Major Issues in Miner Health

"My father started mining a coal seam in northwest Colorado in the 1920s," says Frank Self, safety and health manager at Trapper Mines in Craig, Colorado. "You could take a four-mule team into the mine. There was a big central room, with no pillars [for support]. There was no regulation for the small miners, and no concern about exposure to coal dust. You'd find the methane gas when your lamp ignited it. It was part of the mystique of coal mining."

Those were the bad old days, when thousands of miners died in explosions, roof collapses, fires, and floods each year. Miners worked virtually unprotected in the early days of mining, and were often treated as expendable bodies fulfilling critical roles. "My father once went into the mine and set a charge. It blew up and broke his jaw," says Self. "If you survived a methane explosion, it was a big deal."

Time, technology, and increasingly stringent laws have reduced, but not eliminated, the dangers of mining. Society needs mines and miners. Mined minerals are used extensively in virtually every modern product from air conditioners to zippers; for example, 40 separate minerals go into the manufacture of a telephone, according to the American Mining Association. Without mined products such as coal for fuel, iron, stone, and sand for construction, and copper for wiring, virtually all modern transportation, manufacture, and commerce would cease. Worldwide, only about 50 of the 2,500 known minerals are mined, but they account for 23 billion tons of material removed from the earth each year, mostly from surface mines, according to the International Labor Organization (ILO). The U.S. Geological Survey (USGS) estimates that in 1997, the U.S. mining industry produced $39.5 billion in raw nonfuel minerals, which are used chiefly in industry. Mining contributes about 5% of the U.S. gross domestic product, and a much higher percentage in other countries.

Miners represent approximately 1% of the global workforce, or about 30 million workers, a third of them coal miners (not counting artisanal miners, who work mines informally or illegally). Considering mining-related jobs and miners' families, the mining industry supports an estimated 300 million people. Worldwide, mining is one of the most dangerous occupations relative to other industries; with 15,000 fatal accidents annually, mine workers are subject to 8% of all work-related fatalities, the ILO reports. Miners also face numerous health risks, including dust-related lung diseases, hearing loss, and neuromuscular disorders; roof falls; explosions; and in the case of deep mines, heat stress. In China, for example, according to the ILO's 1994 publication *Recent Developments in the Coal Mining Industry*, 2.5 million miners are exposed to dust diseases, and 212,000 miners were diagnosed with some form of pneumoconiosis (a family of lung diseases caused by dust inhalation) between 1988 and 1993. In the near future, the average death toll from pneumoconiosis in China is expected to increase 10% per year over the current 2,500 annual deaths. Additionally, mining causes widespread environmental damage, including pollution of watercourses with acids and toxic metals, air pollution from diesel machinery emissions, destruction of ecosystems, and defacement of landscapes.

Increasingly stringent health, safety, and environmental regulations, together with rapid technological advances, have resulted in enormous improvements in mining-related human and environmental health in the United States and other industrialized nations. Often, though, technological solutions have reduced certain health risks only to raise new questions about environmental and social issues. Meanwhile, lax regulation in many developing countries still leaves millions of miners at risk. And society's gargantuan appetite for minerals has increased. Mining, at best a dusty and dangerous job that removes millions of tons of finite material from the ground each year, remains absolutely necessary to modern culture and society. Balancing the need for materials and the hazardous nature of mining is central to improving the environmental and human health effects of the industry.

Of Minerals and Men

"Ours is truly a mineral civilization, a civilization which stands and falls on its capacity to

produce staggering amounts of some minerals and varying quantities of many others," wrote Erich Zimmerman in his 1933 book *World Resources and Industries.* His words remain true today. Time and geology concentrated huge reserves of economically important minerals such as coal, iron, aluminum, copper, lead, and precious metals within U.S. territory. The first U.S. ironworks opened in 17th-century Massachusetts, the first commercial coal mine in Virginia in 1745. Gold and silver rushes began in the mid-1800s in California. By 1900, the United States was a wealthy and powerful nation, due in no small part to the labors of its miners.

Today, technological improvements have brought increased mechanization of mining, accompanied by increases in production and decreases in mining employment. In the United States, an estimated 360,000 miners and other employees such as painters, truck drivers, and maintenance workers work at over 11,000 underground and surface mines, according to the Mine Safety and Health Administration (MSHA). This is down from as many as 1 million employees in 1920. Meanwhile, production has increased, and the value of processed mineral materials has risen in 31 of the last 37 years, according to the USGS publication *Mineral Commodities Summaries 1998.* The USGS currently estimates the value of raw minerals production at nearly $39.5 billion, and materials processed with minerals at $413 billion.

