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REVIEW ARTICLE

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History and critical analysis of OSHA crystalline silica rules: A systematic review

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ABSTRACT

The Occupational Safety and Health Administration (OSHA) was created in 1971 following the passage of the Occupational Safety and Health Act on December 29, 1970. Signed into law by President Nixon, OSHA was created to protect the health and safety of American workers from the hazards of their work environments. A significant workplace health hazard, especially in the construction industry, is crystalline silica, or silica dust. Only recently was an official rule on crystalline silica exposure signed into law. Published in the Federal Register on March 25, 2016, the crystalline silica exposure rule was corrected on May 18, 2016, and issued on June 23 that same year. The rule became effective on June 23, 2017. Previously, federal, state, and local programs and initiatives provided guidelines and standards on proactive measures to reduce the health effects of silica on workers. A systematic review of crystalline silica resources was conducted, including the history of crystalline silica as an occupational health hazard, the history of governmental and non-governmental silica standards and guidelines, and the anticipated physical adjustments that industries, specific companies, and other entities plan to implement for future compliance with the new standards. The economic consequences of implementing the new practices and permissible exposure limits have yet to be measured, and there are conflicting outlooks between the data published by OSHA and the studies released by groups representing the affected industries. In April of 2017, the effective date of the new silica rule was delayed 3 months to September 23, 2017.

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History of OSHA Relative to Silica Dust Standards

The practices of Occupational Safety and Health (OSH) and Industrial Hygiene (IH) have become important aspects of business and commerce around the world in the last half-century. They have been both an art and science since the days of antiquity, as long ago as two millennia, when mass production of goods and merchandise for human use was in its infancy, and the hazards associated with the devised processes were just being realized [1]. In the 20th century and moving forward, we now have laws, regulations, and entire organizations devoted to worker health and safety and industrial hygiene. Governmental standards here in the United States originated with the passage of the OSH Act by Congress in December of 1970, which officially went into effect concurrently with the establishment of the Occupational Safety and Health Administration (OSHA) on April 28th, 1971 [2].

The Act specified mandates for both employers and employees in the United States, including the responsibility that employers provide employees a workplace without identifiable health hazards in agreement with OSHA standards. Also, employees have the responsibility to comply with the standards in order to secure their own safety and health in the workplace [2]. Since then, with the advent of new technologies and approaches in the manufacturing and construction sectors, and the new safety and health threats that emerge along with them, it is critical that new and updated standards and guidelines be created for workers in these industries to be safe in their workplace.

Ensuring occupational health and safety at the most basic levels involves identifying potential hazards in the workplace, quantifying associated risks,

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and ensuring that employees are furnished with the proper equipment and provided adequate training to combat these hazards, whether chemical, physical, ergonomic, or biological [2]. Although the technology that industrial workers use in their jobs has changed in the last few decades, the primary role of the IH professional continues to be anticipation, recognition, evaluation, and control of hazards in a work environment in addition to ensuring compliance with OSHA standards regarding specific safety and health hazards that may present themselves in that workplace.

Monitoring potential hazards and sources of possible exposure in workplaces will always be a major focus of the OSH professional. An occupational health hazard that causes concern among Industrial Hygienists, one that is ubiquitous in the manufacturing and construction industries, is the substance known as crystalline silica, also known as silica dust, cristobalite, quartz, or tridymite, each referencing its common natural forms. The history of crystalline silica and its most notorious workplace health hazard, silicosis, traces back to the industrial revolution of the early 1900s and beyond. References to lung problems associated with silica dust have been identified as early as the Ancient Greece civilization and the advent of more advanced architecture and construction techniques in the 16th through 18th centuries [3].

In 1938, the National Silicosis Conference was held and a campaign to "Stop Silicosis" was initiated. In 1974, the National Institute of Occupational Safety and Health (NIOSH) issued a report entitled "Criteria for a Recommended Standard: Occupational Exposure to Crystalline Silica," in which it officially recommended resisting the use of sand as an abrasive blasting agent [4]. In 1996, a silicosis Special Emphasis Program was initiated by the Department of Labor with guidelines to lower and eradicate silicosis from exposure to crystalline silica in the workplace [5]. The most recent changes to OSHA standards and practices regarding crystalline silica, specifically involving the respirable form of silica dust and its permissible exposure limit (PEL), came in the form of a new rule published by the Department of Labor on March 24, 2016. Issued by OSHA on June 23, 2016, and scheduled to go into effect 1 year later in 2017, OSHA delayed the effective date on April 6, 2017. The delay was 3 months, and the PEL rule went into effect on September 23, 2017 [6].

