUM0, MC0, PROJ, bar chart), miners may tend to focus more on some than others. Data was collected on this issue by asking miners, "Of all the different types of information the PDM gives you, which type did you tend to look at the most?" The distribution of responses is as follows:

Response Distribution	
dust exposure for past 30 minutes (MC0)	4
cumulative exposure since shift began (CUM0)	8
projected exposure for the whole shift (PROJ)	8
bar chart	7

One miner said he paid equal attention to MC0 and PROJ. One miner said he primarily looked at the numbers on the first screen rather than the bar chart; but he did not recall paying more attention to any one value in particular. One miner said he looked at MC0 and the bar chart an equal amount. Based on the responses from this relatively small sample, it appears there is no one clearly preferred indicator of dust exposure. As previously mentioned, almost all miners reported looking at their end-of-shift average respirable dust exposure before turning in their PDM at the end of the day.

There are many unanswered questions about how miners will interpret and respond to information from their PDM. Will miners focus on their exposure during relatively short time intervals when their exposures seem to be unusually high? Will they focus on such events only when they seem to occur with some regularity? Will they ignore occasional or random spikes in respirable dust concentrations? Once PDMs have been introduced on a more widespread basis, it should become clearer which types of information miners attend to, and what goals miners are adopting for making judgments about the acceptability of various levels of exposure.

Limitations of the conceptual model. It is important to note that the model presented above (see figure 3) is primarily intended to help explain the behavior of miners as they *first* begin using PDMs and/or those who work in high respirable dust on an *occasional* basis. It is likely that if miners have formed a strong habit of avoiding high respirable dust in all circumstances, they never even stop to consider any of the factors shown in the model. Similarly, once miners have formed a strong habit of going in high respirable dust to perform certain tasks, they may seldom take into consideration any of the factors shown in the model. They may not even take notice of the readings on their PDM.

Over time, miners using PDMs will hopefully learn what they can and cannot do to lessen their exposures to respirable dust, and they may pay less attention to the PDM feedback. Only when they happen to notice numbers that are different than what they have come to expect will they stop to think about what might have caused the unusual reading.

Miners' Receptivity To Wearing PDMs

Worker resistance to change is common. It was anticipated that at least some miners would have reservations about wearing the new PDM. In order to understand what miners might find objectionable about wearing PDMs, they were asked to describe any problems they might have had. They were also asked if they could think of any reasons why miners would NOT want to wear a PDM. The following issues were cited most frequently by miners:

Size and weight
Light cord / sample hose
Cap lamp
Attachment to miner's belt

Size and weight. Several miners noted that the PDM felt heavier and seemed bulkier than the cap lamp battery they normally wore on their belt. The PDM weighs 6.6 pounds. It is 8 ounces heavier than lead-acid battery cap lamp systems, but 1.5 pounds lighter than the combined weight of wearing a lead-acid battery cap lamp and dust sampler. As a result of recent improvements in cap lamp battery technologies, the lead-acid battery cap lamp systems are gradually being replaced by cap lamp systems

that do not weigh as much. Some mobile equipment operators said that, due to the PDM's size and the limited space in their operator's compartment, it was difficult to sit down with it attached to their belt. Some noted that their PDM got "banged around" when they had to work in close quarters.

Light cord / sample hose. The length of the cord running from the PDM on the miner's belt to the sample inlet on their cap lamp was designed to be able to accommodate relatively tall people for the purposes of field testing the manufacturer's prototype units. Some miners complained that the cord was too long and got caught on things as they worked. The cord is wrapped in a durable but rather rough material that some miners complained was uncomfortable when it rubbed against their neck. Those who maintained the PDMs noted that it would have been easier to clean mud off the cord if it had a smoother surface. Some miners thought that the sampling hose sometimes got pinched off when they sat down. When the flow of air gets cut off, an error message appears on the display screen. These error messages (flow error) sometimes caused miners to doubt whether their PDM was working properly.