Over time, intensive mining has exhausted many of the world's richest veins, seams, and quarries, including lodes of iron ore and copper in the United States. Mine operators generally must mine deeper and more extensively to extract sufficient yields. Many have shifted operations overseas as depletion, substitution of cheaper materials, high processing and transportation costs, changing legislation, and social factors have made domestic mines unprofitable. Fluctuations in supply and demand among related industries and natural deficiencies of certain minerals in particular regions have made mining a global commodity.

Health and Safety in U.S. Mines

The U.S. mining industry has undergone major changes in terms of human health and safety. At the turn of the century, some 3,000 miners perished annually from explosions, roof collapses, and suffocation by poisonous gases such as methane, while an unknown number died of progressive respiratory diseases such as black lung and silicosis. Attempts to regulate health and safety in the mining industry first began in 1910, with the establishment of the Bureau of Mines as part of the Department of the Interior. A series of laws and safety regulations improved, but did not eliminate, accidents and injuries: 1,695 fatalities and 78,709 injuries were reported in 1940; 807 fatalities and 50,660 injuries were reported in 1950. These laws mainly addressed safety issues, and endowed inspecting officials with little enforcement power. Questions of health effects related to exposure to toxic dusts, fumes, and noise were largely ignored.

Not until 1969, with the passage of the Federal Coal Mine Health and Safety Act, known as the Coal Act, did the Bureau of Mines acquire any real enforcement power. The Coal Act established health and safety standards for surface and above-ground coal mines, levied fines and criminal penalties for violations, provided free chest X rays for underground miners, and set up a compensation fund for miners disabled by black lung. (No such government-funded program exists for other types of miners or other dust-related diseases, other than state-funded worker's compensation programs.) Mining disasters continued to maim and kill, and miners still suffered a high rate of disabling injuries—21,925 in 1972. That same year, 105 miners died in three separate disasters, and 125 townspeople drowned when heavy rains washed mine sludge down a valley in Buffalo Creek, West Virginia.

The 1977 Federal Mine Safety and Health Act, known as the Mine Act, amended the Coal Act to strengthen enforcement provisions and protection of miners, and consolidate federal safety and health regulations for all mines—coal and noncoal—under a single statute. It also created a new agency within the Department of Labor—MSHA—to carry out its mandates. Today, MSHA enforces health and safety regulations, including mandatory safety standards, through regular sampling by both mine operators and MSHA inspectors to screen for unsafe dust levels. The agency also tracks incidence of illness and injury with research assistance from the National Institute for Occupational Safety and Health, a division of the Centers for Disease Control and Prevention.

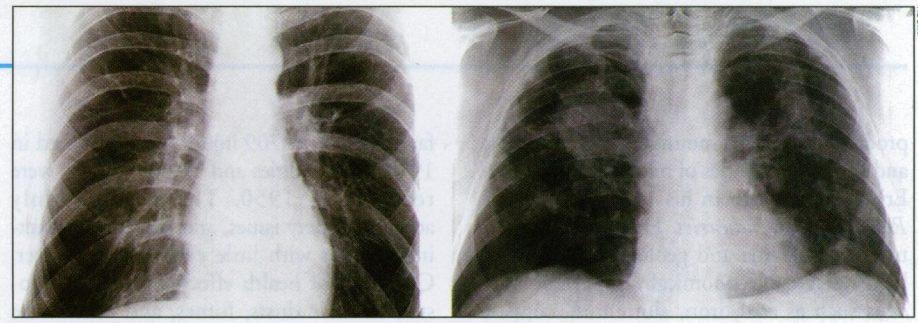
MSHA's establishment and enforcement of safety and health standards has helped make a difference. Mining fatalities dropped from 272 in 1977 to 91 in 1997. But the risks still exist. MSHA records show that over the past decade, an average of 100 fatal accidents have occurred in the U.S. mining industry annually. Such accidents are mostly related to machinery and haulage (hauling minerals out of mines with trucks and devices such as conveyor belts), and are concentrated in coal, stone, sand, gravel, gold, and silver mines. Contributing factors include inadequate training, improper maintenance or use of equipment, and failure to use securing devices such as seat belts and lanyards.

