

# **MINE SAFETY AND HEALTH ADMINISTRATION (MSHA) PROPOSED RESPIRABLE CRYSTALLINE SILICA RULE**

## **PRELIMINARY REGULATORY IMPACT ANALYSIS**

**Docket ID No. MSHA–2023–0001**

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## ABBREVIATIONS

AIS	Abbreviated injury scale
ANSI	American National Standards Institute
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
CAGR	Compound Annual Growth Rate
DOT	Department of Transportation
ESRD	End-stage renal disease
FTE	Full-time equivalent
GDP	Gross domestic product
ILO	The International Labour Organization
ISO	International Organization for Standardization
MNM	Metal and non-metal
MSHA	Mine Safety and Health Administration
NIOSH	National Institute for Occupational Safety and Health
NMRD	Non-malignant respiratory disease
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
PLHCP	Physician or other licensed healthcare professional
PRA	Preliminary risk assessment
PV	Present value
QRA	Quantitative risk assessment
RCMD	Respirable coal mine dust
SOPs	Standard operating procedures
VSL	Value of a statistical life
WTP	Willingness to pay



## EXECUTIVE SUMMARY

Executive Order (E.O.) 12866, as amended by E.O. 14094, and E.O. 13563 direct agencies to assess all costs and benefits of available regulatory alternatives and, if regulation is necessary, to select regulatory approaches that maximize net benefits (including potential economic, environmental, public health and safety effects, distributive impacts, and equity). E.O. 13563 emphasizes the importance of quantifying both costs and benefits, of reducing costs, of harmonizing rules, and of promoting flexibility. E.O.s 12866 and 13563 require that regulatory agencies assess both the costs and benefits of regulations.

A regulatory action is considered “significant” if it is likely to “have an annual effect on the economy of \$200 million or more ...” under E.O. 12866 Section 3(f)(1), as amended by E.O. 14094.<sup>1</sup> The proposed rule “Lowering Miners’ Exposure to Respirable Crystalline Silica and Improving Respiratory Protection” is a significant rule. To comply with E.O.s 12866 and 13563, MSHA has prepared a Preliminary Regulatory Impact Analysis (PRIA) for this proposed rule, presented in this document. This PRIA contains supporting data and explanation for the summary materials presented, including the mining industry, costs and benefits, and economic feasibility. The supporting data and explanations of the summary materials discussed here can be accessed electronically at <http://www.msha.gov> and has been placed in the rulemaking docket at [www.regulations.gov](http://www.regulations.gov), docket number MSHA-2023-0001. MSHA requests comments on all estimates of costs and benefits presented in this PRIA, and on the data, assumptions, and methodologies the Agency used to develop the cost and benefit estimates. MSHA also requests comments on any data and methods that would result in better trend projections for employment, production, or other factors in the mining industry for the analysis that would accompany the final rule.

This PRIA is based on MSHA’s Preliminary Risk Analysis and Technological Feasibility (PRA). It assesses the costs and benefits in the metal and nonmetal (MNM) and coal industries of reducing miners’ exposures to silica to 50 µg/m<sup>3</sup> for a full shift, calculated as an 8-hour time weighted average (TWA) and of complying with the standard’s ancillary requirements. It also assesses the costs and benefits from revising the existing respiratory protection standards. MSHA is proposing to incorporate by reference ASTM F3387-19, “Standard Practice for Respiratory Protection” (ASTM F3387-19), as applicable. ASTM F3387-19 would replace the 1969 American National Standards Institute (ANSI) “Practices for Respiratory Protection.”

MSHA estimates the proposed rule would have an annualized cost of \$57.6 million in 2021 dollars at a real discount rate of 3 percent. Of this cost, over 55 percent is attributable to exposure monitoring; 30 percent to medical surveillance; 10 percent to engineering, improved

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<sup>1</sup> Executive Order 12866 of September 30, 1993: Regulatory Planning and Review. 58 Fed. Reg. 51735. October 4, 1993. Accessed at <https://www.archives.gov/files/federal-register/executive-orders/pdf/12866.pdf> on January 5, 2023.

Executive Order 14094 of April 6, 2023: Modernizing Regulatory Review. 88 Fed. Reg. 21879. April 11, 2023. Accessed at <https://www.federalregister.gov/documents/2023/04/11/2023-07760/modernizing-regulatory-review> on April 19, 2023.

maintenance and repair, and administrative controls; 2.4 percent related to incorporating ASTM F3387-19 respiratory protection practices; and 1.8 percent to additional respiratory protection (e.g., when miners need temporary respiratory protection from exposure at the proposed PEL when it would not have been necessary at the existing PEL). MSHA further estimates that the MNM sector will incur \$52.7 million (91 percent) and the Coal sector will incur \$4.9 million (9 percent) in annualized compliance costs (see Table ES - 1).

