Cal/OSHA, DOT HAZMAT, EEOC, EPA, HIPAA, IATA, IMDG, TDG, MSHA, OSHA, Australia WHS, and Canada OHS Regulations and Safety Online Training

SELECTED HEALTH ISSUES IN MINING

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ABSTRACT

Data on health-related illnesses and disease in the mining industry are scarce, and information on rates and costs is not readily available. Substantial amounts of research are being directed to addressing these issues, including work at the National Institute for Occupational Safety and Health's (NIOSH) mining health and safety laboratories in Spokane and Pittsburgh. This paper briefly discusses the current status of some miner health-related issues, including those involving coal dust, silica dust, diesel particulate matter, asbestos, noise, lead, welding fumes, and skin disorders, as well as research and other activities aimed at protecting miners from occupational illnesses and disease.

INTRODUCTION

Miners are exposed to various potentially toxic or harmful materials or agents, including, but not limited to, fuels, reagents, solvents, detergents, chemicals, coal dust, silica dust, diesel particulate matter (DPM), asbestos, noise, welding fumes, poisonous plants, trona dust, and metal dust.

According to the Centers for Disease Control and Prevention (CDC) (2000) "There are many limitations on the accuracy of illness reporting." Defining what constitutes health or illness and what is an injury is sometimes confusing and often depends on what agency is reporting the data. Table 1 summarizes different ways CDC, NIOSH, and the Mine Safety and Health Administration (MSHA) classify diseases and illnesses in their databases.

Clearly, comparing data from each agency is a challenge. For the purposes of this paper, mining health issues are defined as "any disease or illness employees contract while employed as miners and which could be caused by mining activities." Health issues discussed include coal-workers' pneumoconiosis (CWP), silicosis, lung disorders caused by DPM, asbestosis, hearing loss or impairment, physical disorders resulting from exposure to lead and welding fumes, and dermatitis/skin disorders. MSHA health and illness data from 1983-2001 are used to frame the level of diseases and disorders.

KEY ISSUE CONCERNING DISEASES

If a frog is dropped into a pot of boiling water, it will begin to struggle and show stress immediately (acute injury). However, if the frog is put in a pot of cold water on a burner at low temperature, the water slowly comes to a boil, but because the boiling is slow, the frog won't notice until it is near death (chronic injury). This example can be used as an analogy when investigating traumatic injuries and disease and illness development in miners. Traumatic injuries are quickly recognized (except cumulative trauma-type injuries) and their causes are generally readily identifiable. However, the process of contracting an occupational disease or illness can be slow (i.e., months or years), and miners may be exposed to a toxic or harmful agent for decades and not exhibit any effects of exposure. Furthermore, historically, many miners may not have been adequately instructed about the dangers of specific exposures and to the necessary safety precautions required to maintain their health.

One of the biggest problems in illness and disease in mining is reporting. Figure 1 (after Metz 2002) depicts the relationship between reported and unreported disease and illness as an iceberg and illustrates the magnitude of the problem.

1. Illness or disease is recognized as related to work.
2. Medical attention is received, but no relationship to work is recognized.
3. Symptoms are recognized, but no medical treatment is sought.
4. Miner is affected, but no symptoms are recognized.

In the first case of underreporting, an illness is recognized as being related to work. A miner is aware of the disease or illness, but may be afraid of reporting the disease because of fear of losing his or her job, health insurance, or other job-related benefits. Therefore, the disease or illness is not reported. In the second case, medical attention is received, but neither the attending physician nor the miner associates the disease with the work environment. Again, the disease or illness is not reported. In the third case, the miner has symptoms of a disease, but no medical attention is sought, and the disease or illness is not reported. This

Table 1.—Various illness and disease classifications by agency

	NIOSH	CDC	MSHA
Lung disorders			
Occupational lung diseases	X		
Chronic obstructive pulmonary disease		X	
Dust diseases of the lungs			X
Coal-workers pneumoconiosis		X	
Asbestosis		X	
Silicosis		X	
Byssinosis		X	
Asthma		X	
Respiratory conditions caused by toxic agents		X	X
Repetitive motion			
Carpal tunnel syndrome		X	
Tendonitis		X	
Disorders associated with repeated trauma			X
Other			
Neurotoxic disorders	X		
Noise-induced hearing loss	X	X	
Dermatologic conditions	X	X	X
Psychological disorders	X	X	
Severe occupational traumatic injuries	X		
Reproduction disorders	X		
Poisoning		X	X
Disorders caused by physical agents other than toxic agents			X
Malignant pleural neoplasm		X	
Occupational cardiovascular diseases	X		
Lead toxicity		X	
Pesticide and insecticide toxicity		X	
Hepatitis B		X	
Hepatitis C		X	
AIDS		X	

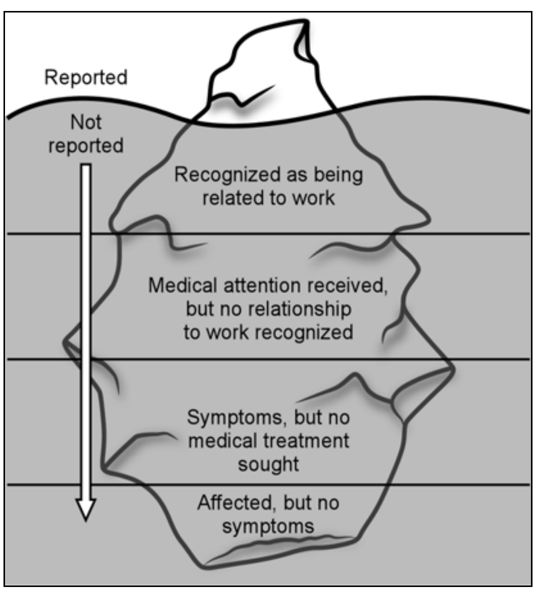

Figure 1.—Disease and illness in the mining industry (after Metz 2002).

again could be because of fear of losing a job, health insurance, etc. Finally, a miner could be affected with a disease, but has no symptoms of the disease. In Metz's opinion, this type of underreporting is one of the most serious in dealing with health issues (disease and illness) in the mining industry. In short, it is probable that even with health and illness data currently collected, the number of miners who actually have a disease or illness caused by mining are underreported.

