SME Annual Meeting
Feb. 22-Feb. 25, 2009, Denver, CO

Preprint 09-031

CHEMICAL-RELATED INJURIES AND ILLNESSES IN U.S. MINING

D.F. Scott, NIOSH, Spokane, WA
E.M. Merritt, NIOSH, Spokane, WA
A.L. Miller, NIOSH, Spokane, WA
P.L. Drake, NIOSH, Spokane, WA

ABSTRACT

The purpose of this study was to determine if miners are at risk from exposures to chemicals used in the mining industry, and determine the nature and sources of the illnesses and injuries. The authors reviewed the Mine Safety and Health Administration's (MSHA) Employment and Accident, Injury, and Illness database and identified 2,705 cases of chemical-related injuries and illnesses that were reported to MSHA from 1999-2006, involving 66 different chemicals. The main source (cause) of chemical-related cases was acids/alkalis (about 39%). The primary nature (effect) of chemical-related cases was chemical burns (about 57%). The job classification where workers incurred the most chemical-related injuries and illnesses was cleaning plant operator/media operator/boney preparation plant operator/crusher worker. The number of nonfatal days lost did not change significantly and overall, the incidence rate of chemical-related cases decreased by 36%. Chemical burns accounted for a large number of injuries; mining companies should carefully examine their personal protective equipment (PPE) requirements, training methods, and safety culture to insure that their workers are protected.

INTRODUCTION

Thousand of miners are routinely exposed to a variety of chemical hazards. With nearly 329,000 operators and contractors working in the mining industry in 2006 (U.S. Dept. of Labor, 2007a), the potential for chemical-related illness and injury is high. In a recently published review of the occupational health hazards associated with mining, a variety of chemical hazards were assessed (Donoghue, 2004). The predominant hazards identified were exposure to silica, coal dust, asbestos, and diesel particulate matter. Other noted health risks included exposure to arsenic, nickel, lead, cadmium, manganese, platinum, cobalt, mercury, cyanide, sulfur dioxide, and xanthates. A report by the Industrial Disease Standards Panel (IDSP, 1994) assessed lung cancer in hard rock mining and the potentially harmful agents included ionizing radiation, arsenic, nickel, sulfuric acid mist, asbestos, diesel emissions, oil mist, blasting agents and silica.

The wide range of chemicals used in mining lead to a variety of potential exposure hazards. Chemicals posing a physical or health hazard can enter the body via three main pathways (Patnaik, 1999).

1. Contact with the eyes and skin- when chemicals come in contact with the skin they can cause dermatitis, rashes, or burns. Alkalis, acids, soaps, detergents, and organic compounds are the most frequent causes of dermatitis and the response to the exposure can be exacerbated by humidity, friction, and excessive heat. Poisonous chemicals, as well as their vapors, can also cross the skin barrier and enter the blood stream (Patnaik, 1999). If a chemical gets into the eye it can burn, cause an infection, or hinder vision. Chemical eye burns typically occur from alkalis, acids, or organic solvents (Weeks et al., 1991).
2. Ingestion- exposure due to ingestion of a chemical can occur if hands are not thoroughly cleaned after handling chemicals. Exposure occurs from subsequent handling of food, utensils, cigarettes, or other items that might be placed in the mouth.
3. Inhalation- inhaled chemicals can cause acute responses such as nausea, headaches, shortness of breath, and asphyxiation, or chronic outcomes such as central nervous system disorders and respiratory illnesses.

A study by the National Institute for Occupational Safety and Health (NIOSH) summarized a survey that focused on injuries, illnesses, and hazardous exposures to mine workers (NIOSH, 2000). This survey included an analysis of MSHA data for the 10 year period from 1986-1995, to determine the number and nature of nonfatal injuries within each commodity. Nonfatal chemical burns and poisonings, listed by type of operator are presented in Table 1. Most of the burn cases resulted from exposure to acids and alkalis, with the eye as the most common site of injury. The majority of the poisonings were from noxious mine gases. The injuries typically occurred in the summer months and workers with less than five years experience had more burns and poisonings than whose who had more experience.

Table 1. Total number of nonfatal injury cases & those caused by chemical burns and poisonings for 1986-1995 (NIOSH, 2000).

