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CONCISE REVIEW

A Brief Review of Silicosis in the United States

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Abstract: Silicosis may be defined as the disease resulting from chronic occupational exposure to silica dust. Silica is primarily composed of quartz dust and has been classified since 2000 as a known human carcinogen by the U.S. government. Silicosis may lead to impairment of lung function resulting from fibrosis of the lungs. This may in turn lead to an increased susceptibility to the development of tuberculosis. Respirable particles are in the size range of less than one micrometer to as large as 30 micrometers. Silicosis is an untreatable, but preventable disease. This review explores the history of silicosis in the U.S. mining industry, including case studies of occupational silicosis.

Keywords: silicosis, USA, mining, silica dust

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Introduction: Silicosis, "The King of Occupational Diseases"

I have worked in the mining industry for over 14 years, mining pyrophyllite, a mineral used as a filler product in ceramic tile, paint, pottery, and refractory industries. To extract and process this mineral, the rock must be drilled, blasted, crushed, dried with a rotary kiln, and ground in grinding mills to a fine powder. The fineness of the finished product is 0%–10% retained on a 200-mesh screening sieve. To give an indication of how small the openings are in a 200-mesh sieve: the width of an average human hair (80 micron) is wider than the opening in this sieve (75 micron). The concern with processing this mineral is that it contains 60%–90% silica and it is a dry process, meaning the material is not processed through wet scrubbers and the dust is not controlled by water. My job for the last 10 of 14 years in mining has been in the health and safety concerns of this industry. I see the politics involved between industry and government, and how the worker gets caught in the middle. I would like to share my personal insights into the reality of the workplaces involved in processing minerals containing silica.

Silicosis defined

Silicosis is a disease caused by inhaling respirable silica dust.[1] Pyrophyllite is just one of many minerals that contain silica. Silica is an abundant mineral that makes up the earth's crust. It can be found in sand, rock, and mineral ore. The inhalation of dust containing crystalline silica can be very harmful to human health and may often be deadly if safety precautions are not used. It has plagued industry around the world since mankind began digging into the earth. Occupational exposures to respirable-sized silica particles include mining, quarrying, drilling, and sand blasting activities.[2] Silicosis is usually caused by exposure to silica particles smaller than 10 micrometers. According to the U.S. National Institute for Occupational Safety and Health (NIOSH), the most important factor in the development of silicosis is "the product of the concentrations of dust containing respirable silica in workplace air and the percentage of respirable silica in the total dust".[3] The disease consists of inflammation of the respiratory system tissues that eventually causes fibrosis, the hardening of the lungs, reducing the ability to breathe efficiently.[4] Exposure to crystalline silica may also increase the risk of developing tuberculosis and other nonmalignant respiratory diseases and contribute to renal and autoimmune respiratory diseases. In addition, the International Agency for Research on Cancer (IARC) has designated crystalline silica as a known human carcinogen.[1] There are three types of silicosis: chronic, accelerated, and acute. Chronic silicosis, the most common form of the disease, usually develops after 10 or more years of exposure to relatively low dust concentrations. Accelerated silicosis results from exposure to high concentrations of silica over a 5 to 10 year period. Acute silicosis is a rare but highly fatal disease caused by brief but massive exposure to dust with high quartz content.[2]

Industry exposure and mortality rates

During 1968–2002, silicosis was recorded as the underlying or contributing cause of death on approximately 74 million U.S. death certificates; and of these deaths, 98% were males. Racial distribution consisted of 88% white, 11% black, and $<$1% other race. From 1968 to 2002, the mortality rate has dropped by 93%.[5] Yet, in 2007, the U.S. Occupational Safety and Health Administration (OSHA) estimated that more than two million employees are exposed to silica in general industry, construction, and maritime industry. NIOSH acknowledges that an unknown number of the 3.7 million workers in 2002 engaged in agriculture had exposure to silica from dust-generating activities. According to the U.S. Bureau of Mines, silica is present in nearly all of mining operations.[4] The age-adjusted mortality rate was elevated during 1968–2002 in several counties in select western, eastern, and central U.S. states. San Juan County, Colorado had the highest age-adjusted mortality rate.[4] The highest concentrations of silicosis-related deaths generally appear to occur in areas associated with mining industries.[4]

Despite the data collected on silicosis, the annual number of silicosis deaths is not accurate because of the undiagnosed cases of the disease. Dr. Kenneth Rosenman, a professor of medicine at Michigan State University performed a study on undiagnosed silicosis cases with startling results: "Our research showed that silicosis deaths represent 4 to 8 percent of the silicosis cases per year"[2] (p. 32). Based upon these estimates, some 2,500 to 5,000 cases could be occurring each year.[2]

The Next Asbestos?—Silica Litigation and Legislation

Given the statistics of this disease in the U.S., it is clear that silicosis is not only a national concern primarily affecting lesser developed countries, but a global issue that must be addressed in developed nations as well. In spite of all the historical data, a better understanding of associated health hazards, and efforts made to stop silicosis, it is still a widespread problem. Historical events in the U.S. have initiated silicosis research and have led to legislation that seeks to curb exposure to silica, but industry continues to fight against imposed regulations to prevent the disease.

