

Underground mine Refuge Chamber Expectations Training: Program development and evaluation

Katherine A. Margolis, Catherine Y. Kingsley Westerman*, Kathleen M. Kowalski-Trakofler

National Institute for Occupational Safety and Health, P.O. Box 18070, Pittsburgh, PA, United States

A B S T R A C T

Refuge chambers are new devices for underground coal mines that provide approximately 96 h of breathable air, water, food, and supplies in the event of an emergency where miners are unable to escape. Researchers at the National Institute for Occupational Safety and Health (NIOSH) developed a training program to prepare miners for what to expect psychologically and physiologically inside of a refuge chamber. The field tests of this training revealed that it was received very positively by miners and helped impart realistic views about the physical discomforts and psychological stresses of being inside a refuge chamber.

1. Introduction

In 2006, several major incidents occurred at underground coal mines in the United States (US), resulting in 19 worker fatalities. These included an explosion at the Anker West Virginia Mining Company Sago Mine in Upshur County, West Virginia, in which 12 miners died; a fire at the Aracoma Coal Company, Inc., Alma No. 1 Mine in West Virginia, in which two miners died; and an explosion at the Kentucky Darby Coal Company Darby No. 1 Mine, where five miners died. These highly publicized mine disasters led to new approaches to mine safety and health, as well as new federal legislation, specifically the Mine Improvement and New Emergency Response Act of 2006 (MINER Act, 2006) (United States Public Laws, 2006). Adding to the pressure to reduce fatalities in mining, the following year on August 6, 2007, an incident occurred at the Crandall Canyon Mine in Utah. Six miners and three rescue personnel died.

One new technology to emerge amid efforts to reduce fatalities is the underground refuge chamber (see Fig. 1).

Refuge chambers are movable chambers that are either made of steel or have tents that inflate from a steel skid. They may potentially save the lives of miners during an underground mine emergency by providing breathable air, food, water, and a safe environment for up to 96 h. If a refuge chamber is employed by miners it will be during a time of stress and emergency. Ounanian

(2007) suggested that psychological factors relevant during emergencies, such as reducing anxiety and improving morale, are important design considerations for refuge chambers. However well-designed a refuge chamber is, those inside are inevitably going to experience some negative psychological effects because of the situation. One way to help miners deal with these effects is to make them aware in advance of the potential reactions to such an experience. To that end, the National Institute for Occupational Safety and Health (NIOSH) designed training for underground coal miners focused on what to expect psychologically and physiologically when using a refuge chamber. This paper presents background information including supporting studies, describes the content of the training, methods for field testing the training, results of the field tests with 336 underground coal miners in western Pennsylvania in the US, followed by discussion and conclusions.

2. Background

Refuge chambers were first mandated by the state of West Virginia in 2007 in response to the 2006 Sago mine disaster. Subsequently, the federal government enacted a law in 2008 requiring the placement of refuge chambers, sometimes referred to as refuge alternatives, in underground coal mines. The Mine Safety and Health Administration (MSHA) defines a refuge alternative as "a protected, secure space with an isolated atmosphere and integrated components that create a life-sustaining environment for persons trapped in an underground coal mine" (Department of Labor, 2008, p. 34143).

* Corresponding author. Tel.: +1 412 386 6673; fax: +1 412 386 6764.
E-mail address: ckq7@cdc.gov (C.Y.K. Westerman).



Fig. 1. Photograph of the entrance to a refuge chamber.

A variety of terms have been used by different groups to refer to refuge alternatives. In general, there are two different types of refuge alternatives defined by their location in an underground mine. The two basic locations are: within 304.8 m (1000 ft) of the working face (the area where the coal is extracted) and outby the working face (the area away from the face toward the mine portal or exit). This paper will refer to refuge alternatives nearest to the working face as *refuge chambers*. Other popular terms for refuge alternatives located at the working face are rescue shelters and refuge shelters. Refuge alternatives located outby the working face will be referred to as *outby refuges*. Outby refuges are sometimes called hardened rooms, outby shelters, and in-place shelters. Outby refuges and refuge chambers collectively will be referred to as *refuge alternatives* in this paper.

After the 2006 Miner Act, NIOSH commissioned a series of studies on refuge chambers. In one study, Ounanian (2007) examined 38 recent mining disasters and found that refuge chambers would have had a positive impact on 12 of 38 disasters or 32% of the disasters in the study. This means that approximately 83 miners (19% of 429 miners involved) would have been positively impacted by refuge chambers. This report also specified that psychological factors would be very influential for miners when using a refuge chamber.

It has been suggested (Ounanian, 2007) that a mining disaster where refuge chambers might have had a positive impact was at Anker West Virginia Mining Company's Sago Mine located in Upshur County, West Virginia. On January 2, 2006 at 6:26 am an explosion occurred at the mine. At the time, 29 miners were underground (Gates et al., 2007). Thirteen of these miners were near the explosion. One was separate from the others and was killed from the blast of the explosion. The other 12 miners were walking toward the mine face when they felt the force of an explosion, and soon after the mine filled with smoke. These men boarded a mantrip (transport vehicle) in an attempt to ride out of the mine. However, their mantrip hit debris blocking their egress. The miners evacuated the mantrip and began walking out of the mine (Gates et al., 2007). During their attempts at escape, several of the miners donned their self-contained self-rescuer units (SCSRs) which provide approximately 60 min of breathable air by supplying oxygen and removing CO₂. Unfortunately, several miners thought that their SCSR were not working, as reported by the sole survivor. At the time of this incident, miners were trained that if they could not escape, they should construct a barricade to isolate themselves from toxic gases and smoke and await rescue. After encountering smoke, dust, and debris, and with no informa-

tion regarding the condition of the mine, the miners returned to their work area, erected a barricade, and awaited rescue.