J. Davitt McAteer, the assistant secretary of labor for MSHA, cautions that any assessment of the dangers of mining must consider the nature of the industry. "You have to consider the uniqueness of mining and look at the underlying problems. A mine workplace changes every 24 hours," he says, referring not only to the revolving shifts of employees but also to such factors as weather, the geographic changes from the mining itself, and the condition of the mining equipment. Incremental changes in regulations, McAteer says, have accompanied the recognition of new safety and health risks. "Mining is safer today than it was 25 years ago," he says. "But it's still dangerous. It's dark [in underground mines], and if you add to that people and heavy machinery, you've got a situation that is risky by its nature."

Deadly Dust

Darkness and machinery are not the only hazards awaiting miners underground. Mining in both surface and underground mines involves drilling and shearing of large quantities of minerals. The clouds of dust raised in displacing these materials can severely damage the lungs, particularly after years of exposure. Thousands of miners suffer from various forms of pneumoconiosis, in which fine dust particles settle in the lungs, causing inflammation and the formation of fibrous scars between the alveoli, or air sacs. With continued exposure—typically 15–20 years—progressive scarring can stiffen the lungs, causing debilitating or fatal decreases in lung function. Coal mining and other mining sectors rank among the industries with the highest proportionate mortality rates (PMRs) from pneumoconiosis. Annual deaths among all industries from pneumoconiotic illnesses have declined gradually, from a high of over 5,000 in 1972 to 3,230 in 1992 according to NIOSH's 1996 *Work-Related Lung Disease (WoRLD) Surveillance Report.* Nevertheless, dust diseases continue to occur and to kill in mining.

The most notorious form of pneumoconiosis is coal worker's pneumoconiosis (CWP), also known as black lung. CWP, a progressive (with continued exposure) and incurable condition, is the cause of close to 60% of mortality from pneumoconiosis over the past 25 years. The disease occurs mostly in coal states, with Pennsylvania accounting for about two-thirds of CWP deaths from 1968 to 1992. CWP begins with the inhalation of small coal dust particles, which cause a localized inflammation, usually in the upper part of the lungs, followed by the formation of fibrous scars. Although asymptomatic in the early stages, as CWP advances, scarred areas in the lungs increase and coalesce. With massive fibrosis, or scarring, pulmonary function decreases, sometimes fatally. Chest X



Black lung legacy. The lung on the right shows the effects of pneumoconiosis in the cloudy, fibrotic tissue which is the body's response to the inhalation of dust. The lung on the left is normal.

rays are the only way to confirm CWP, and there is no cure other than a lung transplant. Annual deaths from CWP have also declined gradually, according to the *WoRLD* report, from nearly 3,000 in 1972 to 1,766 in 1992. But miners are still contracting dust diseases. Between 1987 and 1991, 3.6% of the coal workers examined by X ray had CWP. Although this percentage is down from the 11% diagnosed in 1970–1973, McAteer point out, "We're seeing [dust-related diseases] in people who entered the industry after the 1969 legislation. And these diseases are preventable."

Silicosis, another form of pneumoconiosis, is caused by inhalation of quartz or silica dust. Silicosis is also a major health hazard for miners, and is common in metal and nonmetal mining and quarrying, and iron and steel processing. This disease accounted for almost 15% of all pneumoconiosis deaths during the period 1968–1992, according to the 1996 *WoRLD* report. Deaths from silicosis have decreased from a total of 9,431 over the period 1968–1978 to 4,313 for the period 1979–1990, and were less than 300 in 1992. (Data tend to be several years old because of the length of time it takes to gather, compile, analyze and publish them, but NIOSH experts claim that, because disease incidence changes slowly in mines, the data remain relevant.) According to Robert E. Glenn, a certified industrial hygienist and former NIOSH official who is now president of the National Industrial Sand Association, silica is more biologically active and fibrogenic than some other kinds of dust. A quantity of silica dust can therefore produce more scarring than an equal amount of coal dust.

Dust from virtually any hard mineral can cause lung disease. Dust from aluminum oxide, cadmium oxide, cobalt, graphite, mica, and talc are all considered pneumoconiotic agents. Scientists are also concerned about exposure to the light metal beryllium (used in the aerospace, telecommunications and ceramics industries), which can cause chronic beryllium disease, characterized by weight loss, skin lesions, and reduced lung function. Though awareness of beryllium dust hazards has led to reduced exposure, people working with beryllium can become sensitized to the dust and develop respiratory symptoms. Chronic beryllium disease, though previously associated mostly with beryllium mining, today occurs more frequently in secondary use industries such as beryllium machining, dental alloy preparation, and ceramics.