Operators	All Nonfatal	Chemical Burns	Poisonings
Coal	131,144	701	244
Metal	31,494	733	166
Nonmetal	17,133	239	103
Stone	54,359	1,132	217
Sand & Gravel	19,406	127	141
Totals	**253,536**	**2,932 (1.2%)**	**871 (0.34%)**

A study of all chemical-related injury and illness cases from 1983-2000 was completed by MSHA researchers (MSHA, 2002). That study identified 4,652 chemical burn cases, 805 poisonings, and 635 cases of dermatitis.

The results of these studies, along with concerns for the many workers who are regularly exposed to a variety of chemicals, prompted MSHA to develop the Hazard Communication (HazCom) standard. The standard was designed to increase worker awareness about the use of PPE, and ultimately to reduce injuries, illnesses, and deaths due to overexposure or misuse of chemicals. Learning about the dangers of working with chemicals increases the understanding of the importance of using PPE. In addition, implementation of the information provided on MSDSs regarding the chemical properties and health hazards is important in prevention of overexposure or misuse of chemicals.

The HazCom rule became effective in 2003. Chemicals at a mine would be considered hazardous for the purpose of the rule if the chemical has the potential to harm persons as indicated by any of the following:

1. The chemical's label or MSDS indicates that it is a hazard.
2. The chemical is produced at this location and available evidence concerning its physical or health hazards indicates that it can be a hazard to exposed persons.

Copyright © 2009 by SME

3. The chemical is a mixture produced at this location which contains at least 1% of a hazardous chemical or 0.1% of a carcinogen.

If the answer was yes to any of these questions, and it was not exempted in the MSHA rule, 30 CFR, Part 47, it would need to be on the mine's hazardous chemical list.

To quantify the number of chemicals currently in use, NIOSH queried several hard-rock mining companies in 2008. These mines volunteered to share their chemical inventories, resulting in a list of more than 1,000 chemicals that are currently in use.

This paper summarizes a recent review of the MSHA illness and injury database, which was conducted with two goals. The primary goal was to determine if miners are at risk from exposures to chemicals used in the mining industry, determine the nature and sources of the illnesses and injuries, and communicate that information to the mining industry. The second goal was to investigate trends in the data that might target opportunities for health and safety research that would help prevent chemical-related injuries and illnesses.

METHODS

MSHA's definition of an injury is, "any injury to a worker which occurs at a mine for which medical treatment is administered, or which results in loss of consciousness, inability to perform any job duties on any day after an injury, or transfer to another job" (U.S. Department of Labor, 2007b). An illness is defined as "an illness or disease of a worker which may have resulted from work at a mine or for which an award of compensation is made" (U.S. Department of Labor, 2007b).

When illness or injury occurs in the mining workplace, mine operators and contractors must file a Mine Accident, Injury, and Illness Report (MSHA Form 7000-1) within ten days of the accident, injury, or diagnosed illness (injuries requiring only first-aid are not considered reportable). The report includes demographic information such as age, sex, total years of mining experience, and information regarding the incident, such as the body part impacted, the incident location, the source and nature of the injury, a brief narrative detailing how the incident occurred, and/or other pertinent information. This information is then entered into the MSHA database (U.S. Department of Labor, 2007a). In the current study, data from the MSHA database for the years 1999-2006 were analyzed. The data were imported into a Microsoft Excel[1] database and each case was verified by reading the accompanying narrative (MSHA Form 7000-1).

Injury or illness cases were classified as chemical-related if the worker inhaled, ingested, or came into direct contact (through eyes or skin) with a chemical. Cases that could not be verified were removed from the data set. Cases were reviewed to capture only those that were chemical-related based on the nature and source of the injury (office workers excluded because they have minimal contact with hazardous chemicals). To be considered in this review, cases had to meet the following criteria:

1. Source of injury listed as acids/alkalis, chemicals/chemical compounds, noxious mine gases, or oxygen deficient atmosphere and/or,
2. Nature of injury listed as a chemical burn, poisoning systemic, dermatitis, occupational diseases, black lung, disease/contagious infection, other pneumoconiosis, asbestosis, silicosis, and anthracosis and/or,
3. Contain reference to chemicals including, but not limited to: acids, alkalis and caustic solutions, asbestos, asphyxiates, coal dust, crystalline silica, cyanide, carbon monoxide, heavy metals, metal dusts, mine gases (e.g. sulfur dioxide, oxides of nitrogen, or methane), reagents, respiratory irritants, solvents, and xanthates.