Exposure Routes

For a toxic substance (gas, liquid, solid, or vapor) to produce a harmful effect on a miner, the miner must be exposed to the harmful material. Entry routes into a miner's body include inhalation; absorption through the skin, eyes, or mucous membranes; ingestion; or ears.

Terminology

An annual mortality rate is defined as the number of deaths from a disease per year divided by the number of people in the target population (Gordis, 1996). For example, in the case of coal miners, the annual occupational mortality rate for CWP is the number of coal miner deaths from CWP per year divided by the number of coal miners employed in that year and usually multiplied by 1,000. Incidence rates are defined as the number of new cases of a disease in a population during a specified period of time divided by the number of people at risk of developing the disease during that same period times 1,000 (Gordis, 1996). Prevalence is defined as the number of cases of disease present in the population divided by the number of people in the population during the same time (Gordis, 1996).

Types of health effects and exposures can be classified as either chronic or acute. An acute or accelerated health effect is one developed over a brief period of time and is generally severe in nature; that is, a short exposure of high intensity (Last, 1988). A chronic health effect develops over a long period and is generally of low intensity (Last, 1988). The U.S. National Center for Health Statistics defines “chronic” as a condition lasting 3 months or more (Last, 1988).

The number of persons employed in the mining industry is shown in figure 2, and the number of hours worked in the mining industry is given in figure 3. Since 1984, there has been an overall decline in the number of people employed and hours worked in the mining industry, even though a couple of sectors have realized some growth.

As indicated in figure 4 (CDC Worker Health Chartbook, 2000), in 1997, mining had a nonfatal occupational illness incidence rate of 18.8 per 10,000 full-time workers, which is about the same as for construction workers. Although this rate seems low compared to the rates in manufacturing or agriculture, the mining incidence rate of nonfatal occupational illness and disease could be improved by identifying why and under what specific conditions illnesses occur (i.e., what are the primary causes of illness or disease in the mining industry?).

The frequency of disease or illness from 1983-2001 (figure 5) shows a roller-coaster effect for illness and disease rates in the mining industry.

Although the years 1997 through 2001 show a decrease in the rate of disease and illness in the mining industry, this rate has not returned to the lower levels recorded in 1983-1984. This is true partly because of changes in reporting requirements, but also because of more faithful reporting of illness and diseases once ignored by miners. Many mining companies have emphasized the latter in recent years.

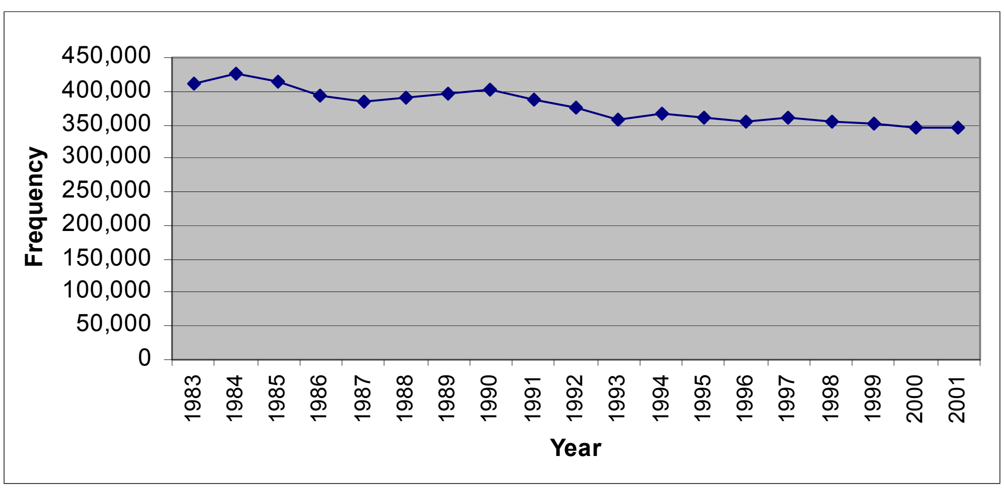

Figure 2.—Number of persons employed in the mining industry 1983-2001 (MSHA data).

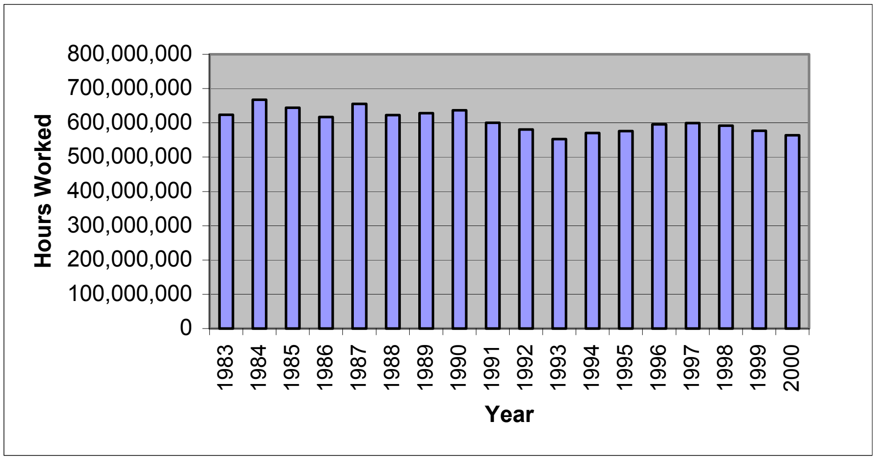

Figure 3.—Employment hours 1983-2001 (MSHA data)