The content of these new regulation 29 CFR 1910.1053 remains the subject of debate and continued scrutiny in regards to their necessity and their impact on the American economy in the manufacturing and construction industries. After all, OSHA estimates over 2.3 million workers are exposed to silica annually. The new rules for mitigating or eliminating the risk of crystalline silica inhalation were issued after 19 plus years in the rulemaking process, thousands of public comments, and much chagrin from industry groups. It remains to be seen whether the silica rules will indeed be effective, or if the Trump administration's OSHA will attempt to delay their official enforcement indefinitely.

Review of Literature on Crystalline Silica and Related OSHA Rule Changes

Silica and its various polymorphs are abundant material in the earth's crust and crystalline silica is the primary component of quartz, which in turn is a common component of numerous building materials [1]. According to OSHA, the main commonalities in workplaces with an increased risk for hazardous exposure to crystalline silica involve cutting, sawing, drilling, and crushing concrete, brick, ceramic tiles, rock, and stone products. This is in addition to industries processing or using large quantities of sand, such as foundries, and those producing glass, pottery, and concrete products. The risk event occurs when particles of crystalline silica, also referred to as silica dust, are small enough to become airborne, becoming a respirable form, and entering the lungs of workers [1]. When a person breathes in silica dust particles that are too small for the body to filter, or there are simply so many particles to breathe in that, the body cannot filter it all, the silica stays inside the body, causing permanent damage and scarring the alveoli in the lungs. This may cause serious diseases, such as silicosis or lung cancer, which both take years or decades for significant symptoms to manifest in affected workers [7,8].

Information from government and higher education sources, such as OSHA, provide insight into how non-corporate entities that use materials that are sources of respirable crystalline silica confront the associated risks. OSHA's crystalline silica website represents the official body of facts provided by the U.S. government regarding the risks of working with materials that are crystalline silica sources. The website includes basic information about the hazard potentials of the substance, as well as the most up-to-date standards and regulations related to these hazard potentials [1].

For comparison purposes, literature dating from 2008 from the nonprofit group formerly known as the Industrial Accident Prevention Association (IAPA) was consulted. Examined was whether crystalline silica general knowledge and standards have changed over the last 10 years and in that regard. Literature from 2003 from the Centers for Disease Control(CDC)/NIOSH was also studied, which outlines prior detection methods and reviews of silica dust hazards in the workplace. Finally, a safety plan from Ohio State University's Office of Environmental Health and Safety, Occupational Safety and Industrial Hygiene was consulted to determine the standards and practices that researchers in a university setting use to prevent the health and safety risks that can be associated with silica dust.

With reference to crystalline silica, PEL rule changes being proposed by OSHA at the time, transcripts of testimonies given before Congress by officials of two non-profit organizations in the IH field were also integral sources. These testimonies by the American Industrial Hygiene Association (AIHA) and American Society of Safety Professionals were consulted because these groups represent IH professionals, read: employees, and not large businesses or corporations. They both explicitly list as primary missions the challenge of meeting the needs of their members, advancing the field of IH, and generally working to promote health and safety in the work environment [1,9]. Both groups were supportive of the rule changes that lowered the PEL for crystalline silica across all workplaces to 50 μg/m3 of air, as compared to the former PEL of 100 μg/m^3, for the general industrial workplace, and much higher limit of 250–500 μg/m^3 of air for construction sites and the maritime industry [10]. PEL is defined as the maximum crystalline silica amount to which workers may be exposed in an 8-hour shift [1].

The testimony from AIHA, delivered by Vice President Daniel Anna on March 21, 2014, made several recommendations for OSHA regarding the rule changes, including concern about the subjective nature of the phrase "visible dust" when diagnosing the proper operation of machinery that, over the course of its operation, may cause an area to be contaminated with silica dust. Other concerns included lack of provisions for the usage of protective breathing equipment if employees feel their health is at risk, even if the activity they are performing does not legally require lung protection; designation of a silica-competent employee who should perform on-the-spot compliance checks; employees and employers following manufacturer specifications when installing engineering controls on job sites; and misuse of NIOSH approved respirators instead of assessing the brand or type. Employers should choose respirators based on the exposure limits they are designed to protect in comparison to the exposure level an employee is at risk of facing. Finally, there is concern over the definition and nature of the phrase "run time," in terms of the length of time a machine is operational on a job site [1]. Much of the content in these recommendations can now be found in the final standards that have been successfully passed into law [10].