Hawk's Nest, WV: "America's Worst Industrial Disaster" (1930–31)

In the 1930's, the event that introduced the nation to the dangers of silica dust, considered one of the U.S.'s worst industrial disasters, took place in Hawk's Nest, West Virginia (WV). To provide water from the New River to a power station at Gauley Bridge, WV, a three mile tunnel was cut through Gauley Mountain. Of the 5,000 workers who were on the worksite, over 2,500 workers were underground at some point, drilling through high concentrations of silica rock with little to no protection from dust. The mineral in rock was so high in silica, it was found to be profitable to produce ferrosilicon, a key component in manufacturing steel. Because of the value of this mineral, the original tunnel diameter was expanded to offset the cost of the project.[6]

The primary method used to cut the tunnel through the mountain was drilling and blasting. Although wet drilling methods were used, they were not used very consistently. Water use may slow down the mining process by as much as 50%. Also, workers rarely observed the settle time for dust after a blast. According to eyewitnesses, water was only used while inspectors were on the job site. Workers were also not supplied with any type of respiratory protection. Since this mining operation took place during the U.S. economic Depression and workers could be very easily replaced, worker complaints were minimal. Of the estimated 2,500 workers who worked in the tunnel, 764 died from acute silicosis and an additional 1,500 ultimately developed the disease.[6,7]

U.S. state and federal responses to the Hawk's Nest incident

Hawk's Nest gained national U.S. attention in 1936, about six years after the completion of the tunnel. The findings of the subcommittee from the U.S. Congressional hearings held over the Hawk's Nest incident were a strong indictment of the builders of the tunnel. The U.S. Bureau of Mines (USBOM) had publicized the adverse effect on health resulting from the inhalation of silica. No protective measures were implemented, including dust suppression with water, proper ventilation, the use of respirators, and vacuum-equipped drills. The hazards to health from silica and prevention methods to exposure were ignored. Workers appeared to be treated with little regard for their health, even after evidence of the disease had emerged. Negligence appeared to be demonstrated by mining operators, causing many workers to be affected by silicosis, leading to the death of some of the workers. It was recommended that other operations with risks of silicosis should to be thoroughly investigated and that the responsible parties should be subpoenaed to answer for their actions.[7] Although the U.S. Congressional subcommittee's findings were highly critical of the mining operations, no further actions were taken. However, the publicity did increase awareness and the use of dust suppression and respiratory protection use among workers exposed to silica. By the end of 1937, a total of 46 states had passed laws relevant to workers with silicosis and many of them incorporated workers compensation for silicosis.[6]

Industry's answer to silicosis and the rebirth of silicosis as a national concern

Hawk's Nest revealed the ugly face of the disease silicosis in America. The mining industry's response to the crisis was convincing state governments to incorporate silicosis into state workers' health compensation schedules after 1935.[8,9] Between 1936 and 1940, only 79 workers were compensated for silicosis. The small number of claims along with other actions by industry to limit the visibility of silicosis enabled the fade of the disease from the public eye. The 1940's brought about a declaration of silicosis being a "disease of the past," whose current victims' disease was the result of unhygienic and primitive conditions of work of a bygone era.[8,9] By the 1950's, silicosis was a forgotten disease by the media and declared "dead" by business and the industrial hygiene community. The booming economy from the postwar era left hundreds of thousands of workers who were victims of dangerous dust exposures with little regard to the potentially resulting disease. In the Gulf Coast region of Louisiana, east Texas, and Mississippi, thousands of workers found jobs in shipyards, offshore oil rigs, and oil refineries performing the job of sandblasting. This became the next generation of silicosis victims. In the 1970's, West Texas physician Steven Weisenfeld was forced out of the medical society for diagnosing Mexican-American workers with silicosis and trying to place blame on the oil companies that dominated the economic and social life of the area. He sent his findings to an old colleague at the State University of New York in Syracuse. Together, they began to uncover a silicosis epidemic among sandblasters in the West Texas oil fields.[8,9]