Cap lamps. A few miners complained that there were dark areas in the center of their spot, making it more difficult to see in their relatively dark work environment. Unlike the cap lamps these miners normally used, the light on the PDM cannot be focused with a knob. Its focus can only be changed by adding and removing shims from the base of the light bulb. This procedure is rather time consuming. It requires removing 3 screws, taking the cover off the light, changing the number of shims, and reinstalling the cover. If the spot is still not focused to the miner's liking, this procedure must be repeated until the right number of shims is determined. A few of the PDM maintainers noted that the bulbs burned out and had to be replaced rather often. They also noted that the lights would sometimes go out before the shift was over. The batteries should be capable of providing at least 12 hours of light when fully charged. The manufacturer believes that the reason the lights sometimes failed before the end of the shift was because of poor connections between the PDM and recharging unit. The manufacturer plans to redesign this connection to ensure the batteries always get fully charged before miners begin their shift. Miners also noted that, unlike their old cap lamps, the PDM lights do not provide any advance warning before the light actually goes out.

Attachment to belt. Miners at the first mine were using a significantly smaller lithium battery for their cap lamps. This battery fit into a small pouch permanently attached to their belts. This prevented the miners from attaching the larger pouches that NIOSH had provided to hold the PDM onto their belt. The miners at this mine were especially bothered by the larger size and the weight of the PDM compared to the small lithium battery they had been used to wearing. Miners at this mine used a metal clamp to attach the PDM to their belt. A few miners noted that PDMs held on by clamps (as opposed to the pouches) had a tendency to fall off their belt. To minimize inconveniences and discomfort, it is suggested that miners who wear PDMs should be given belts that allow attachment via either pouches or clamps, and that the belts have suspenders to help support the load more comfortably.

Seven members of the mine safety staff who helped maintain the PDMs were asked to identify problems and offer suggestions for improving the PDMs. Many of their observations paralleled those of the miners who wore the PDMs. However, two additional observations are worth noting. Maintainers suggested changing the software such that when programming a PDM for the next sample, the default values should reflect whatever value was entered the previous time that PDM was programmed. They said that this would save time and reduce the chances of entering erroneus values during the daily programming process. At one mine, the safety staff strongly suggested adding some type of noticeable signal to let miners know when they are in an area of relatively high respirable dust, and/or when they are approaching the maximum exposure limit for a shift. For example, a flashing light might be used to get the miner's attention. They were concerned that miners will become complacent after wearing their PDM for a while, and stop paying attention to the information on the display.

Miners were asked if they had had experience wearing other types of dust monitors besides the PDM. All but one said yes. Interviewers said to those who had experience wearing both the old and new type of monitor, "I'd like you to think about how the old dust sampling system compares to the new. Which do you prefer?"

The distribution of responses is as follows:

Response Distribution
18 (62%) prefer new PDM
7 (24%) prefer existing monitors
4 (14%) had no preference

Seven miners said that 4 weeks is too long to wear the PDM. Some said they would have preferred the PDM or would have been willing to wear it longer if design improvements are made.

Miners were asked to explain the reasons for their preference. Those who said they prefer the PDM cited the following perceived advantages:

Provides quicker feedback
Doesn't fall off your coveralls like cassettes
Combination light/sampler is more compact
Doesn't get in the way as much
Provides a truer sample of actual exposure because (1) the PDM cannot be removed and left in fresh air while miners go elsewhere and (2) the location of the sample inlet (brim of hard hat) is closer to one's nose, i.e., breathing zone.

Those who said they prefer using traditional dust monitors cited the following reasons:

Lighter and less bulky
The cord does not irritate one's neck
Do not get in the way as much
Could not focus the PDM's cap light

All of these concerns have been conveyed to the manufacturer. Hopefully, the PDM can be redesigned to further enhance acceptance by those who will be using it.