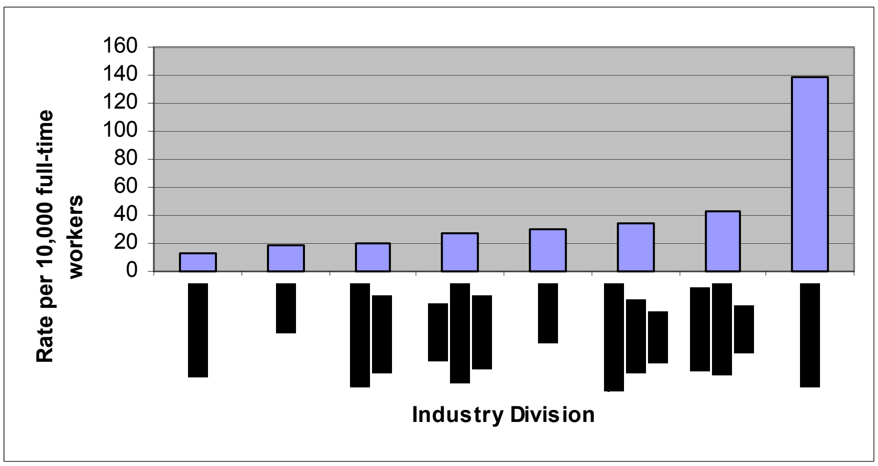

Figure 4.—Incidence rates of nonfatal occupational illness

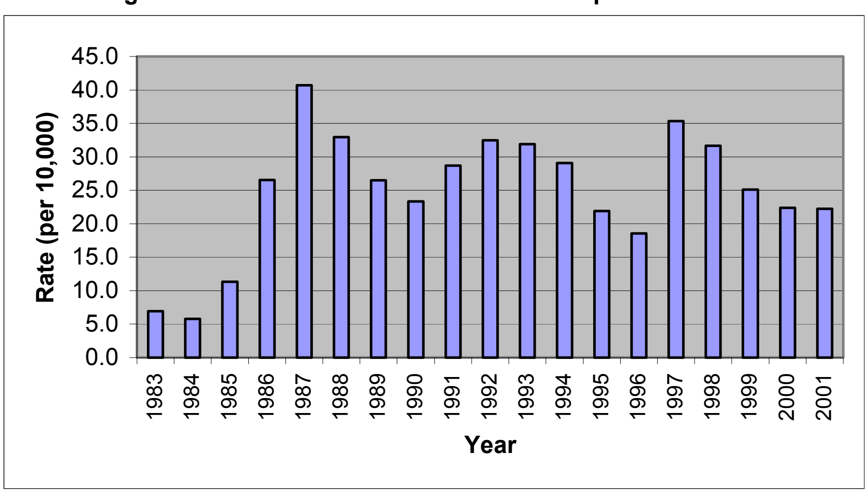

Figure 5.—Rate of disease/illness 1983-2001 (MSHA data)

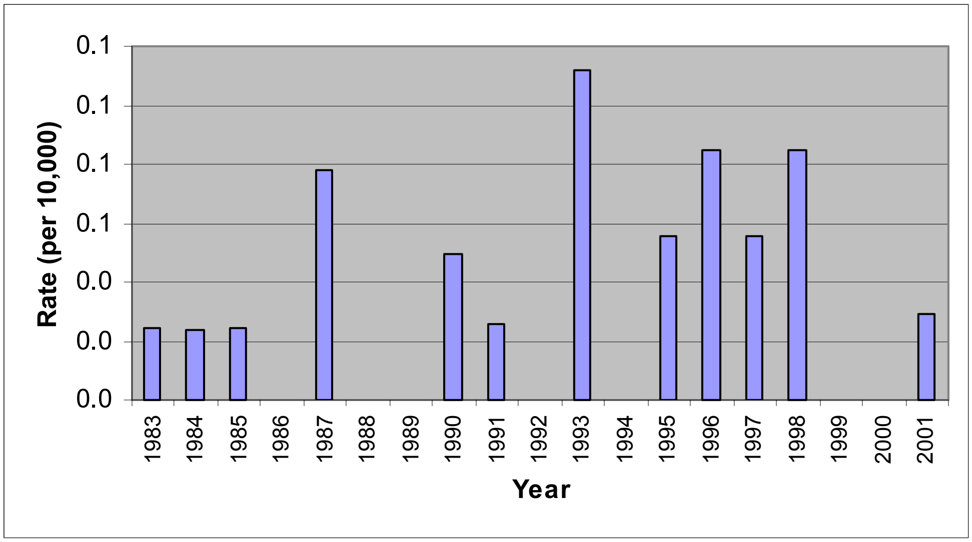

Figure 6.—Rate of contagious or infectious diseases 1983-2001 (MSHA data)

Figure 6 shows the rate of contagious or infectious diseases in the mining industry, which is very low. The category includes such diseases as asthma and chronic obstructive pulmonary disease, lead poisoning, chemical poisoning, physical effects of pesticide and insecticide toxicity, hepatitis B, hepatitis C, AIDS, and tuberculosis.

Coal Dust

The Federal Coal Mine Health and Safety Act of 1969 defines CWP as a "chronic dust disease of the lung arising out of employment in an underground coal mine." Progressive massive fibrosis (PMF) is a complicated form of CWP and is generally associated with breathlessness, chronic bronchitis, recurrent chest illness, and even heart failure. Other complications can be increased risk of tuberculosis and mycobacterial infections. PMF is a distinct disease and is associated with increased mortality. According to Kissell and Colinet (2001), a study in the 1990's showed an average of 2.8% prevalence of CWP; however, miners with more than 30 years of exposure to coal dust had a prevalence of 14%. Kissell and Colinet further attributed 18,245 deaths between 1987 and 1996 to CWP as a direct or contributing cause of death, with 70% of the death certificates listing "mining machine operator" as the occupation.