The Mine Act addresses dust diseases by setting permissible exposure limits (PELs) at 2 milligrams of dust per cubic meter of air (mg/m^3) for coal dust and 1 mg/m^3 for silica. Operators must sample airborne dust levels during as many as 30 shifts annually, and MSHA inspectors also take samples at coal mines on a regular basis, and at noncoal mines where dust levels are found to be excessive. Mines with samples exceeding PELs must take action to control the dust, including "wet mining" (spraying working areas with water to weigh the dust down and keep it from becoming airborne), curtaining off dusty areas, providing heavily filtered respirators, increasing ventilation with fans, and equipping mining machines with air-conditioned cabs for the operators—practices that experts say should be in place wherever dust is present.

While the increasing use of diesel-powered equipment improves the efficiency of mining operations, it also exposes workers (an estimated 13,000 in underground coal mines alone) to diesel emissions, a known human carcinogen containing fine particulate matter that can easily penetrate the lung. Long-term exposure is associated with increased risk of lung cancer, while chronic exposure can cause coughs, headaches, and reversible decreased lung function.

Scientists are also becoming aware of other mining health effects, such as enlargement of the heart muscle and silicotuberculosis, which can occur as secondary effects of silicosis. Exposure to certain metals may have potentially damaging effects as well. Cadmium exposure is associated with pulmonary edema (swelling), for instance, while nickel, arsenic, and chromium exposure are associated with cancer.

Elusive Exposure

Tracking and interpreting incidence of dust exposure and disease in mines is extraordinarily difficult. The 1994 *WoRLD* report projected that in 1991, approximately 150,000 coal workers were potentially exposed to coal mine dust, while an additional 150,000 coal and noncoal workers were potentially exposed to quartz dust. Few data on actual exposure exist, however. Dust samples in which quartz or coal dust levels exceed PELs suggest that workers may be exposed to pneumoconiotic agents. For example, MSHA inspectors reported in the 1996 *WoRLD* report that for the period 1993–1994, 10.8% of 38,960 samples for silica and 5.8% of 32,362 samples for coal dust exceeded PELs.

However, measurements from samples give only a rough approximation of actual incidences of exposure and illness. Varying state-level compensation provisions and refusals to share worker's compensation information have hampered MSHA's information-gathering abilities. Mine operators are required to report cases of dust-related illnesses of which they are aware, but "reporting can depend on whether or not a miner is working when he's diagnosed," says Rhys Llewellyn, chief of MSHA's Office of Injury and Employment Information in Denver, Colorado, "and miners may choose not to report their condition until they elect to transfer to a less dusty area."

High dust levels at a given site do not necessarily imply excessive exposure for all miners, although some mining-related activities are associated with particular risks. A 1991 study of 720 coal operations conducted by MSHA investigators S.M. Ainsworth, Andrew Gero, Paul Parobeck, and Thomas Tomb showed that workers in activities such as rock shearing, jack setting (preparing rock for the insertion of explosives), and loading were exposed to higher levels of respirable coal mine dust. Nor are reports of low dust levels necessarily accurate—they may, in fact, be evidence of cheating. In a five-part series published in the *Louisville Courier-Journal* in April 1998, reporter Gardiner Harris described widespread complicity among coal mine owners, foremen, and workers to provide false information on dust samples, as well as to abandon protective technology and practices for the sake of profits. Joe Main, administrator of health and safety for the United Mine Workers of America, says that in the Appalachian coal fields, the largely nonunionized miners are "held hostage" by the scarcity of local jobs. "Some of these miners don't have a high level of education, so their opportunities are limited," Main says. "They're afraid to complain or testify." Thus, accurate figures on exposure to mine dusts and disease incidence are difficult to come by.

Changing Industry, Changing Illness

New health conditions are appearing as financial forces change the mining industry. One condition is hearing damage, a perpetual risk, but especially as the scale and mechanization of mining operations increases. From 1980 to 1994, 2,287 cases of hearing loss among miners that were reported to MSHA were deter-

mined to be noise induced. Over half of these cases were in coal miners, the rest in metal and nonmetal mine workers, most commonly those from molybdenum, limestone, and gold operations. MSHA requires engineering controls to reduce risk to hearing, but does not require earmuffs or other personal protective devices, which the agency views as a last resort. Few studies have been done on noise exposure and hearing loss in mining.