Analyzing New OSHA Standards on Crystalline Silica

To fully understand the motivations behind, the content of, and technical requirements for compliance with the new crystalline silica regulations, the official recorded entry into the United States Federal Register for the new standards was accessed. Some of the important items in this entry included a highly detailed analysis of the general rationale for the rule change from a health perspective, a cost-benefit comparison, additional stipulations to protect workers from increased health risks due to silica exposure, and all the accompanying data and facts used by OSHA and other organizations as stimuli to create a new and efficacious change to the national silica standards. The OSHA website provides general data on crystalline silica and the associated workplace risks, the official text of the new rules, as well as several other relevant documents and sources that would be of use to businesses, researchers, employees, or other persons who need information about being in compliance. Consulted was the CDC/NIOSH 2003 website, an IAPA guide covering Silica in work environments published in 2008, and a higher education safety program resource from the Office of Environmental Health and Safety, Occupational Safety and Industrial Hygiene at Ohio State University.

At the heart of the new rule change is the lowering of the PEL threshold to respirable crystalline silica from the 1971 regulation of 100–500 μg/m^3, depending on the industry, to the new standard of 50 μg/m^3 of air as an 8-hour, time-weighted average, across all industries regulated by OSHA. The standard calculations used to analyze the amount of crystalline silica dust present in a sample, along with the exposure limit equation, are as follows in the Crystalline Silica Dust Exposure Equation:

PEL (respirable fraction) = 10 ÷ [% quartz + (%cristobalite × 2) + (%tridymite × 2) + 2]

PEL (total dust) = 30 ÷ [%quartz + (%cristobalite × 2) + (% tridymite × 2) + 2]

Exposure = {[mg/m^3(1) × time(1)] + [mg/m^3(2) × time(2)] +...+ [mg/m3(n) × time(n)]} ÷ 480 minutes

Background research and studies on the health effects of respirable crystalline silica have been ongoing for decades. In 1974, there were recommendations by NIOSH to lower the PEL for crystalline silica to the current level [11]. As a result of the belated nature of these rule changes, not only does the 2016 final rule establish the aforementioned lower and safer PEL, but it also specifies the provision of more safeguards for workers in the affected industries, such as, but not limited to, "requirements for exposure assessment, methods for controlling exposure, respiratory protection, medical surveillance, hazard communication, and recordkeeping" [11, p.16286]. OSHA based the establishment of these new standards and practices on years of health data, noted in Table 1—Summary of Lifetime or Cumulative Risk Estimates for Crystalline Silica, as well as numerous studies of the silica dust effect in work environments on the short-term and continued well-being of industrial workers. OSHA finds their authority for rulemaking in the text of the original OSHA Act, which directly compels the agency to use any reasonable measures to reduce legitimate occupational health hazards.

Table 1. Crystalline silica risk estimates.

Summary of Lifetime or Cumulative Risk Estimates for Crystalline Silica					
Health Endpoint (Source)	**Risk associated with 45 Years of Occupational Exposure (per 1,000 workers)** **Respirable Crystalline Silica Exposure (µg/m^3)**				
	25	50	100	250	500
Lung Cancer Mortality (Lifetime Risk)					
Pooled Analysis	10–21	16–23	20–26	24–30	32–33
Diatomaccous Earth Worker study	8	15	30	72	137
U.S. Granite Worker study	10	22	54	231	657
North American Industrial Sand Worker study	7	14	33	120	407
British Coal Miner study	3	5	11	33	86
Silicosis and Non-Malignant Lung Disease Mortality (Lifetime Risk)					
Pooled Analysis	4	7	11	17	22
Diatomaceous Earth Worker study	22	44	85	192	329
Renal Disease Mortality (Lifetime Risk)					
Pooled Cohort study	25	32	39	52	63
Silicosis Morbidity (Cumulative Risk)					
Chest X-ray category of 2/1 or greater	21	55	301	994	1,000
Silicosis mortality and/or X-ray of 1/1 or greater	31	75	440	601	634
Chest X-ray category of 1/1 or greater	6	127	773	995	1,000
Chest X-ray category of 1 or greater	40	170	590	1,000	1,000
Chest X-ray category of 1 or greater					
Tin miners	40	100	400	950	1,000
Tungsten miners	5	20	120	750	1,000
Pottery workers	5	20	60	300	700

Preamble and Development of the Silica Standard

It would be disingenuous to ignore the lethargic process of creating these new silica standards and putting them into effect for the American worker, which may lead to thousands of lives lost from diseases caused by crystalline silica exposure, most notably silicosis and lung cancer. As stated above, it was recommended as early as 1974, by NIOSH specifically, that the silica standard should be set at 50 μg/m^3. Progress toward this goal ended with the publishing of an Advance Notice of Proposed Rulemaking by OSHA less than a year later. No rule change was made at the time, mostly due to an unwilling U.S. Congress to add regulations that might be costly to the manufacturing and construction sectors, in spite of the known safety and health risks [11].