CONCLUSIONS

The information presented in this paper helps delineate the important role of PDMs as a tool for reducing coal miners' exposure to respirable dust. A major strength of this paper is that it is based on information obtained from people who regularly work underground and who will actually be using this new technology. Their assessment of the potential for using PDMs to protect their lungs should most definitely be considered a valuable source of information.

Results from the interviews with miners tend to support the propositions in the first three stages of the conceptual model. Most miners paid attention to PDM feedback and made efforts to reduce their dust exposure. The PDMs were not used long enough at these four mines to provide evidence about the final stage in the model - Institutionalization. The empirical evidence concerning the validity of the model is rather limited. It is hoped that the findings from this study will serve to stimulate additional research and will raise more questions concerning the role of feedback as a determinant of self-protective worker behavior.

One should not conclude that the results of this study are representative of the entire industry. The sample of mines that participated in the study was small, and it was not randomly selected. It is possible that the sample of companies that participated in this study is more committed to ensuring their employees' health and safety than the remainder of the industry.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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APPENDIX A. INTERVIEW GUIDE FOR MINERS REGARDING PDMs

Form Approved
OMB NO. 0920-0698
Exp. Date 11/30/2007

DATE:_____
INTERVIEWER:_____
PDM #:_____
PLEASE DO NOT CIRCULATE OR USE WITHOUT THE PERMISSION OF THE NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY & HEALTH, PITTSBURGH RESEARCH LAB (412)386-6895

1. INTRODUCTION

Hello, my name is _____. I work for NIOSH. NIOSH is doing a research study to get information on what coal miners think about the Personal Dust Monitor and how it might be used to reduce their exposure to respirable dust. Since you have experience using the PDM, we would like to interview you. The interview takes about 20-30 minutes. Your participation is completely voluntary. You don't need to answer any questions you don't want to. Your responses to interview questions will be treated in a confidential manner. We do not record the names of the people we interview. The information you provide will be combined with the information provided by miners at other mines. The results will be compiled and reported in such a way that it will be impossible to identify any single person's answers. Only NIOSH staff who are involved in collecting the information will have access to your answers.

If you do not object to being interviewed, I need you to review and sign this consent form.

[*Give form to miner for signature*].

Do you have any questions before I begin the interview?

2. MINER'S BACKGROUND

To begin, I need to get some information about you and your experience in mining.

2.1 How many years have you worked as a coal miner?

- □ < 2
- □ 2 - 5
- □ 6 - 10
- □ 11 - 20
- □ > 20

2.2 What is your present job?

- □ Shuttle car
- □ Continuous miner
- □ Roof bolter
- □ Electrician
- □ Mechanic
- □ Foreman
- □ Longwall shearer
- □ Longwall jack setter
- □ Utility
- □ Stage loader
- □ Other_____

2.3 How many years have you been on that job?_____

- □ < 1 year
- □ 1- 3
- □ > 3

2.4 How old are you?

- □ < 30
- □ 30 - 39
- □ 40 - 49
- □ 50 and over

3. COMPREHENSION AND USE OF PDM INFORMATION

The next few questions are about the personal dust monitors and the information they provide.

3.1 Including today, about how many shifts have you worn the PDM?

□ More than 15 (3+ weeks)
□ 11 – 15 (2-3 weeks)
□ 6 – 10 (1-2 week)
□ 1 – 5 (a week or less)

3.2 During a typical shift, how many times do you look at the numbers on your PDM?

□ ZERO
□ > 0 (*write number*) _____ → **SKIP** to 3.4

3.3 (If looked ZERO times), Did you ever look at it?

□ No → **SKIP** to *** Section 5. "Problems with the PDM"
□ Yes

3.4 Were there certain times that you were more likely to look at it than others?

□ No → **SKIP** to *** 3.6
□ Yes

3.5 (If YES) When did you tend to look at it?_____

[PROBES] During breaks, certain times of the day, or phases of your job or mining cycle

3.6 I'd like you to answer the next question using one of the options on the response card. Which option best describes how often you looked at your dust exposure number before you turned in your PDM at the end of the day?