[1] Reference to company name or product does not imply endorsement by the National Institute for Occupational Safety and Health.

After identifying the injury and illness cases that were chemical-related, the data were further organized using the groupings in the MSHA database. The groupings included: mine type, part of body affected, standard industrial code, job title, state, source of injury or illness, accident/injury/illness classification, injury type, degree of injury/illness, mine worker's activity at the time of the injury or illness, the nature of the injury or illness, and the narrative describing the injury or illness.

Incidence rates (number of new cases reported each year per 100 workers) were calculated for each year using the identified cases of chemical-related injury and illness. The number of reported cases was divided by the total number of hours worked and multiplied by 200,000 (MSHA standard-assumes a forty hour work week, fifty weeks per year for 100 employees). This calculation was done because MSHA records the hours worked and not the number of employees for each mine. For this review, work hour information was gathered from the Mine, Injury and Worktime, Quarterlies Closeout Editions for 1999-2006 (U.S. Department of Labor, 1999-2006).

RESULTS

The purpose of this review was to determine if miners are at risk from exposures to chemicals used in the mining industry, determine the source (cause) and nature (effect) of the illnesses and injuries, and to communicate that information to the mining industry.

Injury rates and severity

Based on the sorting criteria for this review, there were 2,705 cases of chemical-related injuries and illnesses reported from 1999-2006 (Table 2). The results from the calculation of injury and illness incidence rates during the review period are given in Figure 1. During the four years (1999-2002) the incidence rate fluctuated around 0.130. The HazCom rule was in effect by March of 2003, which may contribute to the decline in the incidence rates from 2002 through 2006.

Table 2. Number of chemical-related injuries and illnesses for the years 1999-2006.

Year	Number
1999	394
2000	382
2001	344
2002	388
2003	317
2004	279
2005	322
2006	279
Total	**2,705**

The severity of the cases is presented in Table 3, according to the injury type (i.e. nonfatal days lost [NFDL] or no days lost [NDL]). NFDL and NDL for illnesses were not summarized because many of the illness cases in the MSHA database show zero for no days lost or nonfatal days lost. There were a total of 619 injuries which resulted in nonfatal days lost (NFDL) and 893 which resulted in no work days lost (NDL). The remaining 1,193 cases were classified as occupational illnesses. For the time period investigated, the NFDL and NDL cases have remained approximately constant; the HazCom rule has had no impact on the severity of the reported cases.

Source and nature of illness and injury

According to the analysis of the injury and illness case narratives recorded in the MSHA database, a total of 66 chemicals were responsible for the 2,705 cases. The sources of chemical-related injuries and illnesses are shown in Figure 2. Acids and alkalis, defined by MSHA to include wet cement, wet grout, shotcrete, lime-cement dust, trona, and rock dust, accounted for about 39% of all cases. Pulverized minerals are defined by MSHA to include fines, particles,

Copyright © 2009 by SME

and mine dust, and accounted for about 28%.

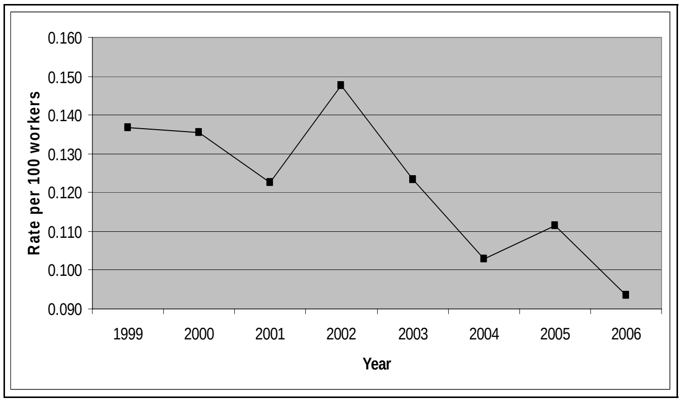

Figure 1. Incidence rates by year for chemical-related injuries and illness (n=2,705)

Table 3. Injuries resulting in NFDL or NDL for 1999-2006.