MSHA limits the noise level to which miners can be exposed over an eight-hour day to an action level of 90 decibels, "about the level of a person screaming loudly," says Larry Grayson, associate director for the Office of Mine Safety and Health Research at NIOSH. "But the statistics we have show that 80% of coal miners and 70% of metal and nonmetal miners have a 25-decibel loss of hearing in either ear by age 60," he says. This means that at a normal conversational volume (about 60–70 decibels), they will miss some words, especially at high frequencies, and lose understanding. Damage appears to increase as time working in the mines increases.

A 1996 MSHA report on occupational illnesses lists 408 repeated trauma injuries including hearing loss, carpal tunnel syndrome, miner's knee (common in "low coal mining" in which miners must frequently crawl on their hands and knees), as well as injuries to the neck, back, hand, and elbow. "You see [such injuries] in smaller mines, less than 50 employees, with thin mineral seams—less than 48 inches—and in activities like roof bolting and shoveling," Grayson explains. He adds that injury rates are higher in smaller mines, which account for about 80% of coal companies, 95% of crushed stone operations, and 80% of metal mines. "In mines with less than 20 employees," he says, "there's a higher rate of serious injuries, and the fatality rate has been three times higher than the rate for large mines." Even though these smaller mines are also regulated by MSHA, they may do a certain amount of corner-cutting due to budget restraints that may prevent operators from implementing or installing safety technology and procedures, even though they are required.

Mining industry health and safety officials universally acknowledge hearing loss and musculoskeletal disorders (such as back and joint injuries and repetitive motion disorders) as major health issues for employees, but tracking and prevention efforts have been remarkably sparse. "There's been very little done to make equipment quieter," Grayson says. "And ergonomic problems are not well defined. There are limited data pinpointing musculoskeletal disorders among reported accidents, though all groups acknowledge that risk increases with age."

MSHA, NIOSH, and mine industry representatives began working on improving definitions of various kinds of injuries, and NIOSH has begun a two-year study to survey various mining conditions and define problems associated with them. MSHA is in the final stages of a rule making process that will reduce the noise action level to 85 decibels. MSHA has also developed regulations to prevent particulate pollution from diesel emissions, although Main says, "MSHA standards only require filtering equipment, and only on heavy-duty production machines, which are only 10–40% of the equipment."

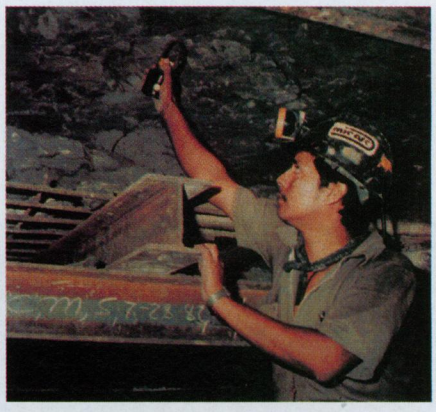
Many mining industry groups see a combination of technology and training as the most cost-effective option for addressing health and safety issues, and also as a way to prevent carelessness among both miners and their employers that can lead to accidents. Glenn says companies are beginning to see the relationship between good safety and health practices and profits. "We need to use all the weapons at our disposal," he says. "MSHA has recently emphasized [using] fall protection [devices], like cables and harnesses, to protect workers from falls. If that technology prevents just one back injury, it's probably paid for itself. But you have to train the worker to use the harness properly and inspect it periodically for wear."

Looking ahead, mining industry and government experts are seeing new problems on the horizon. Says Grayson, "The average age of a miner is 43–50, depending on the sector. So we're looking at an aging workforce, a large number of miners retiring, and a new workforce entering the industry. Are we prepared for that? In 1969, when new miners came in under the Coal Act, we had a high accident rate. MSHA and NIOSH need to find a way to infuse better training into the industry, and to capture the expertise and knowledge those older miners had." Grayson is also concerned about the health of the mine's other employees, the painters, security and maintenance personnel, equipment movers, and drivers who may work temporarily or permanently at mines, and who make up 10–15% of the industry's employees. "They're supposed to be trained, but it doesn't always happen [because of irregular work schedules and other factors]," Grayson says."