The permissible exposure limit (PEL) (unadjusted for quartz content above 5%) for coal dust is 2 mg/m^3 for underground coal extraction using an 8-hour time-weighted average (TWA). According to Kissell and Colinet (2001), 7.4% of all coal mine air samples collected from 1987 through 1996 exceeded this PEL. Figure 7 shows the rate of CWP for the years 1983-2001. An acknowledged 20-to-30-year latency period for CWP does not permit recent exposures to be considered as disease. Nonetheless, a definite improvement in the CWP rate has been recorded, especially since 1997.

Silica Dust

Kissell and Colinet (2001) stated that chronic silicosis involves at least 15 years of exposure to silica, and that from 1987 to 1996, about 421 miners and construction workers died from silicosis. Again, mining machine operators accounted for 14.7% of the deaths. A nuisance dust standard of 10 mg/m^3 triggers regulation by MSHA, and from 1987 to 1996, 15.6% of the dust samples collected from metal mines exceeded the PEL. Figure 8 shows the rate of silicosis in the mining industry. The rate of silicosis in mining

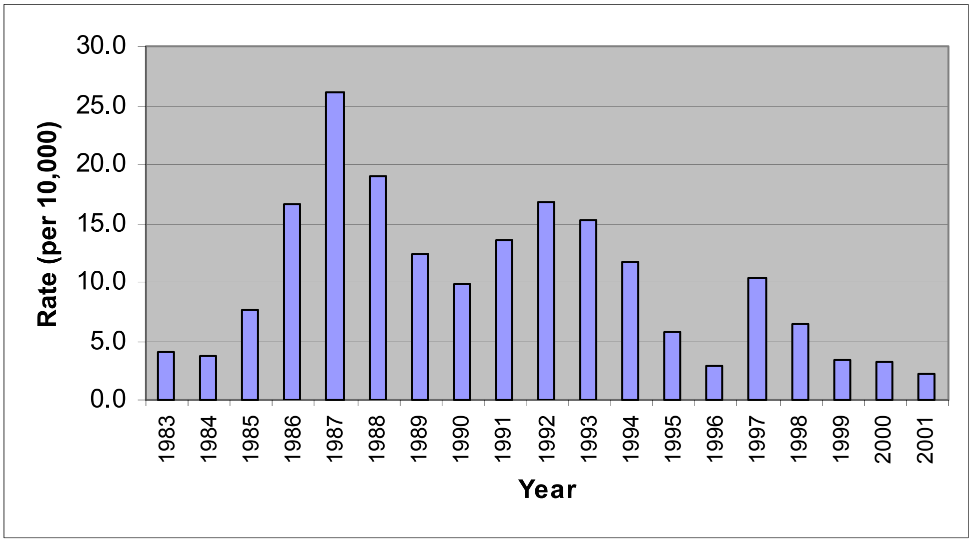

Figure 7.—Rate of CWP 1983-2001 (MSHA data)

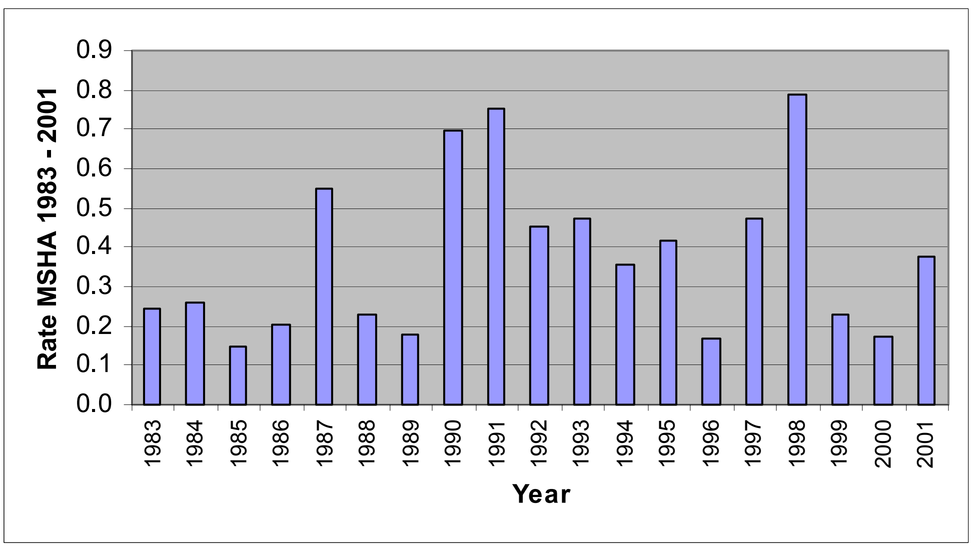

Figure 8.—Rate of silicosis 1983-2001 (MSHA data)

is generally <0.8 cases per 10,000 employees and is not considered to be a major threat to the mining community today.

Diesel Particulate Matter

MSHA's new Standard on Diesel Particulate Matter Exposure of Underground Metal and Nonmetal Miners went into effect July 20, 2002. An MSHA DPM exposure level of 400 µg of total carbon per cubic meter of air (equivalent to 500 µg of DPM per cubic meter) was set, and compliance will be mandatory by July 19, 2003. Noncompliance after that date will result in MSHA citations. Metz (2001) noted that in 1998, the American Conference of Governmental Industrial Hygienists (ACGIH) proposed a TLV-TWA of only 50 $\mu g/m^3$ for diesel particulates <1 µm in size. The ACGIH also classified diesel exhaust as a suspected human carcinogen, and the International Agency for

Cancer Research (IARC) lists DPM as a probable carcinogen. Of interest, again noted by Metz (2001), was the fact that the ACGIH TLV-TWA would require occupational air to be cleaner than ambient air. Importantly, Schnakenburg (2002) estimated the technically feasible level of DPM control today at 90 $\mu g/m^3$.