YEAR	NFDL	NDL
1999	82	105
2000	69	122
2001	72	97
2002	76	117
2003	72	90
2004	68	115
2005	94	127
2006	86	120
Total	**619**	**893**

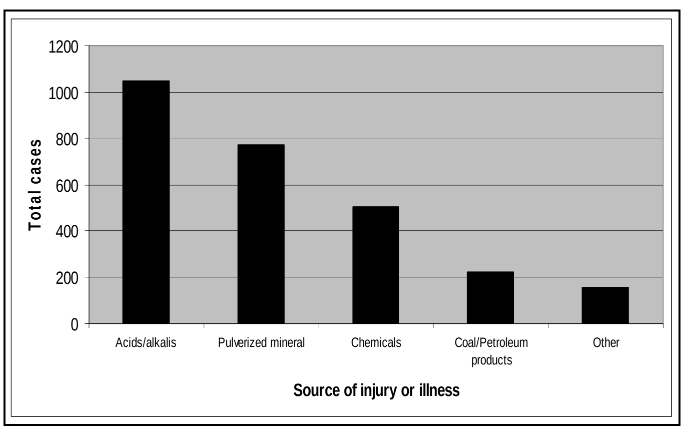

Figure 2. Source of chemical-related injuries and illnesses, 1999-2006 (n=2,705).

Chemicals accounted for about 13%, and coal/petroleum products, including processed coal, clinkers, methane gas, and solvents, creosote, hot oil, hydraulic fluid, anti-freeze, gasoline, and mouse milk accounted for about 8%. These four sources accounted for about 94% of all chemical-related illnesses and injuries.

The nature of chemical-related injuries and illnesses is shown in Figure 3. Chemical burns accounted for about 57% of all cases, followed by coal workers pneumoconiosis (CWP) (24%), poisonings (8%), dermatitis (3%), and silicosis (2%). The main route of chemical exposure was through direct contact (64%) and less than 1% of the cases involved ingestion of a chemical. The most common affected sites were the eyes and chest (lungs), 37% and 29% respectively, while injuries which affected more than one body part accounted for 7% of the cases.

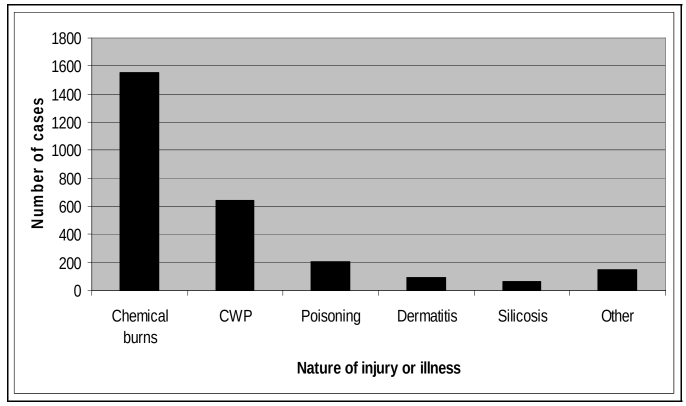

Figure 3. Nature of chemical-related injuries and illnesses, 1999-2006 (n=2,705).

Job Classifications

The number of cases varied by job or profession. The five job classifications with the highest number of injuries and illnesses were:

1. Cleaning plant operator/media operator/boney preparation plant operator/crusher worker (18%),
2. Mechanic/repairman (16%),
3. Laborer/utility man/pumper (12%),
4. Laborer/muck machine operator/pipe gin (6%), and
5. Electrician (3%).

This constitutes about 1,490 cases (55%). Those jobs (276 different job types) with fewer than fifty cases were grouped together and accounted for the remaining 45% of the cases.

For the job classification with the highest number of cases (cleaning plant operator/media operator/boney preparation plant operator/crusher workers), the activities being performed when the injuries or illnesses occurred were:

1. Handling supplies or material, load or unload (24%),
2. Maintaining and repairing machines (21%),
3. Working around mill equipment (11%), and
4. Working with chemicals (9%).

Eighty-two percent of these cases resulted in a chemical burn with acids and alkalis as the most common source of injury followed by chemicals/chemical compounds. These injuries typically occurred in mines where the primary commodities mined were lime/limestone (25%), cement (23%), and alumina (19%). Other significant job-related data included:

1. Approximately 40% of cases among mechanic repairmen occurred during machine maintenance.
2. Common activities among the laborer/utility man/pumper included handling supplies or materials (24%), machine maintenance and repair (20%), and working with chemicals (8%).
3. The most frequent source of injury for electricians was pulverized minerals (47%) followed by acids/alkalis (30%).