In the proceeding decades, the IH field witnessed a wealth of information stream into public view concerning workplace hazards and general health risks presented by respirable crystalline silica. As the years went on, official designations of the substance as harmful to humans were made by several national and international organizations, culminating in a 1991 report from the National Toxicology Program in the U.S. Department of Health and Human Services that labeled respirable crystalline silica as a human carcinogen. This prompted new efforts to establish OSHA regulations in 1992 as part of a set of rule changes first proposed in 1989 concerning air contaminants. These regulations were struck down by the Eleventh District Court of Appeals. In 1994, 1996, and 1997, OSHA initiated several non-regulatory silica standards campaigns, including broad-based outreach programs with silica standards education and training for employers and employees as their primary focal points. OSHA also escalated safety inspections and site risk identifications, as well as increasing efforts to inform the public of health problems arising from silica exposure. In 2003, OSHA consulted with industrial small business owners to gather information about how potential new standards might affect their operations. These efforts also served the purpose of allowing OSHA to collect valuable industry statistics, most importantly from inspections, which would inevitably include details of compliance or non-compliance with the old silica standards [11].

When OSHA examined inspection data collected from 1997–2003 and 2003–2009, they discovered continual and widespread disregard for the 1971 standard, posing a significant risk to occupational health nationwide. As a result, an agreement was reached by many organizations that change to the silica standard was indeed necessary to ensure the health and safety of industrial workers. After once again collaborating and holding discussions with small business and various industry groups from 2010 to 2013, OSHA submitted its notice of proposed rulemaking (NPRM) to the Federal Register for public scrutiny and peer review. Thousands of comments, briefs, and arguments were presented in the months before and after the official hearing before Congress that lasted from March 18 until April 4, 2014 [11]. The final rule was published on March 25, 2016, and officially took effect on June 23, requiring all industries to be compliant with the new standards between 1 and 5 years from the effective date [1].

Rule changes with such scale and consequences for business are bound to have detractors, and the new silica standards are no exception. Although a multitude of feasibility studies were done by OSHA in preparation for the NPRM, including assessing the impact of the necessary regulatory, technological, and economic measures, and despite it being the view of OSHA that the health care cost savings would far outweigh the monetary burden on companies to be in compliance with the new rules (see Table 2), there was and still continues to be pushback from some industries and organizations that represent those companies and industries [11]. Testimony given in 2016 at a House of Representatives Subcommittee meeting on Workforce Protections by representatives from the U.S. Chamber of Commerce, stated clearly that it was the opinion of the Chamber that "the new OSHA silica regulations are not consistent with OSHA's statutory requirements for regulations to be data-driven, feasible, and performance-oriented" [12, p.3]. American chambers of commerce work for businesses and business interests, so it is no surprise that the U.S. Chamber of Commerce would not think highly of new rules brought upon several industries by a regulatory body. Table 2 identifies the numeric details of the OSHA claim that the costs to businesses will be far outstripped by health care savings and benefits to society imbued by the new silica rules [13].

Reaction to the New Silica Standard

The debate surrounding the economic cost of implementing compliance with these new standards and

Table 2. Proposed OSHA silica standard.

Annualized Benefits, Costs and Net Benefits of OSHA's Proposed Silica Standard of 50 ug/m³		
Discount Rate		**3%**
Annualized Costs		
Engineering Controls (includes Abrasive Blasting)		$329,994,068
Respirators		$90,573,449
Exposure Assessment		$72,504,999
Medical Surveillance		$76,233,932
Training		$48,779,433
Regulated Area or Access Control		$19,243,500
Total Annualized Costs (point estimate)		**$637,329,380**
Annual Benefits: Number of Cases Prevented		
Fatal Lung Cancers (midpoint estimate)	162	
Fatal Silicosis & other Non-Malignant Respiratory Diseases	375	
Fatal Renal Disease	151	
Silica-related Mortality	688	$3,268,102,481
Silicosis Morbidity	1,585	$1,986,214,921
Monetized Annual Benefits (midpoint estimate)		**$5,254,317,401**
Net Benefits		**$4,616,988,022**

U.S. Department of Labor, OSHA, Directorate of Evaluation and Analysis, Office of Regulatory Analysis

the occupational health cost to workers is currently at the center of many controversies related to these rule changes. Some companies and organizations that represent them argue that the time and labor it would take for their employees and job sites to be in full compliance with the new standards would represent an undue and unrecoverable burden on their business, increasing costs in the short term without an equivalent benefit to their budgets in the long term. Other companies are more focused on their employees or, it is argued, large and successful enough to favor the rule because of obvious benefits to worker health and long-term wellness [14].