The cases of John Farmer and Lawrence Brown

John Farmer was an African-American sandblaster who worked along the Gulf Coast of Texas during the Depression. His job duties were to sandblast off asbestos and other residue in poorly ventilated inner walls of double-walled ship bottoms. Mr. Farmer often used a face shield to protect against ricocheting particles, a particulate style respirator and sometimes an air-fed hood. The air-fed hood was rarely used for long periods of time due to the heat and humidity of the Southern shipyards. He worked as a sandblaster until 1982, when he retired. At the age of 53, he was diagnosed with "massive progressive fibrosis". A similar evaluation was performed on Lawrence Brown, who died at the age of 46 from silicosis. He had performed the same duties as John Farmer for only 10 years.[8,9]

"The Mississippi cases" (2003–2005)

Just when it seemed progress was being made in silicosis awareness in the workplace, crooked lawsuits threatened the forward motion. In 2002, the state of Mississippi began to show a large increase in silicosis claims. The previous annual average before this year had been less than 100 claims compared to 10,642 claims the year of 2002, then 7,228 and 2,609 the next two years. In response, insurance companies took defensive measures by excluding coverage of silica in renewing policies for the first time in history. In 2005, Judge Janis Graham Jack of Federal District Court in Corpus Christi, TX, questioned the validity of several thousand silica claims that were before her. She identified that all 9,083 plaintiffs who submitted fact-sheets were diagnosed by only 12 doctors and nine of those doctors had diagnosed 99% of those plaintiffs. One doctor performed 1,239 evaluations in a 72 hour period.[4] It was also found that about 65% of the plaintiffs had filed asbestos claims in the past. Judge Jack declared all of the claims before her worthless and that they had been "manufactured for money".[10,11] State-level legislation has specified medical criteria for silica and asbestos cases as a result of the ruling in June of 2005.[4]

From the 1990's to the present, thousands of lawsuits have been filed across the country by lawyers on behalf of workers who labor in "dusty" industries. These lawsuits have reawakened national attention to the ongoing threat of silica exposure.

Prevention of a Disease with No Cure

Silicosis is a preventable occupational disease that has no cure. There are no effective treatments for silicosis available.[5]

Hazard recognition, engineering controls, and air sampling

Hazard recognition is the first step in protecting workers from silica exposure. The U.S. National Institute for Occupational Safety and Health (NIOSH) recommends assessing the potential of worker exposure before a job begins.[2] This is accomplished by identifying any operation that could cause exposure to fine dust. The following jobs in industry are areas where there may be potential hazards: construction (sandblasting, rock drilling, masonry work, jack hammering, tunneling); mining (cutting or drilling through sandstone and granite); foundry work (grinding, moldings shakeout, core room); ceramics, clay, and pottery; stone-cutting (sawing, abrasive blasting, chipping, grinding); glass manufacturing; agriculture; shipyards (abrasive blasting); railroad (setting and laying track); manufacturing and use of abrasives; manufacturing of soaps and detergents.[10] While this may appear to be a comprehensive list, it may not cover every occupational exposure to silica.

Engineering controls are categorized as "best practices" because they prevent exposure before it reaches the worker. Dust collection is the first line of defense in controlling exposure. Vacuums capture the dust generated from machinery. Other controls include "wet methods": watering dusty roads, using water while cutting and drilling, and cleaning affected surfaces with water rather than dry sweeping or using compressed. Automating the workplace, i.e. using automated palletizers, bagging machines, and equipment monitored with programmable logic controllers (PLCs) and computer software, eliminates human exposure.

Periodic air sampling should be performed at worksites affected with silica dust, and oftentimes it is required. A good practice is not only to place monitors on the workers, but to also monitor high traffic work areas. The current MSHA and OSHA permissible exposure limit (PEL) for respirable crystalline silica (quartz) is 100 $\mu g/m^3$ as an 8-hour time-weighted average compared NIOSH's recommended exposure limit (REL) of 0.05 $\mu g/m^3$ as an 10-hour time-weighted average.[3] The PEL is enforced by the corresponding government body and citations are issued with associated fines for overexposure. Corrective action must be taken to reduce exposure to affected workers. The problem with this type of regulation is it can be difficult to enforce when companies alter their practices to avoid enforcement. For example, during a compliance visit, a dust-producing process can be slowed or workers can be instructed to not perform daily duties that may cause overexposure.