Metz (2001) provided a detailed summary of the sources of DPM, how particulates affect the body, and a list of particulate fractions and their toxicity. He further categorized the clinical manifestations of exposure to diesel particulates as either nonneoplastic (acute or chronic) or neoplastic (cancer). While lung cancer can be caused in rats exposed to diesel exhaust, the long-term health effects on miners is not known.

Asbestos

Figure 9 shows a nearly negligible health effect of miners' exposures to asbestos.

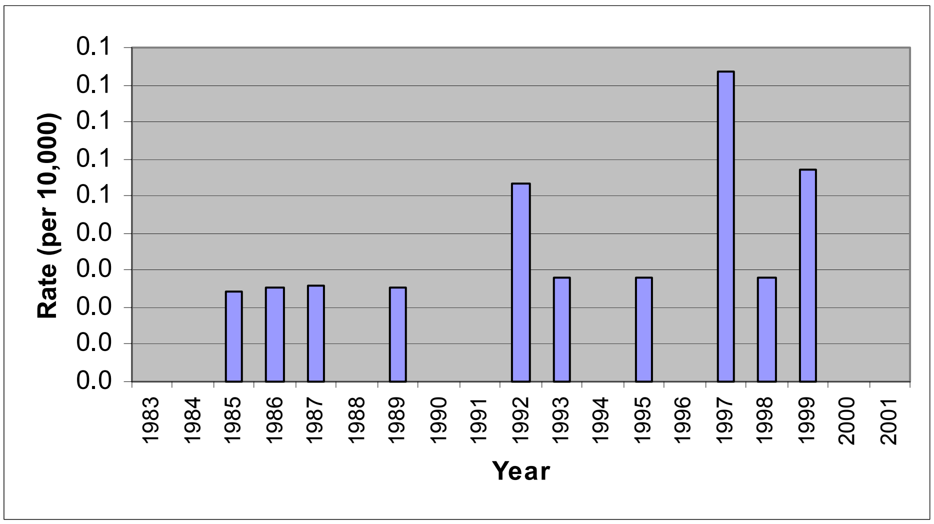

Figure 9.—Rate of asbestosis 1983-2001 (MSHA data)

Noise

Noise-induced hearing loss (NIHL) begins gradually and progressively gets worse. Problems with this disease include loss of the ability to communicate and reduced response to environmental and occupational noise and danger. In the mining environment, the effects of NIHL can be deadly in specific work situations. Bise (2001) listed several factors that influence occupational hearing loss. These factors include the following.

1. Age of employee.
2. Pre-employment hearing impairment.
3. Diseases of the ear.
4. Sound pressure level of the noise.
5. Length of daily exposure.
6. Duration of employment.
7. Ambient conditions of the workplace.
8. Employee lifestyle outside the workplace.

MSHA began enforcing its "noise rule" in the year 2000. It did so in response to its estimate that 13% of U.S. miners (~37,000) would suffer significant loss of hearing (25 dBA or higher) at previously prevailing conditions over a working lifetime. Eight hours of exposure to 90 dBA is the current MSHA-permissible noise level, with no exposure to exceed 115 dBA. Bise (2001) concluded that, although some controversy exists on whether the 8-hour exposure should be 90 or 85 dBA, "current steps taken by the mining industry should enable future generations of mine workers to lead productive and safe lives without fear of suffering from occupationally based NIHL." Figure 10 shows three spikes in the rate of hearing loss from 1983 to 2001. The rate from 1999 to the present seems to have leveled; therefore, to encourage further reductions in hearing loss, more research in this area appears to be warranted.

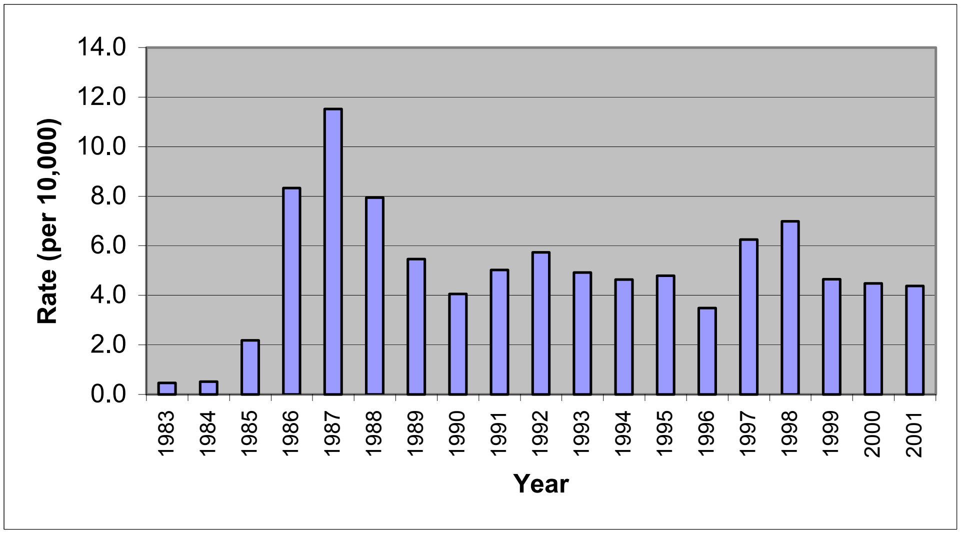

Figure 10.—Rate of hearing loss 1983-2001 (MSHA data)

Lead

The MSHA occupational PEL for lead is 0.01 mg/m^3. Lead miners are normally exposed to lead sulfide. Lead sulfide is poorly absorbed when inhaled (Pon and Gilbert-Jones, 2001) and only slightly soluble in gastric juice, therefore posing a relatively insignificant problem to miners. However, lead oxide and lead sulfate are more soluble and do pose problems. The good news is that most lead mined is in the form of galena (lead sulfide); therefore, lead poisoning is normally not a threat to miners. However, mill and smelter workers are exposed to lead oxide, which does pose a health threat.