The positions of corporate America on this issue are published on the websites of various industry and non-industry groups, biased for or against the regulations, and are considered helpful in gaining an understanding about the differing stances regarding these new rules. One source, which labels itself a building code watchdog website, summarized the strong position against the new silica standards by the National Association of Home Builders (NAHB) and identified several other companies and groups that also oppose the changes. The chairman of the NAHB, a developer and businessman in Illinois, argued before Congress on April 19, 2016, that the new standards will fail to keep workers safe and simultaneously will be severely hampering the economy. He states that the necessary technological changes needed to stay in compliance with the rules are economically impractical for his company and would only serve to raise the cost of housing because his incurred business expenses would be increased [14].

O'Keefe [14, p. 1], however, defends the new standards against this non-compliance claim by citing CDC health figures about the dangers of silica in the workplace, arguing that the "meaningful action" taken by the construction industry, as so stated by the NAHB chairman in his testimony, have not been historically adequate in protecting workers and providing them the safe work environment they deserve. In response, O'Keefe cites Ron Jones, a green building industry professional and founder of the Green Builder Media group. Ron has a firm opinion about the fight over the new rules, claiming that the building industry is almost always a "profits over people" scheme and that those who oppose the new safety standards are more than likely anti-regulatory in their ideology of government. The building industry does not view the new rules favorably simply because they are mandates they are forced to follow. Another group, the Associated General Contractors of America, had a more reasoned opposition approach via the group's spokesperson Brian Turmail in a National

Public Radio interview on March 24, 2016. Brian argued that because of the requirement to quarantine, the dust-producing aspect of a construction job from the rest of the site, the progress of a job is slowed and ultimately leads to inefficiency and economic loss for the project, due to compliance measures [14].

A large firm in favor of the new silica rules is Turner Construction Company. The vice president of federal services for Turner, Chris Jahrling, spoke at a press conference following public comments by U.S. Secretary of Labor Tom Perez, stating that his company anticipated working hard to be compliant with the new standards to help provide a healthier future for their employees. However, the fact that large builders have more resources at their disposal and a greater ability and capacity to comply with the new rules suggest that the obvious losers in the effort to enforce new standards are the smaller, less wealthy builders. These smaller businesses do not often have immediate resources to begin compliance activity. Some small companies argue that the OSHA timeframe of 1 year was not enough time for small construction companies to implement the necessary changes, much less have the money to do so. Mike Collignon, director of the Green Builder Coalition group, offers a more direct take on the issue, saying that most builders are going to be automatically against the new rules simply because they would increase costs for doing business [14].

Methods of Ensuring Compliance with New Silica Rules

Companies operating in affected industries are required and should be in the midst of making the structural and physical changes to their business and practices to be in full compliance with silica exposure limits and associated rule changes. As mentioned previously, companies in the various affected industries were placed on a schedule for full compliance with the new standards. Companies in the construction industry had until June 23, 2017, to make the necessary updates, industry companies including shipbuilding and hydraulic fracturing had until June 23, 2018 (with the exception of updated engineering controls installation that hydraulic fracturing companies have until June 23, 2021, to implement). The types of changes to be made by corporations relate mostly to the addition of hazard controls that may or may not be commonly used on company job sites.

Figure 1 indicates the general effectiveness of various hazard control methods that can be implemented in an industrial setting or work environment. Invariably, industrial companies and other entities may deal with respirable crystalline silica and initiate hazard control activities in different ways given the distinct environment in which they operate. For example, an updated safety plan from Ohio State University regarding crystalline silica recommends several of the basic engineering and administrative controls for dealing with the respirable form of the substance, including "local exhaust ventilation… general ventilation… vacuum methods with high-efficiency particulate air filters… distance… use of water to keep down dust… worker rotation" [15, p.7]. The use of personal protective equipment was also suggested in this literature. Noted is that a PEL of 50 µg/m^3 is referenced throughout this resource, suggesting that the university followed OSHA recommendations even before the new standards were officially published and put into effect in 2016. This is unsurprising,