RESPONSE CARD A

□ 1 every day
□ 2 most days
□ 3 a few days
□ 4 never

3.7 Your PDM has a few different screens with information about dust concentrations. The initial screen has values for MC0, CUM0 and PROJ. Using the options on this card, please tell me how often you look at this initial screen?

RESPONSE CARD B

□ 1 more than 3 times per day
□ 2 at least once per day
□ 3 a few times per week
□ 4 less than once per week

3.8 Another screen on your PDM shows a bar chart. Each bar represents the average dust concentration for 30 minutes. Using the options on this card, please tell me how often you looked at the bar chart screen?

RESPONSE CARD B

□ 1 more than 3 times per day
□ 2 at least once per day
□ 3 a few times per week
□ 4 less than once per week

3.9 Of all the different types of information the PDM gives you, which type did you tend to look at the most?

□ dust exposure for past 30 minutes (MC0)
□ cumulative exposure since shift began (CUM0)
□ projected exposure for the whole shift (PROJ)
□ bar chart (on screen 2)
□ Other_____

3.10 The PDM allows you to start taking a new "second sample" at any point during your shift. Did you ever try out the "second sample" feature on your PDM?

□ No
□ Yes → **SKIP** to 3.13

3.11 (If NO) Are there any reasons why you did not try out this feature?
[PROBES]
Didn't realize it was possible to start a new sample → **SKIP** to *** 3.16
Didn't remember how to start a new sample → **SKIP** to *** 3.16
Didn't want to interfere with the sample data being collected for the whole shift
Too busy with my work to think about it
Not worried about my dust exposure

3.12 Do you remember which button or buttons you push to start a second sample? Please explain.
□ CORRECT
□ DON'T REMEMBER or INCORRECT

SKIP to *** 3.16

3.13 (If YES) How many times did you use this feature?_____

3.14 I'd like you to recall the most recent time you used this feature. What were you trying to find out?

3.15 Were you able to find out what you wanted to know?
□ No
□ Yes

3.16 Dust concentration numbers may go up and down throughout the course of a shift. Did you notice whether your numbers tended to fluctuate throughout the day?
□ No → **SKIP** to *** 3.18
□ Yes

3.17 (If YES) Was it usually clear to you what was making the numbers go up and down?
□ No Please explain why_____
□ Yes Please explain why_____

3.18 Were you ever surprised or concerned by what the numbers on the PDM display were telling you?
□ No → **SKIP** to *** 3.21
□ Yes

3.19 (If YES), I'd like you to recall the most recent time this happened. What were you doing when you noticed the unusual reading?

3.20 Did you do anything to try to reduce your dust exposure?
□ No
□ Yes Please describe_____

3.21 According to MSHA, what is the maximum average number of mg of coal dust per cubic meter that miners should be exposed to during an 8 hour shift? (Assuming no silica is present)
_____mg

4. ATTEMPTS TO REDUCE DUST EXPOSURE

The next few questions are about any attempts you may have made to reduce your dust exposure since you began using the PDM.

4.1 Since you began using the PDM, have you tried to make any changes to see if you could reduce your dust exposure?
□ No → **SKIP** to *** 4.13 on page 11
□ Yes

4.2 (If YES) Please describe the types of changes you made.
Change 1:_____
Change 2:_____

4.3 Did [*Insert Change 1*] make any difference in your dust concentration level?
□ No ——→ **Go to *** 4.8 (Change 2)**
□ Don't know ——→ **OR if there are no other changes, SKIP** to *** 4.13
□ Yes

4.4 (If YES--miner reports he/she was successful in reducing exposure) Did you look at the numbers on your PDM to see if they went down after you made this change?
□ No → **SKIP** to 4.6
□ Yes

4.5 (If YES) What did you see?
4.6 I'd like you to answer the next question using one of the options on the response card. Which option best describes how much you think this change will reduce your overall exposure to dust?