Welding Fumes

NIOSH (1988) lists four gases (acetylene, carbon monoxide, oxides of nitrogen, and phosgene) and 18 metals (arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, silver, tin, titanium, tungsten, vanadium, and zinc) as hazardous agents associated with the welding process. Furthermore, it lists asbestos, fluorides, and silica as other minerals that create hazards during welding. Finally, it views electricity, hot environments, noise, vibration, ionizing radiation, ultraviolet light, and visible light as physical agents that could be harmful to welders. All of the above-listed agents can cause short- and long-term toxic or harmful effects (including cancer), as well as death.

Skin Disorders

Figure 11 shows the rate of skin disorders in the mining industry, and figure 12 shows the causes. While the rate is not exceptionally high, a review of MSHA records shows that many of these illnesses can be prevented. With poison oak/poison ivy and dust being the major contributors to skin disorders from 1983 to 2001, more than 350 illnesses associated with these two causes may have been preventable if proper personal protective (PPE) had been used.

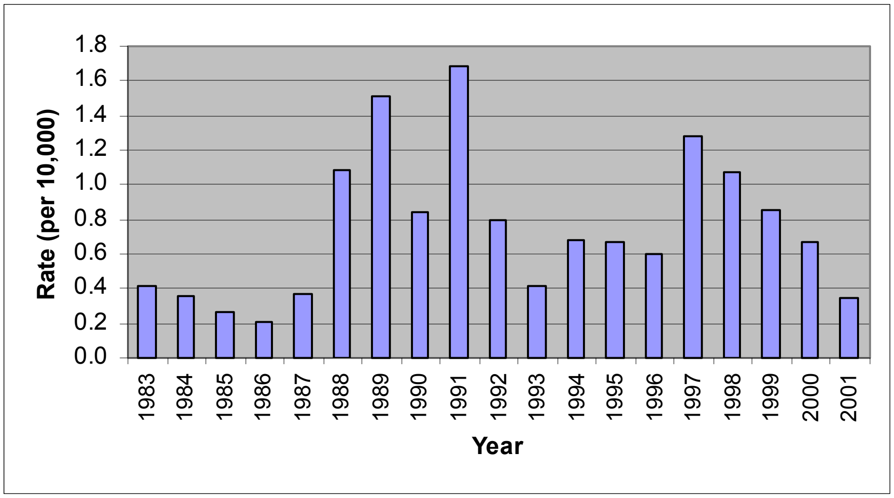

Figure 11.—Rate of skin disorders 1983-2001 (MSHA data)

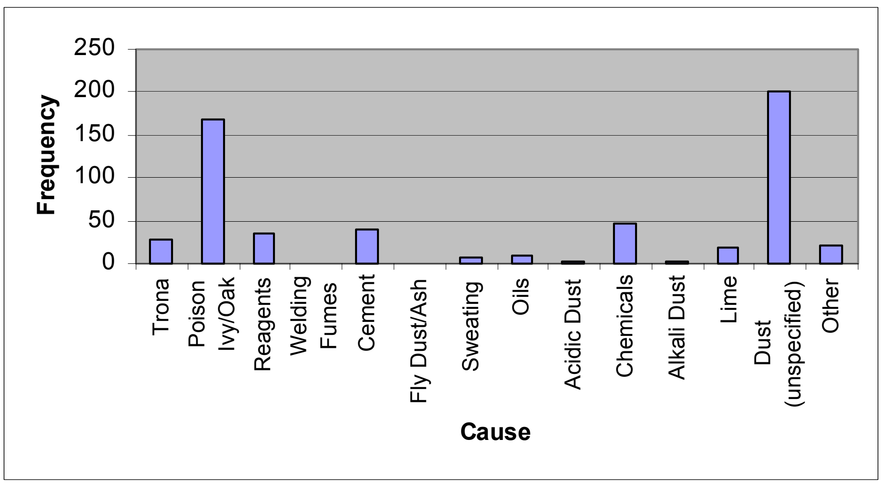

Figure 12.—Causes of skin disorders 1983-2001 (MSHA data)

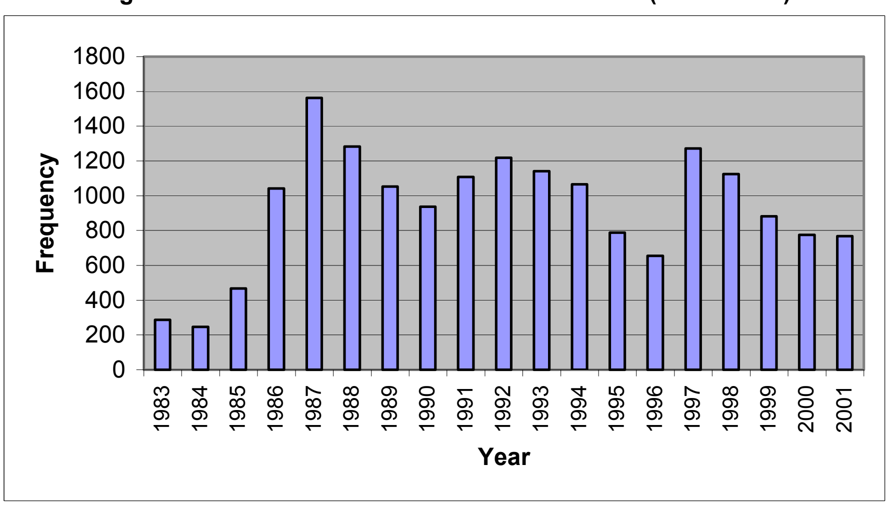

Figure 13.—Lost work days 1983-2001 (MSHA data)

LOST WORK DAYS

The number of days lost to disease and illness from 1983 through 2001 is shown in figure 13. Although the mining workforce has declined during these years, reported cases of disease and illness from 1985 through 2001 are above the levels reported in 1983 and 1984. An average of 930 days per year have been lost because of a miner's disease or illness, and this has had a significant impact on production.