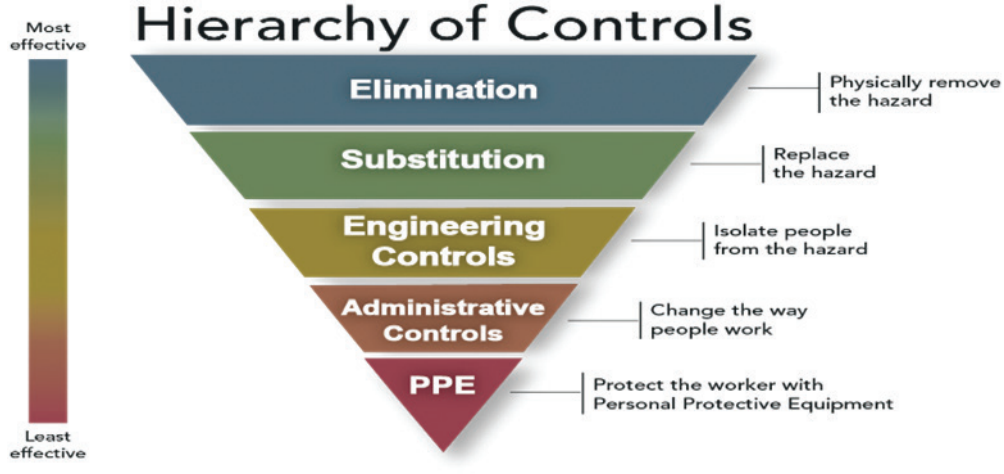

Figure 1. NIOSH controls.

considering that the work and research were done at a not-for-profit university and that the protection and assurance of the safety and health of students and professors are of paramount importance.

An e-newsletter from Construction Executive Magazine detailed the group's advice to construction companies in creating a plan of action to comply with the new silica standards. Several measures are included, including the necessity to use exhaust ventilation (vacuums), or water delivery system to implement silica engineering controls. An exposure control plan is proposed, including identifying and training a silica competent person to ensure that silica standards are being followed. A simpler method, such as limiting dry sweeping of dust at the worksite, is offered [16]. A silica competent person is an employee or managerial staff member who is knowledgeable about respirable crystalline silica and its role as a workplace health hazard, can identify silica dust exposure situations, can implement the correct engineering controls in order to mitigate or eliminate the crystalline silica hazard, and can understand and check for compliance with all standards and practices related to crystalline silica as a workplace health hazard [17].

In their outline for a recommended plan of action, Construction Executive includes the following measures to ensure compliance: 1) review current equipment to decide if more engineering controls, such as ventilation, need to be added, 2) determine if machines need to be modified or if new machines need to be purchased to mitigate or eliminate the silica dust hazard, 3) work with an occupational healthcare specialist who has the ability to administer proper medical examinations in case of exposure, 4) create or improve existing recordkeeping to maximize transparency in regards to compliance, 5) consider hiring an IH professional for daily hazard analysis and compliance checks, and 6) ensure all employees are professionally familiar with all new standards pertaining to the scope of their jobs 16].

The Center for Construction Research and Training published compliance guidelines with the new silica construction industry standards. This group followed OSHA recommendations when considering the addition of necessary engineering controls, and referring to Table 3, a component of the final rule when discussing which kind of hazard controls to use in specific situations. They pointed to specific strategies such as using a water sprayer to collect dust and keeping it from becoming airborne and in range of the breathing zone of workers, using a vacuum cleaner concurrently with a saw or blade that cuts stone and releases silica (to suck up dust particles before they escape into the air, also known as local ventilation), and creating a written action plan addressing instances of crystalline silica exposures or eliminating the hazard of a crystalline silica workplace source. Figure 2 represents a possible exhaust system that can be placed in the vicinity of a worker who is engaging in an activity where there is a threat of silica dust exposure [18].

Economic Consequences of Compliance and the 2017 Delay

Many other industry groups are currently against the new silica regulations and have released their

Table 3. Crystalline silica exposure control methods.