Contractor fatality rates have been consistently high, especially considering that many contractors do not work full time. When factoring in the hours worked by regular employees and contract employees (MSHA calculates incident rates per 200,000 hours), the 1997 metal/nonmetal fatality rate was 0.02 for regular employees and 0.10 for contractors, or five times the rate in regular employees. Less startling disparities exist in coal mining, which reported a 1997 fatality rate of 0.02 for regular employees and 0.03 for contractors. The reason for the disparity is not fully understood, but some MSHA experts believe that contractors may not be as familiar with the mining environment, or may be assigned more hazardous jobs.

Safety in a Global Market

U.S. mining technology and health and safety standards rank among the world's most stringent; they are not the norm, particularly for developing countries who may not have the money or infrastructure to enforce them. Many miners in developing countries face abysmal health and safety conditions rarely encountered by U.S. miners. For instance, in South African diamond mines, the deepest in the world, temperatures can reach 120°F. When such temperatures are combined with high humidity and inadequate ventilation, it can lead to severe heat stress. Some of the world's major mineral producers also hold frightening safety records. "Ventilation in the mines in China is very poor, and when that's true, you have a large incidence of CWP and explosions," says Grayson. According to official records, some 3,000 miners in China's coal and gas mines die each year in fires, explosions, falls, and haulage accidents. "But that's just the federal number," Grayson says. "Accidents aren't monitored federally at the provincial level, but fatalities are estimated at about 7,000."



Inter-American Development Bank

Dangerous development. Around the world, workers are paying the price for the benefits mining brings to developing countries.

Infrastructure weakness and scarce capital contribute to high death rates from mining in a large number of developing countries. Mine explosions and accidents involving old equipment kill an indeterminable number of miners in Russia and Ukraine. According to the ILO report *Recent Developments in the Coal Mining Industry*, about 48,000 people were injured in 1993, 377 fatally, in coal enterprises in that area. The ILO reports that the high injury rate is related to difficult geological conditions in mines, lack of materials and technical supplies (which prompts the use of makeshift equipment), and safety violations

due to organizational and management problems. Governments responding to a questionnaire sent out by the ILO in 1994 reported that 200–500 cases of pneumoconiosis are reported annually in some countries. They also reported that repeated trauma injuries injuries from noise and vibrations are increasingly recognized problems. The Pan American Health Organization estimated in its 1994 *Work Illnesses* report that 8.5 million miners, quarriers, and workers in ceramics, metallurgy, and construction are at risk of silicosis throughout Latin America and the Caribbean, and an estimated 500,000 artisanal gold miners in the Amazon region are exposed to toxic mercury vapors, which can permanently damage human neurological systems and aquatic ecosystems.

"Most of these gold miners operate small artisanal mines employing one to ten people," says Gary McMahon, a consultant to the World Bank's Industry and Mining Unit. "[Small mines are] operating in anywhere from 60 to 100 countries. There are at least 60,000–80,000 [mines] in Bolivia alone, for example, as well as thousands in West Africa and Tanzania. Whereas the larger mines are often self-enforcing, these operations are almost impossible to regulate."

The ILO estimates that at least 6 million artisanal miners are operating worldwide, especially in areas where poverty is endemic. Because artisanal mining is associated with poverty, addressing its health effects must involve a multidisciplinary approach encompassing the legal, environmental, and social factors that drive people to become artisanal miners. "There's no purely technological solution," says McMahon. Currently, some 15 World Bank loans address policy-level changes and the incorporation of environmental considerations in mining codes. Normally, these codes address mining in terms of capacity building and the physical environment, with less emphasis on occupational health and safety issues.

A Healthy Future

For the future, experts envision a move toward larger equipment, larger companies through an increase in mergers (though not necessarily larger individual operations), and an increase in surface mining. Coal mining has witnessed a significant shift from underground to surface extraction. In 1937, only 8% of U.S. coal came from surface mines; today, that figure is over 60%, Llewellyn says. Safety officials predict that a reduction in the underground operations that force miners and machinery to work close together in a dusty environment will reduce the incidence of CWP. But the

Mines and the Environment: A Matter of Balance

The search for minerals can cause significant, long-lasting environmental disruption. Because many economically valuable minerals usually occur as a mixture of substances, miners must extract large quantities of ore to get often much smaller quantities of minerals. For example, at least 30 tons of ore must be mined per ton of copper, and 12 tons of ore per ounce of gold.

National Mine Academy

Stripped of value? Mining's challenge for the future will be to halt unsustainable and damaging technologies.