At the time of this disaster, refuge chambers were not commercially available in the US. As mentioned, miners are taught to barricade if they are unable to evacuate a mine. Miners barricade by hanging heavy ventilation curtains or building an enclosure with available materials, in an attempt to prevent or limit the toxic gases from entering their area. Unfortunately, barricading does not supply oxygen and usually does not create a leak-proof environment. Rescuers were not able to reach the Sago miners for approximately 41 h (Gates et al., 2007). There was only one survivor who was in critical condition when rescued, but survived.

Had refuge chambers been available at the time of the Sago disaster, they may have saved the lives of the 11 men who survived the initial explosion but perished in the end (Ounanian, 2007). All refuge chambers provide approximately 96 h of breathable air. Refuge chambers not only provide oxygen, but also create an airtight seal from the outside environment and remove CO₂ from inside of the chamber.

There are two main classifications of refuge chambers. There are inflatable refuge chambers where a tent-like structure inflates from a steel skid and there are steel structure chambers. Both types can be moved as work in the mine progresses, and both types can be made to accommodate the number of miners working on a shift, ranging from 8 to 30 miners. In addition to the oxygen supply and carbon dioxide scrubber system, refuge chambers contain waste facilities, first-aid kits, food and water. Although refuge chambers are customizable, space inside is limited. The federal law requires at least 1.39 square meters (15 square feet) of floor space per person in addition to certain volume requirements based on the mine height (Department of Labor, 2008). Table 1 displays these parameters.

3. Previous studies

Due to the novelty of refuge chambers in the US, there have been no previous studies on the psychological and physiological reactions for those using a mine refuge chamber. However, literature from other fields can be analyzed to extrapolate how using a refuge chamber might affect miners.

Miners using refuge chambers will find themselves in cramped quarters with little personal space. Early research in the 1960s on confined groups was conducted in the laboratory under far better circumstances than miners would face. In particular, in a series of studies that Altman and Haythorn (1967) conducted at the Naval Medical Research Institute in Bethesda it was suggested that being cooped up with a peer in a small apartment with adequate food and recreational material for a week or two is a highly stressful event.

Due to the cramped quarters, miners may also be forced to remain in one position for a long period of time. Gotshall et al. (1994) found that after sitting for 2 h, male subjects experienced an elevated mean arterial pressure. Studies of airline passengers have also found that sitting for a prolonged period may lead to

Table 1
Volume per person based on mine height.

Mine height (cm) ^a	Unrestricted volume (cubic meters) per person
91.44 or less	.85
>91.44 and ≤106.68	1.06
>106.68 and ≤121.92	1.27
>121.92 and ≤137.16	1.49
>137.16	1.70

^a Includes an adjustment of 30.48 cm for clearances.

pulmonary embolism and/or deep vein thrombosis. Age and obesity are risk factors that augment the likelihood of these two conditions (Dalen, 2003). Although no data is available on the weight or body mass index (BMI) of miners, mining is often considered a gray occupation. According to the National Mining Association (NMA), in 2008 the median age of a coal miner in the US was 44 (NMA, 2009). In addition to the health risks, sitting in one position may also cause discomfort. Fredriksson et al. (2002) found that an increase in seated work was associated with neck or shoulder pain in males. Therefore, some miners may face health risks and/or discomfort from sitting for a prolonged period.

Refuge chambers are also likely to be hot and humid. The federal law states that the apparent temperature in a fully occupied refuge chamber shall not exceed 95°F (35°C) (Department of Labor, 2008). Apparent temperature is considered a measure of discomfort taking into account the combined effects of air movement, heat, and humidity on humans (Department of Labor, 2008). Based on engineering tests conducted by NIOSH it is likely that there will be high apparent temperatures approaching 95° which will lead to discomfort (Office of Mine Safety and Health, 2007). High levels of heat and humidity can cause sweating, paleness, cramps, tiredness, weakness, dizziness, headache, nausea or vomiting, and fainting (NIOSH, 2009). People who are older, overweight, and have high blood pressure and/or heart disease will be especially susceptible to the effects of heat.

It is also likely that due to the stress of the situation and the uncomfortable accommodations, miners may have difficulty sleeping in a refuge chamber. Linde and Bergstrom (1992) found that even one night without sleep may lead to reduced cognitive performance on Raven's progressive matrices, a problem-solving task. Bohnen and Gaillard (1994) also found that one night of sleep deprivation led to degraded performance over time on a task tracking exercise. In addition, sleep deprivation has a negative impact on mood (Weinger and Ancoli-Isreal, 2002). Therefore, miners in a refuge chamber may find it difficult to move and sleep and may have physiological reactions such as cramping, sweating, and body aches.

Previous research suggested that the expected psychological problems associated with prolonged confinement to refuge chambers include: anxiety, withdrawal, apathy, aggression, hostility, depression and irrational, impulsive behaviors. It has been suggested that miners are expected to suffer more from the immediate shock of the disaster itself and the resultant presence of dead and injured persons, than any other variable. Shock and confusion followed by disbelief are initial reactions to a disaster. The way miners cope with the initial shock many times determines how successfully they tolerate their confinement (Helmreich, 1986; Baum, 1986; Ursano, 1986; Ursano et al., 2003; McCoy et al., 1983).

Additional studies reported by the same researchers suggested possible sources of refuge chamber discomfort may include a change in food, lack of water, noise, sanitation facilities, lack of exercise, the behavior of others, disturbances in sleep, boredom, temperature, crowding, communication, leadership and inability to concentrate. Interestingly, some of this research concluded that stress tolerance increases with the quality of group cohesion, leadership, motivation, equipment, medical assistance, and experience/training.