DISCUSSION

Based on results from this review, 2,705 miners suffered either an injury or illness caused by chemical exposure during the period 1999-2006. While the MSHA illness and injury database is not the only source of information regarding chemical-related miner injuries and illnesses, it is a unique and valuable tool for analyzing the types of cases. Analysis of the case narratives along with the quantitative data presented led to the following summations regarding incidence rates, the sources and nature of illnesses, and injuries and job types as they relate to exposure to chemicals.

Injury rates and severity

About 2% of all injuries and illnesses reported to MSHA from 1999-2006 were chemical-related. While this percentage is small, it translates to an average of 338 cases yearly. The overall incidence

Copyright © 2009 by SME

rates for chemical-related injuries and illnesses declined about 36% from 2003-2006 (0.12 in 2003 to 0.09 in 2006). The implementation of the HazCom rule in 2003 may have contributed to the decline.

About 23% of the injury cases resulted in NFDL, about 33% resulted in NDL, and the remaining 44% resulted in restricted activity. It was not possible to determine the illness NFDL or NDL, because no information was entered in the MSHA "INJTYPE" (injury type) variable. The significance of injuries to the mining industry translates into lost resources, including workers (injuries and lost work days), and economic loss. For example, Camm and Girard-Dwyer (2005) estimated the cost of one nonfatal injury at a sand and gravel mine to be $46,400 in 1990; when accounting for inflation in 2008 dollars, the cost is $77,650.

Source and nature of illness and injury

The 2,705 cases of illnesses and injuries were associated with 66 different chemicals. However, about 67% of all the identified cases were a result of pulverized minerals (specifically coal dust) and acids/alkalis (specifically lime and cement).

Coal dust is the single leading cause of illness among miners and is responsible for CWP, which results from inhalation of coal dust and continues to be a significant problem in the mining sector. Because CWP has a latency period of 20-to-30 years, it is difficult to determine if or when the number of cases will begin to significantly decrease. In addition, a resurgence of CWP in certain geographical areas may present a new health and safety research challenge (Dos and others, 2005). Coal dust is the leading chemical contributing to chemical-related illnesses and researchers need to continue to develop new methods (e.g. NIOSH Personal Dust Monitor) to protect coal workers from inhalation of coal dust (Volkwein and others, 2004).

Acids and alkalis (specifically lime and cement), were the source of about 38% of the total cases. Combined, injuries and illnesses from exposures to lime and cement totaled more than coal dust. MSHA narrative data verify that most lime and cement cases are from direct exposure to the skin, resulting in chemical burns. For example, selected narratives mention that workers wait until the end of their shift to remove clothing and footwear after significant exposure to lime. This allows the lime to be in contact with the skin for longer periods of time and often results in severe chemical burns. Wearing the proper PPE, including protective eyewear, gloves, and hats is essential to prevent burns from lime contact. Immediately removing the contaminated clothing decreases the likelihood of a chemical burn occurring.

The most common body part affected were the eyes. Nearly 37% (988) of the cases resulted in injuries to the eyes. As liquid chemicals are transferred from container to container or used for certain applications, splashing can occur. Based on MSHA narratives from 1999-2006, nearly 125 "chemical-to-the-eye" injuries could have been prevented every year if workers routinely used protective eyewear. It is not known why workers fail to wear protective eyewear.

Job Classifications

The job with the highest number of injury and illness cases was cleaning plant operator/media operator/boney preparation plant operator/crusher worker. This particular job is actually a compilation of several jobs. Cleaning plant operators are responsible for maintenance of plants, media operators are responsible for handling reagents (light oils), boney preparation plant operators oversee removal of "bone" from coal, and crusher workers use large crushers to break mined material. Many of the identified cases involved both inhalation and direct contact during handling of chemicals. Some of the cases result in CWP from workers inhaling coal dust generated during handling and/or crushing operations, illuminating the need for proper PPE when working with coal dust.

Jobs that involve handling lime/cement also present high risk for workers. It is apparent from the case narratives that there are many job types that have potential for exposure to these materials. It is important to address the resulting burn cases through mitigation of the sources of exposure rather than looking at the problem from a job classification perspective.

Because the MSHA database lists a total of 281 different job classifications, there are many jobs for which relatively few illnesses and injuries are associated. This makes it difficult to explain worker risk from job description alone and highlights the importance of examining the sources and nature of injuries more closely, as they often are more indicative of risk than job type alone. Another drawback of looking at only the job classification is that injured workers may not have been engaged in work that falls within their job description. For example, a roof bolter may have suffered a chemical-related injury or illness while performing an activity other than roof bolting. Therefore, the job classification may not be a reliable factor for determining a chemical-related case.