Thus, mining displaces an estimated 50 billion tons or more of earth and other materials per year worldwide, according to the International Labor Organization (ILO). Many of the environmental effects of mining depend on how well or badly this disturbed material is handled. Waste rock and effluents from various kinds of mines can contaminate surface water and groundwater with acids, mercury, cyanide, arsenic, and copper, changing or destroying local or downstream aquatic habitats, not to mention causing health problems in the people who drink the water. Addressing these problems means balancing the need for minerals against social and economic needs, environmental and health considerations, and visions for future sustainability. Mining has affected little territory relative to other land uses—only one-quarter of one percent of U.S. land, or about 900 square miles, according to the American Mining Association. The industry's environmental record has improved, despite steady increases in production: air emissions of lead, particulate matter, sulfur dioxide, and volatile organic compounds by the metals processing industry, for example, have decreased dramatically in the last 50 years, according to the EPA's *National Air Pollutant Emission Trends, 1900–1996.*

However, mining remains a major air polluter, partly because minerals processing is immensely energy- and materials-hungry. The steel industry, for example, requires about 75 tons of coal and 25 tons of limestone for every 100 tons of iron processed (95 million tons were produced in the United States in 1996). And the environmental effects of mining can spread far beyond the mining site.

Increasing public concern has led to more stringent environmental regulations, especially for coal mining, which already has fairly comprehensive environmental regulations in place. The 1997 Surface Mining Control and Reclamation Act, which mandates adherence to environmental standards and remediation of certain environmental damage in active and abandoned coal mines, established a system to collect fees for coal mine reclamation. Laws for noncoal mining are affected by federal regulations, but are generally issued by the states, and may vary widely from one state to another. But recent events in West Virginia show that even in coal mining, other factors besides laws influence environmental protection.

In West Virginia (as well as other Appalachian coal fields), acid mine drainage (AMD), produced when waste rock reacts with air and water, severely polluted thousands of miles of streams near surface mines, including the headwaters of the Potomac River, which flows into the Chesapeake Bay. Some stream beds turned orange from iron deposits, and fish died in water that could be as acidic as vinegar. AMD from underground coal mines formed a series of large subsurface acid pools that seep into the Monongahela River basin, which flows to the Ohio and the Mississippi. One of these pools, the Fairmont Pond, stretches 75,000 acre-feet between Morgantown and Wheeling, West Virginia, and reaches the Pennsylvania border.

By law, mining companies must remediate water pollution problems "in perpetuity" when a mine is closed. Things don't always work that way, however. "In the '80s, some companies pledged to treat AMD and then went out of business," says James McElfish, a senior attorney with the Washington, DC-based Environmental Law Institute.

Cleanup programs conducted by the Office of Surface Mining, the EPA, and other federal and public interest organizations have reduced AMD in some rivers, such as the Potomac. General environmental legislation, including the Clean Air Act and the Clean

logistics of intensive mining worries health and safety officials. "When a mine operates 24 hours a day, there's a lot of shift work," Self explains. "At Trapper, employees will work days, swing shifts, and graveyard shifts all in one month. I don't care what they say—shift work is hard on people. You see less resistance to colds and flu. People are tired and cranky. It's hard on family life, and then family problems become work problems, and there are issues with safety."

MSHA and NIOSH are conducting intensive outreach on CWP prevention. To improve tracking of silicosis, NIOSH has offered free, confidential chest X rays to miners in several states. MSHA has proposed new standards on protection against hearing loss among miners, and on installation of filters on certain coal-mining equipment. These standards have not yet been finalized.

Studies on environmental health in mines are ongoing. MSHA is conducting studies on hearing loss, and is working in coal mines field-testing 10 continuous dust monitors that show elevated dust levels as they occur so that action can be taken on the spot. MSHA and the National Cancer Institute are collaborating on a study on exposure to diesel fumes in nonmetal mines. Field data collection will be finished in early 1999.

Critics of MSHA and the mining industry urge a continued tightening of mining regulations to address present and future health and safety concerns, and stricter penalties for violations. But industry experts aren't sure that legislation will solve the problems. "MSHA has had a very positive impact on injury and illness," says Self. "But we're now at a frustrating crossroads. I don't think we can legislate much more safety and health into the mining industry. That might make mining operations more difficult, but it won't stop miners from violating safety rules and procedures."