One field where knowledge may be gleaned is aeronautics. Negative effects of flight missions on the immune system have long been documented (Taylor, 1993). However, some of these effects may be due to changes in gravity and radiation (Chouker et al., 2002) and not just captivity, which would be the main concern for individuals in refuge chambers. Other studies have noted that the changes found in the immune systems of astronauts post flight are similar to the changes that stressful situations may cause and may not be due to space travel alone (Taylor et al., 1986). Shimamiya et al. (2004) studied the effects of a 10 day confinement with-

out space travel on the immune system and psychological aspects of humans. It was found that confinement leads to a change in the distribution of immune cells caused by stress. Although it is not likely that miners will use a refuge chamber for 10 days, it is still reasonable to assume that given the situation they will experience stress and possibly immune system changes.

The US Bureau of Mines also commissioned earlier studies on refuge chambers which reported that miners will likely feel anxiety due to confinement and uncertainty in the emergency situation (McCoy et al., 1983). Other studies have found that in the event of an emergency it may be common to feel stress or anxiety but that panic is rare (Loewenberg, 1952; Baker and Chapman, 1962). Although it is unlikely that miners will panic, they will likely experience some psychological and physiological reactions to using a refuge chamber. It is, therefore, important to train miners about how to best handle the emergency situation. Previous studies outside the mining industry have concluded that individuals' behavior and decision making is influenced by prior experiences and training (Mendonca et al., 2006).

It is particularly important that miners be well trained on the potential psychological and physiological impacts of refuge chambers as previous research has shown that pre-event information, experience, and training can help individuals respond in an emergency (Everly et al., 2008). However, most of the onus of providing refuge chamber training has been placed on the refuge chamber manufacturers, and they have developed training manuals primarily focused on the technical aspects of how to operate the refuge chamber. As a result, there is currently very little training available concerning the psychological and physiological aspects of using a refuge chamber. Although it is important for miners to know how to operate refuge chambers to access their life-saving supplies and equipment, it is also important for miners to be trained on what to expect psychologically and physiologically. To fill this need, NIOSH has developed expectations training for refuge chambers. Expectations training is essential as it "provides trainees with sufficient physical, cognitive, psychological, and behavioral information (beyond the necessary technical information and hands-on experience) to allow them to understand any potential symptoms that they may experience while performing a task or action" (Kowalski-Trakofler et al., 2008, p. 173).

Miners may also react due to the nature of the situation. If miners use a refuge chamber in an emergency, it will be a time of stress and great uncertainty and there is a possibility that some miners may be injured or unaccounted for. Because of this, miners may be stressed, confused, and disoriented when they enter and use a refuge chamber. From a psychological standpoint, preparation is the most significant part of planning for a disaster. If miners have all of the available knowledge about the operation of refuge chambers and what it might be like to spend a few days in one, it will help them in case they find themselves in such a circumstance. Miners will be better prepared to cope with the situation, and to support any co-workers that are having difficulties with the experience.

4. The training

A training program was designed to teach miners about what to expect both psychologically and physiologically if they were to use a refuge chamber. The training was designed by the authors of this paper. Extensive research was conducted to design this training including multiple interviews and visits with refuge chamber manufacturers, stakeholders, and miners. The final training is a 12 min Adobe Flash multimedia presentation that is run on a computer.

The Refuge Chamber Expectations Training followed sensory stimulation theory which posits that better learning occurs when