REGULATIONS

As mentioned earlier, new regulations were implemented recently regarding noise and DPM exposures. The new hazardous chemical rule in MSHA's 30 CFR Part 47 (the "HazCom Rule") went into effect September 23, 2002, at mines with more than five employees and will go into effect March 21, 2003, at mines with fewer than five employees. The intent of this standard is to protect miners from chemical hazards that could cause occupational lung diseases, occupational cancers other than lung cancer, occupational cardiovascular diseases, reproductive disorders, and/or neurotoxic disorders. The new rule requires mine operators to do the following:

1. Inventory the chemicals at a mine or mill and determine which are hazardous.
2. Keep a list of hazardous chemicals.
3. Establish a written HazCom program.
4. Prepare a label and Material Safety Data Sheet (MSDS) for its product(s).
5. Make sure that containers of hazardous chemicals are labeled.
6. Keep a file or book of MSDS's for hazardous chemicals at the mine.
7. Train miners about the HazCom program and the hazardous chemicals to which they could be exposed.
8. Allow miners to look at HazCom information or give them a copy if requested.

MSHA inspectors will issue citations to mines and mills that do not comply with the new standard.

DISCUSSION

Grayson and Watzman (2001) recognized the six following emerging realities in the mining industry.

1. Conditions will degrade rather than improve.
2. In the future, mining will be deeper, and thinner seams and veins having a lower-grade ore will be extracted.
3. Reserves will be discontinuous.
4. A significant number of new miners will join the workforce.
5. The mining industry will face tougher competition.
6. Fewer companies will exist due to mergers.

Therefore, based on these factors, more health-related issues and problems can be expected.

Grayson and Watzman (2001) also recommended that further improvements in mining will require the industry to do the following:

1. Seek new or modified mining methods and new technologies,
2. Organize and manage work more effectively,
3. Demand more health and safety features on mining equipment,
4. Ensure that best work practices are integral to accomplishing work,
5. Seek breakthroughs in handling some of the most persistent problems,
6. Incorporate health, safety, and environmental aspects into every facet of planning, and
7. Set goals and objectives systematically to drive continuous improvements across the board.

No. 6 (incorporate health, safety, and environmental aspects into every facet of planning) will be one of the greatest challenges facing the mining industry in the future, but it will likely pay huge dividends in reducing injury and disease rates as well as mining costs.

Bailey (2001) supported an "Industrial Hygiene Process" to answer questions about worker exposures to health problems. He listed the following questions, which are applicable to the identification of health issues in mining.

1. What hazards *might be* present?
2. What potential hazards *are* present?
3. What are the priorities for assessment?
4. What levels of exposure and illness are present?
5. How bad is it?
6. Is it fixed; are the employees well?

The mining community could benefit substantially by applying Bailey's Industrial Hygiene Process in every facet of mine planning and development to help reduce miner's illnesses and diseases.

- In the area of hearing loss, the effects of sudden noise (impulse noise) are not well understood. Levels considered hazardous have not been identified or studied sufficiently.
- The overall lack of health and illness data collected by a central responsible agency is paramount. This gap is considered one of the greatest in identifying illness and disease in the mining community.
- Historically, the mining industry has tended to lump methods to address health and safety issues. Health issues deal specifically with illness and disease; safety issues include accidents, injuries, and fatalities. Effective methods for studying these two diverse topics are different. As noted, mining health issues can be acute or chronic and need classic epidemiological and public health knowledge, including knowledge about personal protective equipment and control technologies, to address them effectively. Safety issues generally do not address chronic problems and do not require the sophisticated techniques associated with cohort studies and analyses, establishing baselines on the workforce, and site-specific, long-term exposure patterns.
- The mining industry, academia, government research agencies, and the medical community still have significant progress to make in miners' health. There is a need for serious studies involving mining health issues, and these can best be addressed through strong research partnerships.
- Miners need better illness and disease recognition skills in general, which will reduce illnesses and diseases more dramatically. To this end, appendices A-G summarize current and past research at NIOSH's Spokane, WA, and Pittsburgh, PA, mining research laboratories.
- Finally, underreporting is recognized as probably the greatest problem in assessing the magnitude of illness and disease in mining.

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APPENDIX A. SILICA DUST

1. Silica Dust Control in Metal/Nonmetal Surface Mining. Andrew Cecala and Greg Chekan. Pittsburgh Research Laboratory (FY01, FY00, FY99).
2. Control of Silica Dust Exposures in Underground Coal Mining. Gerritt Goodman. Pittsburgh Research Laboratory (FY01, FY00, FY99).
3. Development of Enhanced Spray Dust Capture Principles for Improved Silica Dust Suppression. John Organiscak. Pittsburgh Research Laboratory (FY01, FY00, FY99).
4. Dust Measurement and Control. Don Tuchman. Pittsburgh Research Laboratory (FY00)
5. Dust Control in Surface Coal Mining. Jeff Listak. Pittsburgh Research Laboratory (FY01, FY00, FY99)
6. Silica Dust Control for Underground Metal/ Nonmetal Mines. Greg Chekan and Roy Grau III. Pittsburgh Research Laboratory (FY00)
7. Control of Silica Dust in Underground Metal/Nonmetal Mines. Robert Timko. Pittsburgh Research Laboratory (FY99)
8. Mining Dust Control Applied to Other Industries. Ed Thimons. Pittsburgh Research Laboratory (FY99)
9. Controlling Respirable Silica Dust During Underround Mining. G. Goodman. Pittsburgh Research Laboratory (FY98, FY97)
10. Surface Mine Dust Control. Steven Page and John Organiscak. Pittsburgh Research Laboratory (FY97)