More and more mines, as well as MSHA itself, are turning to behavioral solutions: improved training and education programs to increase compliance, even if that means exceeding regulatory limits. That, Self says, means good preventive programs, good equipment and training, and individual responsibility to use equipment correctly and not take risks. Summarizing the attitude now prevailing among miners, government, and the mining industry alike, Glenn says, "[Mine employees] should be able to work their entire lives and not risk loss of life or reduced quality of life at retirement."

Stephanie Joyce

Water Act, contributed to the closure of many of West Virginia's acid-producing mines, which produced pollution-causing high-sulfur coal. But the EPA estimates that in 1995, 488 miles of streams were too acidic to support fish life.

Federal law and environmental protection are only part of the reality of land use; economic incentives among mine operators and local employees also play a part. "There are fightin' words on both sides," says Gary Bryant, an environmental engineer in the EPA's Wheeling office. As the northwestern mines reduced operations, coal companies bought thousands of acres of land in southern West Virginia and began large-scale mountaintop removal—stripping mountaintops to extract the low-sulfur coal buried beneath them. Coal extraction increased from 131 million tons in 1986 to a record 174 million in 1996, generating $4.4 billion in revenues.

The waste was dumped as valley fills. "During the Carter administration, regulations required valley fills to be constructed in terrace-like lifts," McElfish says. "But this is very expensive for coal mining." The West Virginia miners now commonly dump waste rock in a controlled gravity placement, then regrade and replant. This type of valley fill has buried 467 miles of headwater streams, according to Cindy Rank, an activist with the West Virginia Highlands Conservancy, a citizen's group. The effects on aquatic and terrestrial ecosystems are only now being studied. "And we don't know about the long-term effects or stability of these large structures that are being built. Are they as stable as the Pyramids, or will they start moving down the valley with the next hundred-year flood?" says McElfish.

History shows that mine constructions can fail disastrously. This past May, a breached earth dam used in an open-pit metals mine near Seville, Spain, released 4 million cubic meters of water and silt from a settling pond. The water, contaminated with unknown quantities of cadmium, mercury, arsenic, and other heavy metals, flooded 2,000 hectares of land and threatens Doñana National Park, one of Europe's most important wetlands. A similar accident took place in Bolivia in 1996.

In developing countries, environmental regulation is often lax and poorly enforced by underpaid, ill-equipped civil servants. Increasing public awareness, ongoing nationalization of state-owned mines, and investment by foreign (often well-regulated) companies may be the beginning of a change. And international organizations such as the World Bank are working to update environmental codes. The worst problems, in terms of environmental damage, come from the small mining operations, especially the artisanal miners, whose numbers are estimated at between 6 and 10 million worldwide.

Small groups and families, operating with low-tech equipment and often illegally, are responsible for much of the pollution associated with small gold mines, such as mercury dumping and dredging. "These people are terrible in terms of environmental contamination, and there are also problems with health and safety," says John E. Tilton, the William J. Coulter professor of mineral economics at the Colorado School of Mines in Golden. Tilton points out that overall, the performance of mining companies has improved substantially, not just in terms of the environment but also in relation to cultural issues. The industry has begun responding to the needs of local populations who may, for example, see the mining area as part of their traditional or sacred lands. "Mining companies are realizing that the success of their project depends greatly on how they deal with these issues," he says.

Recently, industry and environmentalists have joined forces to put mine-damaged lands to use. Mine-scarred lands have been transformed into a number of golf courses, including the Pete Dye Golf Club, built in Bridgeport, West Virginia, above a maze of coal tunnels. Other courses have been constructed over disused limestone, sand, and gravel quarries. Other abandoned sites have become roosts for thousands of bats—important pollinators and insectivores that are now imperiled by habitat destruction. And some environmentalists even oppose the rehabilitation of certain sites because they have become home to many unusual species. In Britain's West Midlands, for instance, rare meadow grasses have colonized limestone slag heaps at defunct blast furnaces, and a whole ecosystem of unique organisms has developed among the acidic, sandy wastes of some of the former East Germany's abandoned coal mines.

Though the overall environmental impacts of mining have eased, they have not disappeared. The demand for steel, copper, lead, and aluminum remains strong, and with it comes the concomitant demand for coal and other fuels. Economic need and demands for more and cheaper minerals will continue to foster debate over how to prioritize corporate, community, and environmental concerns. How this debate is resolved will affect ecosystems and communities for generations to come.

Stephanie Joyce