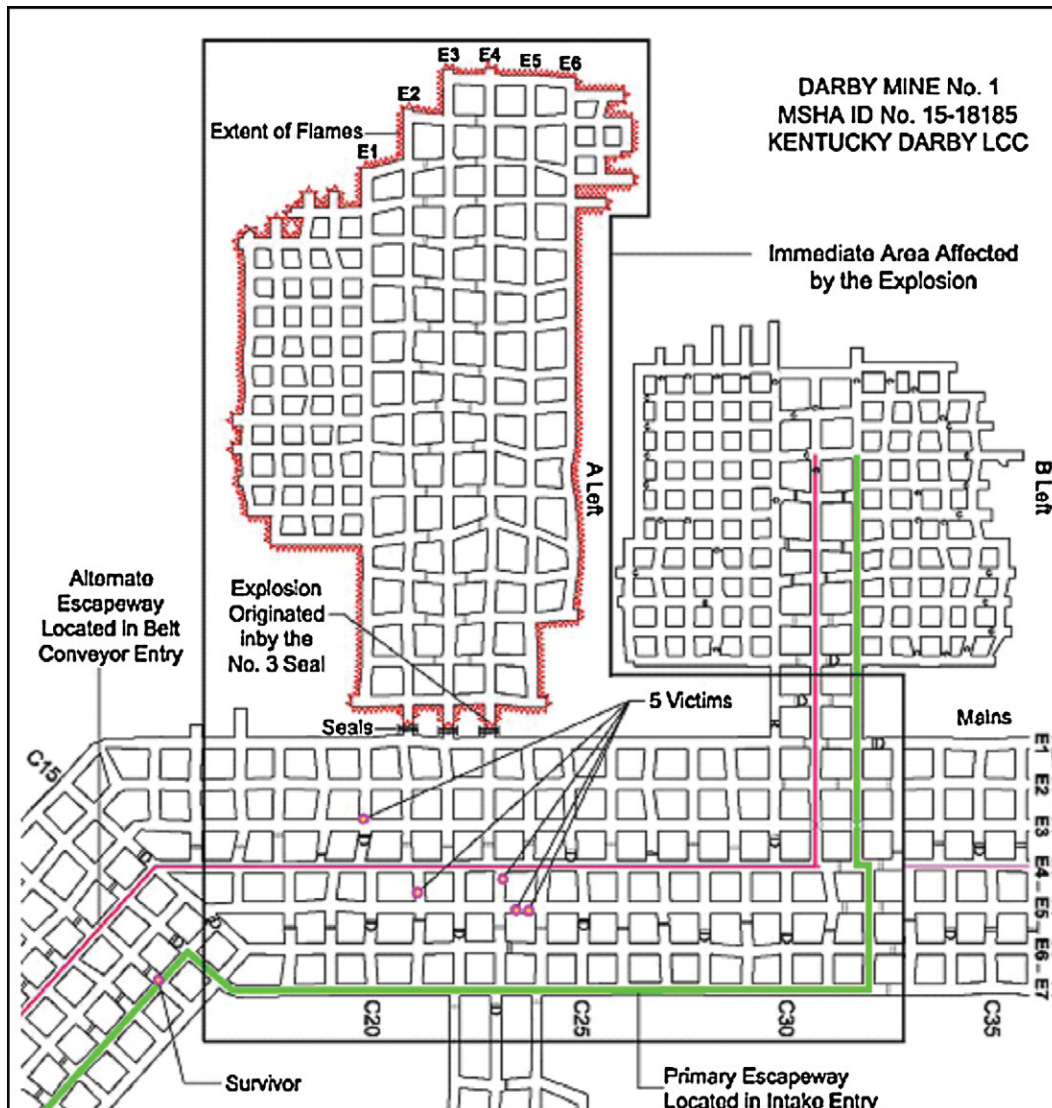


Fig. 2. Map of Darby Mine.

a variety of senses are stimulated (Laird, 1985). Laird (1985) asserts that most learning occurs after people see something, followed by hearing it, and further, that learning is greater when multiple senses are stimulated. This also follows Mayer's (2005) multimedia learning hypothesis which states that people learn more deeply from words and pictures together as opposed to just words. Mayer (2005) asserts that people have two information-processing systems. One is for verbal information and one is for visual information. When both of these systems are stimulated people learn more deeply because the systems work together and maximally engage the human brain.

Based on these two ideas, this training attempted to stimulate multiple senses by including video, pictures, animations, and audio recordings of interviews with miners who had previously used a refuge alternative during a mine emergency in Canada. When the program is played, animation and a narrator's voice accompany the visual stimuli on the screen.

The program begins with a description of a past mine emergency at Darby Mine, one of the 2006 mining incidents. Fig. 2 shows a map of this mine and was included in the training program. This disaster was chosen because a refuge chamber may have had a positive impact for three of the victims (Ounanian, 2007). The narration begins with "[i]t was a typical Saturday at the mine during a maintenance

shift. There were six miners underground. Two of the miners rode a buggy¹ down the return airway with a set of torches as they were going to remove metal straps from the roof at the intersection of the number one and number 3 seals. Suddenly at around 1:00 am, in the sealed A left section of the mine, a methane explosion occurred – a result of cutting the roof strap. The two miners died instantly. The other four miners were working in the B Left Section. They attempted to escape and encountered thick smoke. The miners eventually became separated from each other. One miner survived and three died due to carbon monoxide poisoning with smoke and soot inhalation."

After this description, the presentation informs miners about the two main types of refuge chambers and the basic components inside most chambers. The information is presented in conjunction with audio clips from interviews with miners talking about their experiences inside of a refuge chamber. Part of one of these interviews speaks to what is in a refuge chamber; the miner states, "...they all have Port-A-Potties in them and there's water in there and they got those horrible little life raft biscuits in there for – like they're 2500 calories a biscuit. So you're not going to starve to death. It's not going to be your nice sit-down supper, but you will survive."

¹ A buggy is a vehicle used to haul coal from the working face to a conveyor belt in an underground mine.

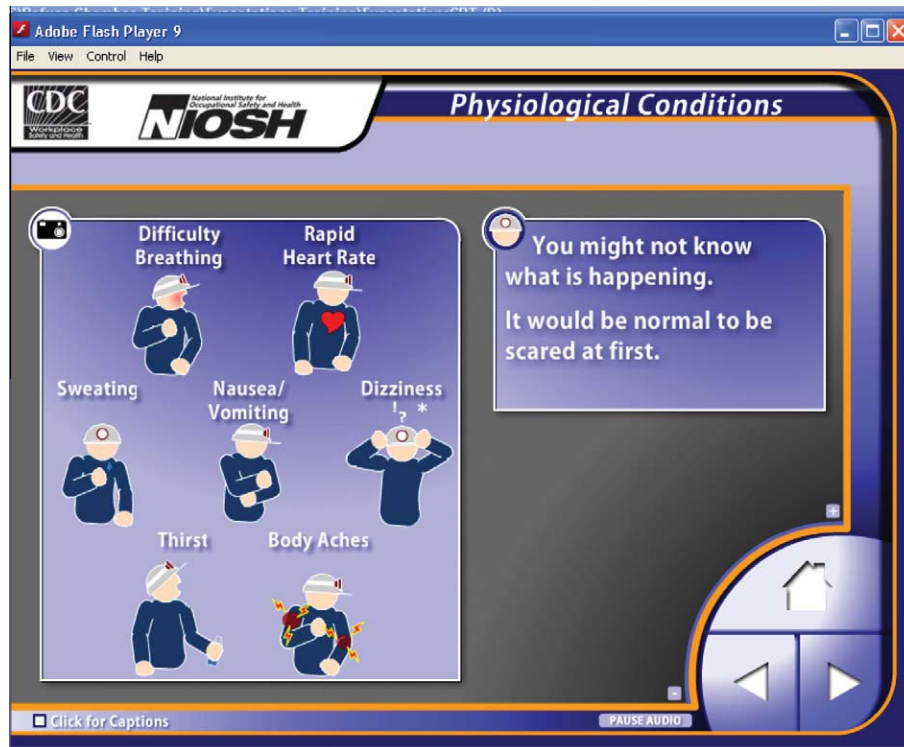


Fig. 3. Example of a screen in the training program.

Following this, information about what to expect both psychologically and physiologically is presented. Regarding responses to the emergency situation he was in, one of the miners who previously used a refuge chamber says, “[n]o there was no panic. There was one individual that I – was the last guy that I expected to show any signs of panic and he was a long-time miner that’s worked in other mines, and what he did was he went to a table and he just closed up, he was just really quiet and I kind of knew then, Okay, there’s something bothering him.” This particular audio clip was chosen to emphasize that people do not panic in an emergency but it is normal to feel stressed.