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3. Fundamental Scattering Properties of Respirable Dusts and Suspended Particulate Matter. C.D. Litton. Pittsburgh Research Laboratory (FY00)
4. Dust Control for Longwall Mining. Jay Colinet. Pittsburgh Research Laboratory (FY01, FY00)
5. Improved Dust Control Technology for Longwall Mining. Jay Colinet. Pittsburgh Research Laboratory (FY99, FY97)
6. Improved Application and Monitoring of Dust Control Parameters. Ellsworth Spencer. Pittsburgh Research Laboratory (FY99, FY97)
7. Fixed Site Dust Monitoring. Bruce Cantrell. Pittsburgh Research Laboratory (FY99)
8. Influence of Coal Seam Properties on Dust Generation. John Organiscak and Jeff Listak. Pittsburgh Research Laboratory (FY98, FY97)
9. Control of Respirable Dust in Noncoal Mines and Mills. Andrew Cecala and Robert Timko. Pittsburgh Research Laboratory (FY98, FY97)
10. Control of Silica Dust in Underground Metal/Nonmetal Mines. Andrew Cecala and Robert Timko. Pittsburgh Research Laboratory (FY98, FY97)
11. Improved Application and Monitoring of Dust Control Parameters. J. Colinet. Pittsburgh Research Laboratory (FY98)
12. Respirable Dust Measurement and Analysis (Instrumentation). Kenneth Williams. Pittsburgh Research Laboratory (FY98)
13. Personal Dust Dosimeter. Jon Volkwein and Steven Page. Pittsburgh Research Laboratory (FY97)
14. Instrumentation. Kenneth Williams. Pittsburgh Research Laboratory (FY97)

APPENDIX C. METALS EXPOSURE

1. Metals at Mining Sites. Pam Drake. Spokane Research Laboratory (FY01)
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3. Chemical Hazards at Active Metal/Nonmetal Mines. Pam Drake and Russell Levens. Spokane Research Laboratory (FY97)
4. Investigation of Silicate Dust Generation and Rare-Earth Element Behavior in Coals. Stephen Schatzel. Pittsburgh Research Laboratory (FY00, FY99)
5. Exposure to Toxic Substances in Dust at Nonmetal Mines. Patrick Hintz and Pam Drake. Spokane Research Laboratory (FY00, FY99)

APPENDIX D. HEARING/NOISE

1. Hearing Loss Prevention. David Byrne. Pittsburgh Research Laboratory (FY01, FY00, FY99)
2. Cross-Sectional Survey: Noise Exposure Pattern/ Sources. Eric R. Bauer. Pittsburgh Research Laboraory (FY01, FY00, FY99)
3. A Model Hearing Conservation Program for Coal Miners. David Byrne. Pittsburgh Research Laboratory (FY01, FY00, FY99)
4. Engineering Controls for Hearing Loss Prevention. Peter Kovalchik. Pittsburgh Research Laboratory (FY01, FY00)
5. Investigation of Impulse Noise in Mining. Alex Smith and Michael Sapko. Pittsburgh Research Laboratory (FY01)
6. Evaluating the Role of Positive and Negative Emotion in Promoting Hearing Conservation Behaviors Among Coal Miners. Charles Vaught. Pittsburgh Research Laboratory (FY01)
7. Communications and Technology Transfer for Hearing Conservation. Roy Bartholomae. Pittsburgh Research Laboratory (FY99)
8. Technical Assistance for Hearing Conservation. Jim Rider. Pittsburgh Research Laboratory (FY99, FY97)
9. Audiometric and Noise Survey in the Sand and Gravel Industry. Deborah Landen and Gail McConnell. Pittsburgh Research Laboratory (FY99)
10. Quiet-By-Design Engineering Noise Control. J. Burks. Pittsburgh Research Laboratory (FY98, FY97)
11. Hearing Conservation Communications/ Technology Transfer. J. Burks (FY98, FY97)

APPENDIX E. ERGONOMICS

1. Engineering Controls for Reducing Jolting and Jarring Injuries in Surface Mines. Fred Biggs and Rusty Miller. Spokane Research Laboratory (FY01, FY00)
2. Reducing Injury Risk from Jolting and Jarring on Mobile Equipment. Fred Biggs and Walter Utt. Spokane Research Laboratory (FY01)
3. Ergonomics Interventions in Mining. Jon Volkwein. Pittsburgh Research Laboratory (FY01, FY00, FY99)
4. Systems Approach To Reduce Manual Task Injuries. Sean Gallagher. Pittsburgh Research Laboratory (FY99)

APPENDIX F. DIESEL PARTICULATE

1. Dust Measurement and Control. Jon Volkwein. Pittsburgh Research Laboratory (FY01)
2. Reducing Diesel Particulate Exposures in Western Mines. Art Miller. Spokane Research Laboratory (FY01, FY00, FY99)
3. Diesel Engine Emissions Measurement and Analysis. Bruce Cantrell. Pittsburgh Research Laboratory (FY01, FY00, FY99)
5. Diesel Partnership Research. George Schnakenberg. Pittsburgh Research Laboratory (FY01)5
6. Diesel Particulate Dosimeter. Jon Volkwein. Pittsburgh Research Laboratory (FY00)
6. Diesel Engine Emission Measurement and Analysis. Bruce Cantrell and Emery Chilton. Pittsburgh Research Laboratory (FY98)
7. Instrumentation: Diesel. Bruce Cantrell and Emery Chilton. Pittsburgh Research Laboratory (FY97)

APPENDIX G. MISCELLANEOUS

1. Toxic Fumes from Blasting. James Rowland. Pittsburgh Research Laboratory (FY01, FY00)
2. Engineering Controls for Reducing Surface Mining Health Hazards. Fred Biggs and Richard Miller. Spokane Research Laboratory (FY97)
3. Skeletal Modeling for Protective Mine Gear. Marc Filigenzi. Spokane Research Laboratory (FY97)