In summary, from 1999-2006, 2,705 miners suffered either an injury or illness from exposure to chemicals. The information assembled for this review indicated that the incidence rates for chemical-related illness and injury steadily declined, but the annual number of cases is still nearly 300. Coal workers pneumoconiosis was the single most common illness listed, while chemical burns were the most common type of injury. The burn cases are mainly associated with materials containing lime and cement and the most common injury was to the eyes.

Based on this review, the mining industry should focus on prevention of chemical-related injuries and illnesses resulting from exposure to acids/alkalis including wet cement or grout, shotcrete, lime, trona, and rock dust. Chemical burns accounted for many injuries and illnesses; therefore, safety management personnel in mining companies need to carefully examine their PPE requirements, training methods, and safety culture to insure that their workers are protected. In order to decrease the number of burn injuries, a thorough investigation is needed to determine what factors (e.g. lack of safety training, lack of proper safety equipment, or repetitious tasks which can lead to shortcuts) are responsible for these cases.

ACKNOWLEDGEMENTS

Thanks to Laura Martini at NIOSH's Spokane Research Laboratory, who provided expertise in extracting and formatting the MSHA data.

REFERENCES

1. Camm, T. and Girard-Dwyer, J., 2005. Economic Consequences of Mining Injuries. *Mining Engineering.* Vol. 57, no. 9, pp. 89-92.

2. Donoghue, A.M., 2004. Occupational Health Hazards in Mining: an Overview. Occupational Medicine. Vol. 54, pp. 283-289.

3. Dos, V.C., Antao, S., Petsonk, E.L., Sokolow, L.Z., Wolfe, A.L., Pinheiro, G.A., Hale, J.M., and Attfield, M.D., 2005. Rapidly Progressive Coal Workers' Pneumoconiosis in the United States: Geographic Clustering and other Factors. Occupational and Environmental Medicine. Vol. 62, pp. 670-674.

4. IDSP, 1994. Industrial Disease Standards Panel (1994) Report to the Workers' Compensation Board on Lung Cancer in the Hardrock Mining Industry. IDSP Report No. 12, Toronto, Ontario, pp. 24. Accessed November, 2008. http://www.canoshweb.org/odp/html/rpt12.htm

5. MSHA, 2002. U.S. Department of Labor. MSHA Accident, Illness and Injury and Employment Data (Part 50) for 1983-2000, unpublished MSHA powerpoint presentation "Needing HazCom….", revised 06/30/02.

6. NIOSH, 2000. Injuries, Illnesses, and Hazardous Exposures in the Mining Industry, 1986-1995: A Surveillance Report. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH). Publication No. 2000-117, 141 pp.

7. Patnaik P., 1999. A Comprehensive Guide to the Hazardous Properties of Chemical Substances. John Wiley & Sons, Inc., 2nd ed., 1999, part IV, pp. 17-25.

Copyright © 2009 by SME

8. U.S. Department of Labor, 2007a. MSHA Employment and Accident/Injury/Illness data base. Accessed November, 2007. http://www.msha.gov/drs/drshome.htm

9. U.S. Department of Labor, 2007b. Mine Accident, Injury, and Illness Report MSHA Form 7000-1 Definitions. Accessed November, 2007. http://www.msha.gov/forms/70001def.HTM

10. U.S. Department of Labor, 1999-2006. Mine Injury and Worktime, Quarterly Closeout Editions. U.S. Department of Labor, Mine Safety and Health Administration, Program Evaluation and Information Resources, Information Technology Center, Closeout Editions 1999-2006.

11. Weeks, J.L., Wagner G.R., Rest, K.M., Levy, B.S., 1991. A Public Health Approach to Preventing Occupational Diseases and Injuries, *in* Preventing Occupational Disease and Injury. American Public Health Association, Washington, DC, pp. 11-63.

12. Volkwein, J.C., Vinson, R.P., McWilliams, L.J., Tuchman, D.P., and Mischler, S.E., 2004. Performance of a new Personal Respirable Dust Monitor for Mine Use. NIOSH Report of Investigation 9663, 24 pp.

Copyright © 2009 by SME