The newness of refuge chambers means that very few miners have used or even seen one. The audio clips were included to give miners a realistic preview of what an experience inside a refuge chamber would be like. Although every refuge chamber is slightly different, providing accounts of miners’ experiences in refuge chambers adds authenticity and reliability to the training.

Fig. 3 shows an example screen shot from the program. Animations were included not only to follow sensory stimulation theory but also to convey normal reactions to the emergency situation. Informing miners about typical reactions to the situation will help them be better prepared to cope with the situation if they do find themselves in a refuge chamber.

The instructor’s guide is a short manual which accompanies the Flash presentation. It includes discussion questions that trainers can ask the trainees before and after viewing the presentation. The training can be conducted with a group or as individual training. The instructor’s guide includes lesson plans for both methods.

5. Method

5.1. Subjects

In order to gauge the effectiveness of this training, a field test was conducted at a large underground coal mine in Southwestern

Pennsylvania, US with 336 underground coal miners. All participants were male and ranged in age from 19 to 66. The median age was 49. This appears to be representative of the national population of coal miners where the median age was 44 in 2008 (National Mining Association, 2009). Participants ranged in total mining experience from less than 1 year to 46 years, with a median of 22 years. This also appears to be comparable to the national population of coal miners where the median number of years experience is 20 (NMA, 2009). Total years experience at this mine ranged from 0 to 42 years with a median of 6 years. Total years experience in present job ranged from 0 to 35 years with a median of 3 years. There is no national data available on the total years experience at current mine or total years experience in present job.

5.2. Procedure

Miners were shown the training in groups of 15–25. Five different female trainers administered the training including four NIOSH researchers and the cooperating company’s trainer. There was no evidence of difference by trainer in terms of miners’ attitudes toward the training or relevance of the training.

The training was given as part of the Annual Refresher training. Annual Refresher training is mandated for all US miners (Department of Labor, 2008). Miners receive 8 h of Annual Refresher training per year which includes specific content areas including emergency response and escape. For the expectations training, miners were first told about the new federal legislation concerning refuge chambers. Then they were engaged in discussion with two questions. The first question was, “What type of items might you want in the refuge chamber if you were to spend up to four days in one?” After discussion of the responses to this question, miners were asked, “How do you think members of your crew might react if they were in a refuge chamber for up to four days?” After discussion of the responses to this question, miners were shown the Refuge Chamber Expectations Training on a large LCD projector as one

Please circle the number which tells how much you agree or disagree with the following statements:

Statement:	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1. Overall this training was excellent.	1	2	3	4	5
2. Overall this training was interesting.	1	2	3	4	5
3. Overall this training was easy.	1	2	3	4	5
4. Overall this training was informative.	1	2	3	4	5
5. Overall this training was important.	1	2	3	4	5

Please circle the number which tells how much you agree or disagree with the following statements:

Statement:	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
6. I feel better prepared if I ever find myself in a refuge chamber.	1	2	3	4	5
7. I am more aware of what it would be like in a refuge chamber.	1	2	3	4	5
8. I have a better idea of how someone might respond in a stressful situation like when using a refuge chamber.	1	2	3	4	5
9. This training was relevant to my job.	1	2	3	4	5
10. I liked the format of this training.	1	2	3	4	5

The following questions ask about what you saw in the presentation. Answer either yes or no.

	YES	NO
11. Will every miner react in the same way to being inside a refuge chamber?	<input type="checkbox"/>	<input type="checkbox"/>
12. Can it be expected that when in a refuge chamber, a miner could experience a variety of physical symptoms, such as dizziness or body aches?	<input type="checkbox"/>	<input type="checkbox"/>
13. Can paying attention to your breathing help to reduce any anxiety you may feel while in a refuge chamber?	<input type="checkbox"/>	<input type="checkbox"/>
14. Is it normal for miners to experience negative side effects due to the loss of sleep, such as confusion, while in a refuge chamber?	<input type="checkbox"/>	<input type="checkbox"/>
15. Can it be expected that miners will panic in the event of an emergency?	<input type="checkbox"/>	<input type="checkbox"/>
16. Is it normal for miners to experience symptoms, such as nightmares and flashbacks, even after surviving an emergency?	<input type="checkbox"/>	<input type="checkbox"/>

Fig. 4. Actual training evaluation form used to collect data prior to reverse coding.

group. After viewing the training, miners were asked, "After viewing this presentation, how do you think that your crew would react if they were to spend up to four days inside of a refuge chamber?" This question was asked again after the training to see if miners' knowledge and opinions about refuge chambers had changed. After this discussion, the miners were given a short survey to evaluate the training.

Attitudes toward the training were measured with items 1–5. The original Likert-type scaling is displayed in Fig. 4 (e.g., 1 = strongly agree, 5 = strongly disagree). However, to simplify the explanation of the results, the scores were reverse coded so that 5 = "strongly agree," 4 = "agree," 3 = "neither agree nor disagree," 2 = "disagree," and 1 = "strongly disagree." The effect of reverse coding is that higher numbers indicate more positive

attitudes toward the training and lower numbers indicate more negative attitudes toward the training. These items were summed to create an attitude scale which had a reliability (Cronbach's α) of .87, indicating the scale has an acceptable level of internal consistency.

Increased awareness about what it would be like in a refuge chamber was measured with items 6–8 (see Fig. 4). Items were reverse coded in the same manner as the attitude scale. The items were summed to create a scale which had a Cronbach's alpha value of .792.

Six items were used as a knowledge check. These six items were based on important learning points stressed in the training. The correct answer for items 11 and 15 was no and the correct answer for the remaining items was yes.

Participants were asked if this training was relevant to their job (item 9; see Fig. 4) and if they liked the format of this training (item 10; see Fig. 4). Each was measured with one item using a five-point Likert scale.

6. Results

Mean attitudes toward the training were high, indicating positive attitudes toward the training, as individual item means ranged from 3.98 to 4.30 out of a five-point scale. Fig. 5 displays the mean score on each of the five items used to measure attitudes toward the training (items 1–5).

Attitudes toward the training were also analyzed for correlation with the age of the participants. Only the item “Overall this training was easy,” was significantly correlated with the age of the participant such that as age increased, there was less agreement that the training was easy. The correlation of age with each of the five attitude items is reported in Table 2.

Participants also reported high levels of awareness about what it would be like in a refuge chamber after viewing this training. Mean responses to these items ranged from 3.74 to 3.88. Fig. 6 displays the mean score on each of the three items used to measure awareness of refuge chambers (items 6–8).

For most questions, participants scored very well on the knowledge check. The question that asked, “Can it be expected that miners will panic in the event of an emergency?” was marked incorrectly by 93.2% of participants. The percentage correct and incorrect is listed in Table 3 for all knowledge check questions.

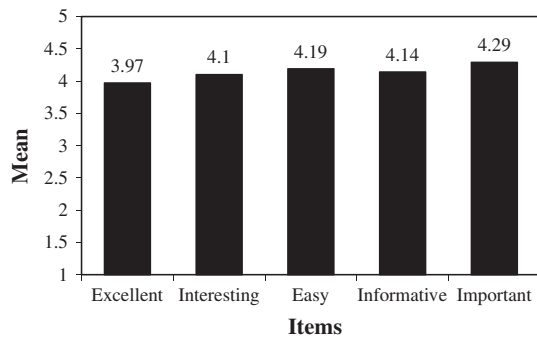


Fig. 5. Attitudes toward the training.

Table 2
Correlation of attitude items with age of participant.

Item	Excellent	Interesting	Easy	Informative	Important
Age	$r = .02$	$r = .03$	$r = -.18$	$r = -.03$	$r = -.03$
	$p = .77$	$p = .65$	$p = .00^*$	$p = .66$	$p = .63$
	$n = 320$	$n = 320$	$n = 320$	$n = 320$	$n = 320$

* Correlation is significant at the .01 level.

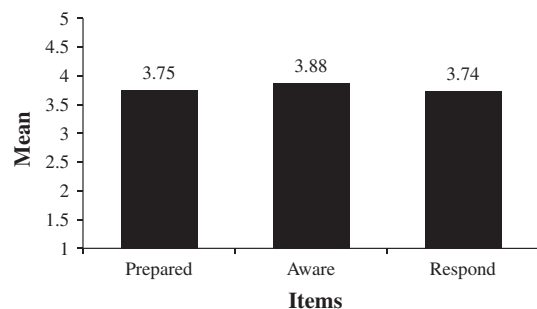


Fig. 6. Awareness of what it would be like to spend time in a refuge chamber.

Miners were asked if they liked the format of the training. The mean response was 3.92 on a five-point scale. Fig. 7 shows the percentage of responses to the statement, “I like the format of this training.” A correlational analysis was also conducted using SPSS to see if there was a relationship between liking the format of the training and age. The relationship was not found to be statistically significant, $r = .036$, $p = .526$.

Miners were also asked about the relevancy of this training to their job. The mean was 4.11 out of a five-point scale. Fig. 8 presents the responses to this question.

7. Discussion

Overall, this training was very positively rated by miners. Attitudes toward the training, the format of the training, and the relevancy of the training were all rated very highly by miners. With the exception of the item that asked if miners were likely to panic, the knowledge check items also confirmed that after viewing this training, miners were knowledgeable about what to expect psychologically and physiologically when using a refuge chamber. Many miners still believed that panic would be a likely response to an emergency. It is a common mistake to think that people panic in an emergency whereas the data show panic actually happens in a limited number of individuals (Canter, 1980; Johnston and Johnson, 1988). The routine roles of individuals tend to be extended in a crisis and thus the social order is maintained. (Johnston and Johnson, 1988). “The social behavior and cognitive processing of individuals stays remarkably close to what can be seen in ordinary, daily behavior” (Canter, 1980 p. 3). As an example, in 2009 when a jet plane was forced to land in New York City on the Hudson River shortly after take-off the passengers behaved in such a manner as to demonstrate the lack of panic most individuals experience during an emergency. They demonstrated an orderly evacuation after the emergency landing and awaited rescue (Prochnau and Parker, 2009) This does not mean individuals are not afraid and will not exhibit some erratic behavior, but the tendency in such a situation is to maintain normal behavior and, some research has shown, to help one another (Sime, 1983).

The positive evaluation of this training is important as this program was a significant advance in the technology used to train coal miners. Mine trainers often utilize older technologies with a single form of media such as video, power point, or even overheads for mine training. Flash presents a relatively new and unfamiliar training format to miners. The mining population is also aging, presenting another potential barrier to the use of new technology such as Flash in training. However, sensory stimulation theory (Laird, 1985) suggests that better learning occurs with the stimulation of a variety of the senses, which may not be provided by a single form of media such as those commonly used by mine trainers. This training program addresses the issue of multiple sense stimulation by using Flash to create a multimedia training presentation. Flash is different from media used by mine trainers in the past because it combines multiple types of media in one easy-to-use presentation. It works similarly to a PowerPoint presentation with audio and video files embedded along with written content. This research found that miners liked this type of format and were able to recall much of the information imparted in the training; thus, the format seems to be a success, even with the aging population in mines.

This was also a unique type of training for coal miners in terms of content. Although the importance of psychological response during a mine emergency was mentioned in a 1995 NIOSH publication (Kowalski), the focus was mainly on responders – mine rescue personnel. There is a scarcity of training that focuses on the physiological and psychological well-being of those trapped in the mine during an emergency. However, this type of training is

Table 3
Knowledge check results.

Item	% Correct	% Incorrect
11. "Will every miner react in the same way to being inside a refuge chamber?"	97.1	2.9
12. "Can it be expected that when in a refuge chamber, a miner could experience a variety of physical symptoms, such as dizziness or body aches?"	96.5	3.5
13. "Can paying attention to your breathing help to reduce any anxiety you may feel while in a refuge chamber?"	97.4	2.6
14. "Is it normal for miners to experience negative side effects due to the loss of sleep, such as confusion, while in a refuge chamber?"	99.4	.6
15. "Can it be expected that miners will panic in the event of an emergency?"	6.8	93.2
16. "Is it normal for miners to experience symptoms, such as nightmares and flashbacks, even after surviving an emergency?"	98.1	1.9

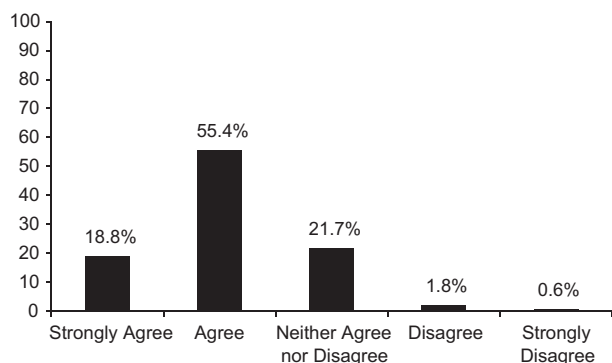


Fig. 7. Distribution of responses to the statement, "I like the format of this training."

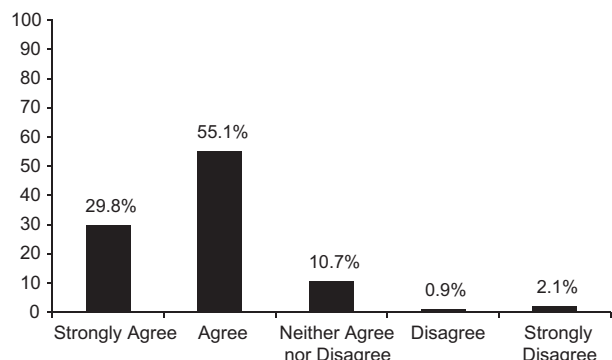


Fig. 8. Distribution of responses to the statement, "This training was relevant to my job."

useful and important because refuge chambers likely will be used during times of emergency in the future.

A limitation of the evaluation of this training was that it was a post-test only evaluation. Because miners have a very structured training schedule and are not accustomed to filling out surveys, the researchers determined to design this study as a post-test only study. There is no measure of the knowledge that miners had about what to expect psychologically and physiologically in a refuge chamber prior to this training. Therefore, there is no measure for change in knowledge due to this training.

Despite this limitation, the evidence that is available from the post-test suggests this training is a strong tool for teaching miners about what to expect psychologically and physiologically inside a refuge chamber. It advances the field of mine training by using new software to deliver training and by introducing a new and timely curriculum. Refuge chambers are potentially life-saving but only if miners are well educated about how to operate the chamber and what to expect from themselves and other miners if they unexpectedly find it necessary to use a refuge chamber.

8. Conclusions

Although training about what miners can expect both psychologically and physiologically is important, this type of training should be used in conjunction with other types of training. Miners must have a thorough, hands-on training on how to operate and when to use a refuge chamber. NIOSH is in the process of developing a suite of training materials related to refuge chamber use. The first of these is a decision making training simulation, "Harry's Hard Choices: Mine Refuge Chamber Training" (Vaught et al., 2009), which may be used in conjunction with the present training program. "Harry's Hard Choices: Mine Refuge Chamber Training" is available for download at the NIOSH website.

Acknowledgements

The authors wish to thank David Beshero of NIOSH, Lindsey Debor formerly of NIOSH, Jackie Saccamano of Emerald Coal Resources, LP an Affiliate of Alpha Natural Resources and the dedicated underground coal miners for their support with this study.

References

- Altman, L., Haythorn, W., 1967. The ecology of isolated groups. *Behav. Sci.* 12, 169–182.
- Baker, G.W., Chapman, W.W. (Eds.), 1962. *Man and Society in Disaster*. Basic Books, New York.
- Baum, Andrew. 1986. *Biopsychosocial Effects of Disasters: Three Mile Island. Conference Proceedings "Individual and Group Behavior in Toxic and Contained Environments: A Conference to Explore the Psychological Effects of Chemical and Biological Warfare, The Airlie House, Airlie, Virginia Dec 12–14, 1986.* Department of Psychiatry, F. Edward Hebert School of Medicine, Uniformed Services University of the Health Sciences, Bethesda, MD. Published December, 1987.
- Bohnen, H.G., Gaillard, A.W., 1994. The effects of sleep loss in a combined tracking and time estimation task. *Ergonomics* 37, 1021–1030.
- Canter, D. (Ed.), 1980. *Fires and Human Behavior*. David Fulton Publishers, London, pp. 1–12.
- Chouker, A., Smith, L., Christ, F., Larina, I., Nichiporuk, I., Baranov, V., Bobrovnik, E., Pastushkova, L., Messmer, K., Peter, K., Thiel, M., 2002. Effects of confinement (110 and 240 days) on neuroendocrine stress response and changes of immune cells in men. *J. Appl. Physiol.* 92, 1619–1627.
- Dalen, J., 2003. Economy class syndrome: too much flying or too much sitting? *Arch Intern. Med.* 163, 2674–2676.
- Department of Labor. Federal Register, Mine Safety and Health Administration, 2008. *Refuge Alternatives for Underground Coal Mines; Final Rule*. 251. Department of Labor. Federal Register, Mine Safety and Health Administration. 30 CFR Parts 7 and 75.
- Everly, G., Perrin, P., Everly, G., 2008. *Psychological issues in escape, rescue, and survival in the wake of disaster: CDC Contract No. 254-2008-M-24817 for the National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory.*
- Fredriksson, K., Alfredsson, L., Ahlberg, G., Josephson, M., Kilbom, A., Wigauers Hjelm, E., Wiktorin, C., Vingard, E., 2002. Work environment and neck and shoulder pain: The influence of exposure time. Results from a population based case-control study. *Occup. Environ. Med.* 59, 182–188.
- Gates, R.A., Phillips, R.L., Urosek, J.E., Stephan, C.R., Stoltz, R.T., Swentosky, D.J., Harris, G.W., O'Donnell, J.R., Dresch, R.A., 2007. *Report of investigation, fatal underground coal mine explosion, January 2, 2006. Sago Mine, Wolf Run Mining Company, Tallmansville, Upshur County, West Virginia, ID No. 46-08791.* US Department of Labor, Mine Safety and Health Administration, Arlington, VA.

- Gotshall, R.W., Aten, L.A., Yumikura, S., 1994. Difference in the cardiovascular response to prolonged sitting in men and women. *Can. J. Appl. Physiol.* 19, 215–225.
- Helmreich, R.L., 1986. Living in contained Environments. Conference Proceedings Individual and Group Behavior in Toxic and Contained Environments: A Conference to Explore the Psychological Effects of Chemical and Biological Warfare, The Airlie House, Airlie, Virginia December 12–14, 1986. Department of Psychiatry, F. Edward Hebert School of Medicine, Uniformed Services University of the Health Sciences, Bethesda, MD. Published December, 1987.
- Johnston, D.M., Johnson, N.R., 1988. Role extension in disaster: employee behavior at the Beverly Hills Supper Club fire. *Sociol. Focus* 22, 39–51.
- Kowalski-Trakofler, K.M., Vaught, C., Brnich, M.J., 2008. Expectations training for miners using self-contained self-rescuers in escapes from underground coal mines. *J. Occup. Environ. Hyg.* 5, 671–677.
- Laird, D., 1985. *Approaches to Training and Development*. Addison-Wesley, Reading, Mass.
- Linde, L., Bergstrom, M., 1992. The effect of one night without sleep on problem-solving and immediate recall. *Psychol. Res.* 54, 127–136.
- Loewenberg, R.D., 1952. Psychological reactions in an emergency (earthquake). *Am. J. Psychiatry.* 109, 384–385.
- Mayer, R.E., 2005. *The Cambridge Handbook of Multimedia Learning*. Cambridge University Press, Cambridge.
- Mendonca, D., Beroggi, G.E.G., vanGent, D., Wallace, W.A., 2006. Designing gaming simulations for the assessment of group decision support systems in emergency response. *Safety Sci.* 44, 523–535.
- McCoy, J.F., Berry, D.R., Mitchell, D.W., 1983. Development of guidelines for rescue chambers, vol. II. US Bureau of Mines Contract No. JO387210, October 1983, Foster-Miller, Inc., Waltham, MA.
- National Mining Association, 2009. Most requested statistics – US coal industry. Washington, DC. <http://www.nma.org/pdf/c_most_requested.pdf>.
- National Institute for Occupational Safety and Health, 2009. Heat stress <<http://www.cdc.gov/niosh/topics/heatstress/>>.
- Office of Mine Safety and Health, 2007. Research report on refuge alternatives for underground coal mines. <http://www.cdc.gov/niosh/mining/mineract/pdfs/Report_on_Refuge_Alternatives_Research_12-07.pdf>.
- Ounanian, D., 2007. Refuge alternatives in underground coal mines, Phase I Final Report, NIOSH Contract No. 200-2007-20276, July, Foster-Miller, Inc., Waltham, MA.
- Prochnau, W., Parker, L., 2009. *Miracle on the Hudson: The Survivors of Flight 1549 Tell their Extraordinary Stories of Courage, Faith, and Determination*. Ballantine Books, New York.
- Shimamiya, T., Terada, N., Hiejima, Y., Wakabayashi, S., Kasai, H., Mohri, M., 2004. Effects of a 10-day confinement on the immune system and psychological aspects in humans. *J. Appl. Physiol.* 97, 920–924.
- Sime, J.D., 1983. Affiliative behavior during escape to building exits. *J. Environ. Psychol.* 3, 21–41.
- Taylor, G.R., 1993. Immune changes during short-duration missions. *J. Leukocyte Biol.* 54, 202–208.
- Taylor, G.R., Neale, L.S., Dardano, J.R., 1986. Immunological analyses of US Space shuttle crewmembers. *Aviat. Space Environ. Med.* 57, 213–217.
- Ursano, R.J., 1986. Introduction to Individual and Group Behavior in Toxic and Contained Environments: A Conference to Explore the Psychological Effects of Chemical and Biological Warfare, The Airlie House, Airlie, Virginia December 12–14, 1986. Conference Proceedings Individual and Group Behavior in Toxic and Contained Environments: A Conference to Explore the Psychological Effects of Chemical and Biological Warfare, The Airlie House, Airlie, Virginia December 12–14, 1986. Department of Psychiatry, F. Edward Hebert School of Medicine, Uniformed Services University of the Health Sciences, Bethesda, MD. Published December, 1987.
- Ursano, R.J., Fullerton, C.S., Norwood, A.E. (Eds.), 2003. *Terrorism and Disaster: Individual and Community Mental Health Interventions*. Cambridge University Press, Cambridge, UK.
- United States Public Laws, 109th Congress – Second Session Convening January 7, 2005 PL 109-236 (S 2803) June 15, 2006. Mine Improvement and New Emergency Response Act of 2006 (MINER ACT).
- Vaught, C., Hall, E., Klein, K., 2009. Harry's Hard Choices: Mine Refuge Chamber Training. Information Circular 9511. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. March. <<http://www.cdc.gov/niosh/mining/products/product160.htm>>.
- Weinger, M.B., Ancoli-Israel, S., 2002. Sleep deprivation and clinical performance. *JAMA* 287, 955–957.