RESPONSE CARD C

- □ none
- □ a small reduction
- □ a moderate reduction
- □ a large reduction

4.7 Have there been any drawbacks or disadvantages to [*insert Change 1*]?

CHANGE 2_____

4.8 Did [*Insert Change 2*] make any difference in your dust concentration level?

- □ No → **SKIP** to *** 4.13
- □ Don't know → **SKIP** to *** 4.13
- □ Yes

4.9 (If YES--miner reports he/she was successful in reducing exposure) Did you look at the numbers on your PDM to see if they went down after you made this change?

- □ No → **SKIP** to 4.11
- □ Yes

4.10 (If YES) What did you see?
4.11 I'd like you to answer the next question using one of the options on the response card. Which option best describes how much you think this change will reduce your overall exposure to dust?

RESPONSE CARD C

- □ none
- □ a small reduction
- □ a moderate reduction
- □ a large reduction

4.12 Have there been any drawbacks or disadvantages to [*insert Change 2*]?
4.13 Since the PDMs were introduced, has anyone (else) at this mine changed the way they are doing their job in order to reduce their exposure to dust?

- □ No or Don't Know → **SKIP** to 4.15
- □ Yes

4.14 (If Yes) Please describe._____
4.15 Can you think of any (other) ways the PDM information might be useful for reducing miners' exposure to dust?

- □ No → **SKIP** to *** Section 5
- □ Yes

4.16 (If Yes) Please describe._____

5. PROBLEMS WITH THE PDM

The next few questions are about any problems you may have had using the PDM.

5.1 Did you have any problems using the new PDM?

- □ No → **SKIP** to 5.3
- □ Yes

5.2 (If YES) Please describe._____
5.3 Could anything be changed to improve the PDM?

- □ No → **SKIP** to 5.5
- □ Yes

5.4 (If YES) Please describe._____
5.5 Can you think of any reasons why miners would NOT want to wear the new PDM?

- □ No → **SKIP** to 5.7
- □ Yes

5.6 (If YES) Please describe._____
5.7 Did you ever wear one of the old types of dust sampling monitors?
- □ No → **SKIP** to *** Section 6
- □ Yes

5.8 (If YES) I'd like you to think about how the old dust sampling system compares to the new. Which do you prefer?
- □ No preference → **SKIP** to *** Section 6
- □ OLD Please explain why _____
- □ NEW Please explain why _____

[PROBES] Less hindrance/more comfortable to wear, Quicker feedback, More accurate

6. TRAINING

The next few questions are about the training you received on your PDM.

6.1 Thinking about the training you were given before you started using the PDM, is there anything that could be changed to improve it?
- □ No
- □ Yes

6.2 (If YES) Please describe._____

6.3 Using this card, please tell me how confident you are that you know how to do each of the following with your PDM:

RESPONSE CARD D
1 very confident
2 confident
3 not completely sure
4 no idea

How confident are you that you could…

_____ 6.3.1 Find your average dust concentration for the past 30 minutes.
_____ 6.3.2 Find your average dust concentration since the beginning of the shift.
_____ 6.3.3 Find your average dust concentration for the whole shift after the unit has automatically shut itself off at the end of the day
_____ 6.3.4 Start collecting a second sample of dust concentration values at any time you want to during a shift
_____ 6.3.5 Find out if you have already exceeded the legal limit for dust exposure during a single shift

6.4 If the MC0 number goes above 2.0, does that mean you have exceeded the dust standard?
- □ YES
- □ NO

6.5 If the PROJ number goes above 2.0, does that mean you have exceeded the dust standard?
- □ YES
- □ NO

6.6 How often did you refer to the Memory Jogger Card?
Was it helpful?

That is all the questions I have. Is there anything you would like to ask or tell me?

Thank you for helping us with this study.