Regular medical examination, education, and respiratory protection

Regular medical examinations must be provided to any worker exposed to silica.[2] An annual X-ray may assist in limiting the onset of the disease before it reaches advanced stages. In addition to regular exams, promoting a healthy lifestyle among employees is important. Though smoking has not been proven to increase the risk of contracting silicosis, studies have shown exposure to silica is associated with chronic obstructive pulmonary disease (COPD), including bronchitis and emphysema; the results of some epidemiologic studies suggest that these diseases may be less frequent or absent in nonsmokers.[3]

Educating workers about silicosis is key since there can be lifetime health complications and even fatal consequences. There are several resources available from government agencies such as NIOSH, the Mining Safety and Health Administration (MSHA), the Occupational Safety and Health Administration (OSHA), and some local Department of Labor (DOL) offices. There are several effective prevention videos available, such as *Silicosis: Incurable but Preventable*, available from Marble Institute of America.[11,12] Educating employees before allowing them to start work is important, but refresher training is equally important. MSHA requires 24 hours of general safety training before a new employee can begin work, along with 8 hours of refresher training once a year. This allows the dangers of silica to remain on the forefront of the workers' minds.

Use of respirators should be the last line of the defense and not heavily relied upon, particularly if respirator use is generally sporadic unless someone is policing the workers and respirators are not very effective in higher concentrations. The previously described story of John Farmer is an example of what happens when respirators are depended on for protection against silica dust.

Implementation is vital

Prevention and elimination of silicosis and silica-related disease in the United States are priorities of NIOSH, OSHA, MSHA, and the American Lung Association (ALA). International health agencies have also expressed concern about the continuing occurrence of silicosis and silica-related diseases. The International Agency for Research on Cancer (IARC) recently reviewed the results of post-1986 epidemiologic studies of lung cancer and occupational exposure to crystalline silica.[3] These government agencies are pressing for better air quality conditions for workers exposed to silica. It is industry's role to stop denying silica as a hazard in the workplace. Proper controls and procedures need to be implemented whenever it is feasible as technology improves.

Conclusion: The Prevalence of a Silent Killer

Silicosis has been mishandled throughout the history of the U.S., starting with Hawk's Nest, WV and continuing to the present. The U.S. mining industry continues to deny hazards associated with silica exposure while keeping it away from the public eye. This, along with faulty lawsuits from the early 2000's, leads to questions about the validity of silicosis. Despite political and industrial debate, the worker's exposed to silica continue to suffer. Since chronic silicosis is the most common form of silicosis, generally occurring after 10 or more years of exposure, this can give workers a false security, or "it will never happen to me" mentality. While this is the train of thought industry appears to follow, this is the type of thinking that needs to be altered.

Events like Hawk's Nest shape the future for improving work conditions, but after 75 years, this event has been largely forgotten. It is unlikely another large-scale event of acute silicosis like that at Hawk's Nest is likely to occur during the 21st century in the U.S. Workplace monitoring by employers and regulators, public scrutiny, organized labor oversight and vastly improved communication all serve to reduce that likelihood. Yet silicosis is still a prevalent occupational disease.[6] An X-ray reader at NIOSH, Dr. Petsonk expresses his frustration: "every time I see a young person with severe scarring in the lungs from silicosis, I get outraged".[2]

Today, an effective environmental health and safety (EH&S) professional must make every effort to stay informed about safety and health hazards and their outcomes. While employers and line managers retain the responsibility for safety and health performance, it is essential that the EH&S professional help management fulfill that responsibility.[6] MSHA has proposed the S-Miner Act to keep on pace with safety in changing industry. The Act asserts that miners continue to face long-term health risks from hazards like exposure to coal dust, silica, and asbestos. In response to this, the Act proposes the silica exposure limits be cut in half to meet NIOSH's REL.[13] This regulation imposed on industry will either require companies to keep up or shut down. These measures may lead to some loss of jobs in industry, but are necessary to protect its most valuable resource: people.

Disclosures

This manuscript has been read and approved by all authors. This paper is unique and is not under consideration by any other publication and has not been published elsewhere. The authors and peer reviewers of this paper report no conflicts of interest. The authors confirm that they have permission to reproduce any copyrighted material.

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The authors would like to alert the readers to the following changes in their article.

Data quoted from Bang et al[1], was paraphrased in the article. Although it may have slightly altered the understanding of the information.

The following section from the article-

"During 1968–2002, **silicosis was recorded as the underlying or contributing cause of death on approximately 74 million U.S. death certificates; and of these deaths, 98% were males."**

Should be read as-

"During 1968–2002, of approximately 74 million death certificates, **silicosis was recorded as the underlying or contributing cause of death on 16,305; a total of 15,944 (98%) deaths occurred in males.**"

The Journal Editor confirms these changes do not affect the overall conclusions of the article.

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