Equipment/Task	Engineering and Work Practice Control Methods	Required Respiratory Protection and Minimum Assigned Protection Factor (APF)	
		≤ hours/shift	> 4 hours/shift
Stationary masonry saws	Use saw equipped with an integrated water delivery system that continuously feeds water to the blade.	None	None
	Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.	None	None
Handheld power saws (any blade diameter)	Use saw equipped with an integrated water delivery system that continuously feeds water to the blader.		
	Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.		
	When used outdoors.	None	APF 10
	When used indoors or in an enclosed area.	APF 10	APF 10

studies that point to the economic inconvenience of taking the necessary steps to comply with the new rules. The National Federation of Independent Business, a small business rights lobbying firm, released their numbers on the costs associated with compliance with the new standards across all industries, finding there would be a $7.2 billion dollar loss to the economy as well as significant job losses over a 10-year period. The National Association of Manufacturers, listed as a non-profit organization with the mission of tracking legislation and policy affecting manufacturers, has come out vehemently against the new silica standards, with the president of the group claiming that the costs will be difficult to recoup even for large businesses and will be devastating for smaller builders [19]. An example of one of those smaller businesses is the Whitacre Greer Company, a brick builder in Alliance, Ohio. CEO Janet Whitacre Kaboth testified before a House committee in February 2016 that the cost of compliance for her business would be approximately 1 million dollars for the first year. She said that it might not be possible for her company to obtain a loan for that amount of money to pay for the necessary engineering controls to comply with the new standards [19].

A Safety and Health Magazine article detailed the numerous petitions filed for review of the rule change almost immediately after it was published on March 25, 2016. Seven court challenges were submitted from various organizations both for and against the new standards and a final rule within 10 days of its issuance. The American Federation of Labor and Congress of Industrial Organizations (AFL/CIO) was one of the challengers who were in favor of the rule changes but believed that the regulations can be still stronger, thus the reasoning behind their petition. It is the opinion of the AFL/CIO that the rule does not go far enough in forcing the removal of a worker due to medical reasons if the exposure to silica at a job site is dangerously high [10].

Another organization in favor of the silica rule but believes it could be improved was the North American Building Trades Unions (NABTU). They see a possible loophole in the law that could be exploited by companies, specifically the provision that a worker must undergo medical surveillance after the use of a respirator on the job for 30 days out of a year. NABTU argues that this will open the door for employers to simply continually hire new workers for a job that requires the use of a respirator for more than 30 days. Companies, NABTU claims, will fire or la30, thereby allowing the company to avoid the medical surveillance stipulation in the rules. Additionally, it is the opinion of the United Automobile Workers that the PEL could go even lower than 50 micrograms, even 25, and their petition to the courts reflected this judgment [10].

Other petitions demonstrated the dislike of the rule changes by various groups, including the National Stone, Sand, and Gravel Association. The organization asserted, through a press release delivered by CEO Michael Johnson, that no further lowering of the PEL was required to protect worker health. National Stone disagreed with both the new silica rules as well as the basis claimed by OSHA for their necessity. Johnson's article also detailed some of the testimony given before Congress at an

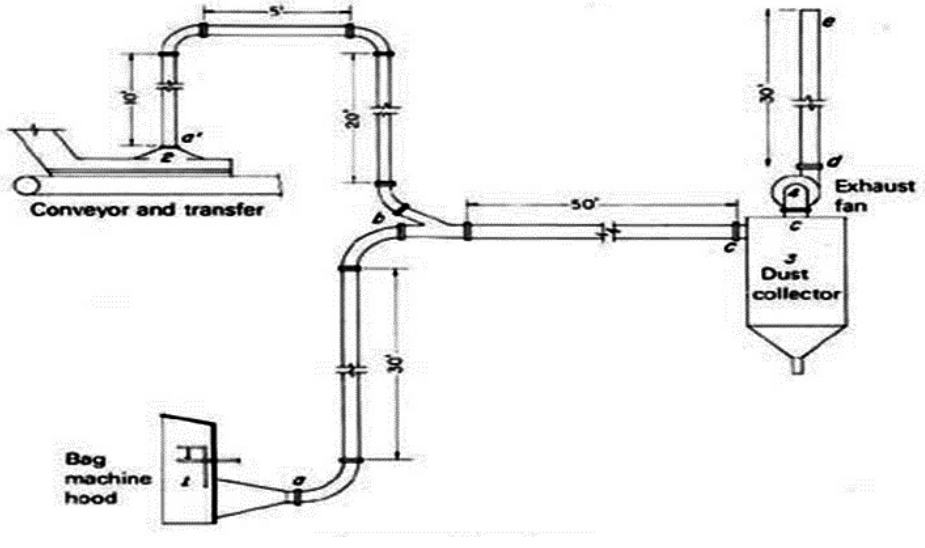

Figure 2. Engineering control.

April 2016 hearing in the House of Representatives, including statements from Janis Herschkowitz, president of Regal Cast, a foundry company based in Lebanon, Pennsylvania. She claimed that due to the nature of her company's operations, it would be almost impossible to maintain an average silica dust level of 10 μg/m^3, and the company would find itself in a perpetual non-compliance state with the new standards [10].