**Table ES - 1. Summary of Estimated Compliance Costs by Provision and Commodity, 2021 (in Millions of 2021 \$)**

Provision or Sector	Number of Mines	0 Percent Real Discount Rate		3 Percent Real Discount Rate		7 Percent Real Discount Rate	
		Annualized Cost	Percent	Annualized Cost	Percent	Annualized Cost	Percent
All Mines by Provision							
Exposure Monitoring		\$30.60	54.5%	\$32.02	55.6%	\$34.30	57.3%
Exposure Controls		\$5.65	10.1%	\$5.75	10.0%	\$5.90	9.9%
Respiratory Protection		\$1.03	1.8%	\$1.03	1.8%	\$1.03	1.7%
Medical Surveillance		\$17.49	31.2%	\$17.37	30.2%	\$17.20	28.7%
Subtotal, Part 60 Costs		\$54.76	97.6%	\$56.17	97.6%	\$58.43	97.6%
ASTM 2019		\$1.36	2.4%	\$1.40	2.4%	\$1.46	2.4%
Total, All Mines	12,631	\$56.12	100.0%	\$57.57	100.0%	\$59.89	100.0%
All Mines by Sector							
Total, All Mines	12,631	\$56.12	100.0%	\$57.57	100.0%	\$59.89	100.0%
Metal/Nonmetal, Total	11,525	\$51.31	91.4%	\$52.67	91.5%	\$54.85	91.6%
Coal, Total	1,106	\$4.81	8.6%	\$4.90	8.5%	\$5.04	8.4%

Note: Medical surveillance cost is the average cost under the assumed participation rates of 75 percent and 25 percent.

In its analysis, MSHA annualizes all costs using 3 percent and 7 percent discount rates as recommended by OMB. MSHA bases the annualization periods for expenditures on equipment life cycles and primarily uses a 10-year annualization period for one-time costs and 20-year for medical surveillance. However, MSHA annualizes the benefits of the proposed rule over a 60-year period to reflect the time needed for benefits to reach the steady-state values projected in MSHA's PRA. Therefore, MSHA's complete analysis of this rule is 60 years (which corresponds to 45 years of working life and 15 years of retirement for the current miner population). MSHA holds the employment and production constant over this period for purposes of the analysis.<sup>2</sup>

For both MNM and coal mines, the estimated costs to comply with the proposed PEL (50 µg/m<sup>3</sup>), assumes that all mines are compliant with the existing PEL of 100 µg/m<sup>3</sup> for MNM

<sup>2</sup> This modeling strategy implicitly assumes that the 10-year cost annualization repeats five more times to cover the same 60-year analytic period as the benefits model. Thus, one-time costs incurred in the first year implicitly repeat in years 11, 21, 31, 41 and 51. This may introduce a tendency toward overestimation of compliance costs.

mines (for a full shift, calculated as an 8-hour time-weighted average) and 85.7 µg/m<sup>3</sup> for coal mines (for a full shift, calculated as an 8-hour time-weighted average).

MSHA estimates that:

- The proposed respirable crystalline silica rule will result in a total of 799 lifetime avoided deaths (63 in coal and 736 in MNM mines) and 2,809 lifetime avoided morbidity cases (244 in coal and 2,566 in MNM mines) once it is fully effective (so that all miners, working and retired, have been exposed only under the proposed PEL) (see Table ES – 2).
- Over the first 60 years, annual cases avoided will increase gradually to the steady-state values (i.e., long-run per-year averages). Upon reaching the steady-state values, annual cases avoided will be constant from year 60 onward because all miner cohorts that start work under the Proposed Rule, will have identical lifetime risks. From Table ES - 3, in the first 60 years, the proposed rule would result in a total of 410 avoided deaths (377 in MNM and 33 in Coal) and 1,420 avoided morbidity cases (1,298 in MNM and 122 in Coal), which are the benefits MSHA monetized in its benefits analysis.
- The total benefits of the proposed respirable crystalline silica rule from these avoided deaths and morbidity cases are \$175.7 million per year in 2021 dollars.
- The majority (60.7 percent) of these benefits (\$108.0 million) are attributable to avoided mortality due to non-malignant respiratory disease (NMRD) (\$52.8 million), silicosis (\$28.1 million), and end-stage renal disease (ESRD) (\$19.9 million), and lung cancer (\$7.2 million).
- Benefits from avoided morbidity due to silicosis are \$53.2 million per year: \$48.7 million for MNM mines and \$4.6 million for coal mines (see Table ES - 4).
- Benefits from avoided morbidity that precedes fatal cases associated with NMRD, silicosis, renal disease, and lung cancer, are \$14.5 million: \$13.3 million for MNM mines and \$1.2 million for Coal mines (see Table ES - 4).

**Table ES – 2. