Underground Mine Refuge Alternatives

A look at food, water and sanitation requirements

BY A.G. MAYTON AND J.R. HEBERGER

Underground coal mine explosions, such as the January 2006 Sago mine disaster, have dramatically demonstrated the need to provide mine refuge alternatives for miners who are unable to exit the mine and are forced to take refuge during mine disasters or emergencies.

The Mine Improvement and New Emergency Response (MINER) Act of 2006 requires that underground coal operators include refuge alternatives (RAs) in their Emergency Response Plans. Mines presently use three types of refuge alternatives: mobile steel, mobile inflatable tent and built-in-place (BIP).

Considering the importance of equipping RAs well for emergencies, this article reviews the Mine Safety and Health Administration (MSHA) regulations for food, water and waste disposal/sanitation in RAs. Information received from RA manufacturers is presented on food, water, and sanitation products and methods provided in their RAs. Issues that may arise from using these products are also discussed, along with possible solutions.

MSHA Standards for Rations in Refuge Alternative

Food, water and waste disposal requirements are stipulated in the mandatory mine safety standards promulgated by MSHA. The Code of Federal Regulations (CFR) Title 30, Part 75.1507, gives guidance on food, water and sanitation for refuge alternatives. The specific regulations for food and water state that the RA should be stocked with the following: a minimum of 2,000 calories (Cal) of food and 2.25 quarts (qt) of potable water per person per day in approved containers sufficient to sustain the maximum number of persons reasonably expected to use the RA for at least 96 hours. These regulations specify only the amount of food and water rations that should be available for each miner per day using the RA, and not necessarily how much of the rations each miner should or will consume. Regarding waste/sanitation, the regulation merely states that each RA includes sanitation facilities.

Refuge Alternative Supplies

For this review, the major mine RA manufacturers were visited or contacted by email and telephone. Nine manufacturers provided information with details on food and water rations as well as waste disposal products. Emergency ration and sanitation product manufacturers and distributors were also contacted to answer questions about their products.

Food rations — Most of the emergency food rations supplied with RAs are fortified food bars (Figure 1). The major brands include Mayday, ER Bar, S.O.S., Datrex and Mainstay. One RA manufacturer indicated its intention to use a yet-to-be-determined liquid food product similar to consumer nutritional food shakes. These bars comprise wheat-based ingredients and show similar texture, but vary in nutritional content. They are ready-to-eat, non-thirst provoking, and generally described as hard, dry bars, similar to a thick piece of hardtack. Common flavors are coconut, lemon and apple cinnamon. Some accentuate nutritional content with considerable detail (100% of major dietary requirements), while others provide a rather brief description of nutrients included (Figure 2). Package labels reviewed ranged in calories from 2,000 to 3,600.

Figure 1: Five examples of emergency food rations commonly used in refuge alternatives. Some rations must be broken into smaller pieces, while others are enclosed individually in plastic wrap.

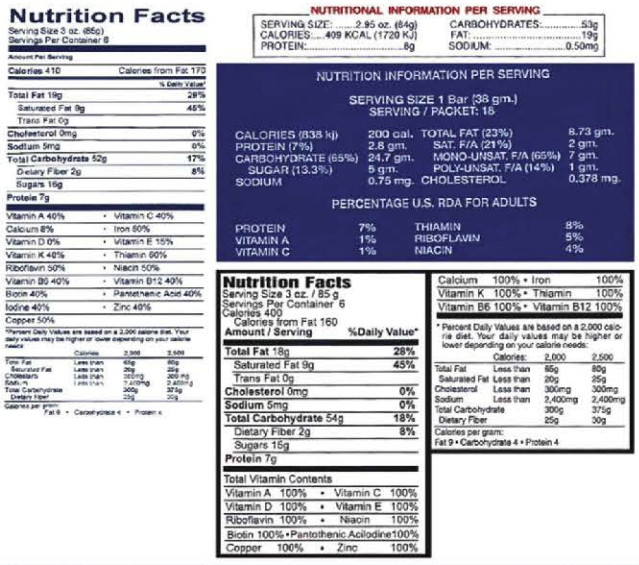

Figure 2: Examples of differing nutritional content from the packaging of four different emergency food rations.

Water rations — A variety of water products and sources are used in RAs (Figure 3). Samples of packaged water collected include: AquaBlox, Datrex, ER (QuakeKare), Mainstay and S.O.S. Food Lab Inc. The samples include 8.5-fl. oz., juice box-type packages (with bendable straws) and 4.2-fl. oz foiled pouch-type packages. Other types observed during field visits or noted from telephone conversations with manufacturers included: 8- to 16.9-fl. oz. plastic bottles and 6- to 7-gal containers from which smaller quantities of water are dispensed. One RA manufacturer indicated that it uses public water and treats it with an additive to extend the shelf life to five years.

Figure 3: Examples of emergency water rations: water boxes, foil pouches, water bottles and water treatment tabs for treating water from domestic sources.

Sanitation/Waste disposal products — Chemical toilet kits consisting of disposable plastic bags with treating and deodorizing agents (Figure 4) are the predominant choice for waste disposal. Many of these products are identical to portable toilet systems sold for camping and other outdoor activities. Some RAs have interior compartments for the used bags. One manufacturer offers a flush toilet in the air-lock area of the RA that expels the waste outside the chamber. BIP RAs usually offer, in addition to the chemical toilet kit selections, other waste/toilet options such as a camp toilet with lid and hand sanitizing gel, a mine-constructed urinal, and a mine-constructed separate toilet room with a marine-type flushable toilet and associated flushing and sanitizing products (Figure 4).

Figure 4: Examples of toilets in a bag that can be used on their own or with a collapsible toilet (left). Separate toilet room constructed by the mine (right) with marine-type flushable toilet and associated flushing and sanitizing products.

Potential Issues With Refuge Alternative Supplies

Food and water package instructions — Many RA manufacturers use food and water products intended for emergency survival and mostly include products manufactured to comply with International Maritime Organization (IMO) and International Convention for the Safety of Life at Sea (SOLAS) requirements for life-saving appliances. These products meet standards that are approved by the U.S. Coast Guard and the International Organization for Standards (ISO) 18813 and include specific instructions for marine use. One concern is that instructions on packaging for using these food and water products may be confusing to miners taking refuge. Not all ration manufacturers provide clear instructions for their products as many address use specifically for emergencies at sea. For instance, one food ration package states: "Eat two food bars per person per day." Each bar in this package is 400 Cal, so eating two bars would provide only 800 Cal total.

Water ration instructions vary according to the manufacturer. One brand states: "Drink no water the first 24 hours unless sick or injured or in desert conditions. Thereafter, approximately two 4-fl. oz. bags per day minimum." Another brand gives the following instructions: "Consume one box (8.45 fl. oz.) per person per day."

None of the food and water ration instructions stated to consume more than the MSHA regulation of a minimum of 2,000 Cal and 2.25 qt of water made available per person per day, and nearly all stated to consume less.

Moreover, the package labeling is complicated because it includes serving size or content information, ingredient information, and sometimes additional instructions, which often mention water consumption. One food ration indicates "Save drinking water. Do not drink water during the first 24 hours unless sick, injured or in desert conditions. After first the 24 hours, drink no more than 500 ml (1/2 liter, approx. 16 oz.) per day. Never drink seawater, not even mixed with fresh water."

Finally, serving sizes are different among the products evaluated. There are no specific instructions provided for use in a refuge alternative, nor to indicate how much an individual should consume to meet the 2,000-Cal ration per miner.

A simple solution to the possible confusion is consistent labeling of food and water items in a manner specific for use in mine RAs. The packaging could state how much food and water to consume according to the MSHA regulations. Eliminating multiple directions for how to use products in different scenarios could mitigate any misunderstandings with food and water servings. Additionally, placards with the minimum and maximum rations per person per day, supplemental training, or packaging food and water rations by miner per day could help with allocating rations.

Food ration ingredients — The ingredients in food rations could pose an issue if miners are known to have certain allergies or require gluten-free food. Only one food ration identifies allergens and states "Allergens: Contains Soy and Wheat," and another only states "Contains: soy, wheat." All of the main brands of rations contain wheat and soy (as they increase shelf life), while only one names coconut as an ingredient. Although it may be impractical to outfit all RAs, it may be possible for mines to supplement with other types of food sources if miners are known to have allergies.

Dehydration — There is a serious concern of heat and humidity buildup inside an occupied refuge alternative. The heat and humidity generated by the occupants and the carbon dioxide scrubbing system could lead to severe discomfort or heat stress depending on the starting mine ambient temperature. The National Institute for Occupational Safety and Health (NIOSH) and other studies have documented that high heat and humidity will be present inside occupied RAs. These conditions put miners in RAs at an increased risk of heat stress. If fluids lost in sweat are not replaced, dehydration can occur.

Quantity of water

Humans would die in a few days without water, as all cells and organs need it to function. Total body water has a critical influence on core body temperature, as dehydration can increase core temperature. Considering the heat- and humidity-related water

loss that may occur in a RA underground, miners taking refuge may need more than the MSHA-recommended minimum of water per miner per day of 2.25 qt.

The 2005 Institute of Medicine's dietary reference intake (DRI) reports for water list 3.9 qt per day as the recommended daily average intake of water for men 18 to 50 years old and 2.9 qt per day as the average intake of water for women 18 to 50 years old. DRIs are set to optimize health and therefore are likely well above the amount required in an emergency situation. In the context of this article, it is important to note that these guidelines account for water from foods and fluids; the food ration bars are likely very low in water, but do contribute to an individual's fluid needs. The IMO requires 1.59 qt of water per person to be stored on life rafts while the North Atlantic Treaty Organization requires a minimum 1.06 qt per person per day in distressed submarines.

Chilean researchers reported in Safety Science that participants in a 2014 study perceived the 1.06 qt water as acceptable. Their study included 20 participants sheltered in an RA for 48 hours where humidity and temperature were controlled.

The Army's Heat Stress Control and Heat Casualty Management publication indicates guidelines for water intake and work/rest cycles, given various temperature ranges for soldiers performing easy work such as weapon maintenance or marksmanship training (Table 1). These guidelines are for the average-sized and heat-acclimatized soldier wearing battle dress uniform. In temperatures above 90°F, the guidelines suggest 1 qt of water per hour. (Note: hourly fluid intake should not exceed 1.5 qt and daily fluid intake should not exceed 12 qt.) Daily water requirements for heat-acclimated sedentary soldiers range from 5 qt to 8 qt per day at apparent temperatures of 80°F to 95°F.

These recommendations from the U.S. Army Research Institute of Environmental Medicine, although not directly applicable to underground mine RAs, may be considered when assessing miners' needs for emergency water rations within a mine RA. Based on this comparison, it could be argued that the MSHA standard of 2.25 qt of water per day per person may not be enough to prevent dehydration and heat-related disorders if the RA interior temperature is high. Further, miners in refuge will be wearing their mining clothing and will also have to perform minor tasks to keep the refuge alternative functioning, which will raise their need for water intake.

WBGT Index [°F]	Water intake [qt per hour]	Work/Rest [minutes]
78-81.9	0.5	No Limit
82-84.9	0.5	No Limit
85-87.9	0.75	No Limit
88-89.9	0.75	No Limit
90+	1	50/10

Table 1: Fluid replacement and work/rest guidelines for warm weather training conditions for the average-sized and heat-acclimatized soldier wearing battle dress uniform performing easy work.

Electrolytes

Maintaining the correct balance of electrolytes affects hydration of the body and is extremely important for regulating the acidity of blood (pH), muscle function, and other important processes — as electrolytes are critical for fluid movement between and inside cells. When the body sweats, water and electrolytes are lost. Excessive sweating can cause electrolyte imbalances and dehydration, which increases core body temperature during work in hot environments.

Normally, water alone is sufficient for hydration, however, electrolyte replacement may be necessary. The Army and Navy both report that sports drinks are an effective source for electrolyte replacement during prolonged periods of profuse sweating in hot weather, especially when a normal diet is not consumed.

MSHA regulations only address quantities of emergency food and water. They do not take into account electrolytes or other nutrients and their importance for individual health. Figure 2 shows that the information printed on the packaging of different food rations varies considerably for sodium, which is the primary electrolyte lost through sweating.

The samples of emergency rations have very low amounts of sodium, ranging from 10-69 mg per daily serving. Since the food rations are intended for emergency marine survival, they conform to maritime emergency ration standards, which state that the maximum sodium content be 0.2% of the food ration.

Many factors influence sweat composition such as sweat rate (which depends on clothing, climate and work intensity), diet, hydration and heat acclimation. For those performing sedentary activities in very hot climates, sodium intake is suggested to be around 6 to 12 grams per day. At 6 grams, the emergency rations contain 0.2% to 1.2% of the suggested sodium, while at 12 grams, emergency rations contain 0.008% to 0.6% of the suggested sodium.

Since the emergency rations have such low electrolyte content and miners in refuge may sweat profusely due to the high heat and humidity, it is likely necessary to provide miners with some type of electrolyte replacement in order to maintain important bodily functions. Commercially available sports drinks are an effective source of electrolyte replacement, but should not totally replace water. Salt tablets are not recommended as they do not address water replacement needs and can irritate the stomach, leading to vomiting, which can exacerbate fluid losses.

Quantity of Food

The four main criteria that affect ration levels are: activity level, weight, demographic composition and environmental temperature. For miners taking refuge, the most applicable variables are activity level and environmental temperature. Miners in RAs will not be engaging in much activity; therefore, fewer calories are needed. If the RA has no cooling device, the high temperatures diminish the body's craving for food. Moreover, the aforementioned 2014 Chilean study also found that the 2,000-Cal diet was acceptable. Therefore, the 2,000-Cal per-miner, per-day food requirement seems sufficient, if not excessive for the survival of miners in refuge. With the potential for reducing food rations, the amount of space required for food storage could be reduced to make additional space available for potable water.

Sanitation

Coal mines with sufficient vertical height (head clearance) should be able to accommodate RAs equipped with toilet facilities such as current camping or marine-type devices. But in low-coal mines, such devices would require awkward postures. The best choice for these mines may be the simple toilet-in-a-bag products. Moreover, an additional liberal supply of sanitation items should be considered for use at the refuge communal toilet, including antibacterial liquids/sprays for cleaning up bodily fluids.

Some RA manufacturers choose a waste disposal system that discharges human waste to the floor environment outside the chamber. Discharging waste to the immediate exterior of the RA is undesirable, since it will foul the immediate surroundings of the RA and serve as a potential source of contamination for individuals yet to arrive at the chamber, including mine rescue teams.

Personal Factors

An individual miner's health is crucial to how well he or she can survive in a refuge situation. If miners are fit and in good health before going into refuge, they will likely be fine as long as there are adequate rations. If miners have chronic diseases such as high blood pressure, heart disease, diabetes, or obesity when going into an RA, electrolyte depletion can distress the heart and renal function, complicating existing conditions. According to the U.S. Army Research Institute of Environmental Medicine, poor physical fitness, skin disorders, certain medications, alcohol use, flu and fever are notable risk factors that can negatively impact the regulation of body temperature. Miners in refuge with any of these conditions, combined with hot climates and high humidity conditions, are at increased risk of heat-related disorders.

Conclusions

Considering the information received from RA manufacturers and the makers/distributors of emergency food/water rations and products, NIOSH researchers found that the food, water and sanitation products supplied by RA manufacturers meet the MSHA standards set forth in 30 CFR 75.1507. However, most food and water rations provided by RA manufacturers are intended for emergencies at sea; consequently, the instructions for such products may be confusing to miners taking refuge. Eliminating multiple directions for how to use products in different scenarios could mitigate any misunderstandings with food and water servings. Also, the environment inside the RA is likely to have high humidity and heat; therefore, electrolyte and water loss may initiate dehydration and other heat disorders. Increasing water supplies and electrolyte replacement are worth considering, whereas MSHA's 2,000-Cal per-person, per-day food ration guideline seems appropriate. Sanitation systems in RAs should be adequately supplied with antibacterial wipes and nontoxic, antibacterial products for cleanup, and discharge should be directed away from travelways.

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