On April 6, 2017, the U.S. Department of Labor issued a statement on the silica rules, officially pronouncing that it was delaying the effective date for construction industry compliance with the new regulations for 3 months, from June 23 to September 23, 2017. The press release cited a need for additional time "to conduct additional outreach and provide educational materials and guidance for employers" [6]. However, the statement also mentions that OSHA expects employers in the construction industry to continue to take steps to come into compliance with the new permissible exposure limit and that "employers should also continue to prepare to implement the standard's other requirements, including exposure assessment, medical surveillance, and employee training" [6].

The delay has been met with equal parts of condemnation and praise. The AFL/CIO issued a statement decrying the onset of disease and possible mortality in the future as a result of the delay. However, industry groups such as the Associated General Contractors of America noted in a statement that while they approve of OSHA's announcement of the stay, "a 3-month delay does not change the fact that the technology does not exist to enable firms to fully comply with this new rule," and argues that a "better approach would be for OSHA officials to revisit this rule and work with us to put in place measures that are technologically possible and then focus on ensuring total compliance with that new standard" [20].

Conclusions and Future Implications

Although there has been considerable blowback from many industrial corporations and the organizations that represent them, it is undeniable that these new silica standards were necessary and long overdue to become law. Silicosis is a disabling, non-reversible, sometimes fatal lung disease that causes chronic bronchitis, lung cancer, and kidney disease, and is associated with autoimmune and cardiovascular diseases. As far back as 1974, it was suggested that the permissible exposure limit for crystalline silica be lowered to 50 μg/m^3 of air. Resistance in the industries, however, and the unwillingness of lawmakers to act on such a costly matter of industrial regulation has resulted in the new limit not been implemented until today [11]. It is possible that untold thousands or millions have died and are fated to die in approaching days because of four-plus decades of inaction on the exposure threshold. Lung cancer and silicosis are serious diseases. Those who have suffered and are suffering due to their work environment in construction or related industries could have had their distress prevented. Better practices and tighter regulations concerning this hazardous respirable substance could have alleviated workers' physical, emotional, and mental suffering and monetary costs.

Silicosis is not curable, but it is preventable. In construction, exposure to silica comes from chipping, cutting, sawing, drilling, grinding, sanding, and crushing concrete, brick, block, rock, and stone products. In manufacturing, sandblasting, and foundries, there is silica exposure from using sand products. OSHA has identified the industries, occupations, and materials that indicate the probable use of crystalline silica [21] (OSHA). The Respirable Crystalline Silica Rule addresses separate standards for construction and general industry that includes maritime. Methods of sample analysis from OSHA, NIOSH, and Mine Safety and Health Administration are specified, and they must be conducted by accredited laboratories following stated quality control procedures. Areas of silica exposure must be regulated, engineering controls implemented to control the dust, and respiratory protection provided for exposure above the PEL. A written exposure control plan must be established and implemented where there is exposure to respirable crystalline silica, and general housekeeping must not include dry sweeping and unventilated compressed air cleaning. The company Hazard Communication Program must include silica labeling and the risks of respirable crystalline silica in addition to employee access to safety data sheets. Medical surveillance is to be made available at no cost to employees who are occupationally exposed to silica above the PEL for at least 30 days per year. Many of these regulations have been voluntarily met by companies since exposure control was first proposed.

The research has been done and the standards proposed to protect workers. The Silica Rule specified separate effective dates for construction and general industry as well as hydraulic fracturing in the oil and gas industry. Because of the effective date delay, some of the deadlines have passed. The position of businesses on the issue, who may very well be overburdened financially by having to

comply with the new standards, and the position of OSHA, who has known about the dangers of crystalline silica for decades, should both be considered on their merits. However, OSHA can use their authority as a regulatory agency to benefit American industrial workers and can fulfill their duty to act in the best interests of American workers with this impactful rule change. A continuing OSHA delay of the effective date of the new silica rules, under the guidance of the Trump administration, casts doubt on whether an industry-wide change will truly be implemented concerning silica exposure.

Author contributions

Conceptualization, R.A and T.R.; Methodology, R.A and T.R.; Validation, R.A and T.R.; Formal Analysis, R.A and T.R.; Writing-Original Draft Preparation, R.A.; Writing-Review & Editing, R.A and T.R.; Visualization, R.A.; Supervision, T.R.

Conflicts of interest

The author declares no conflict of interest.

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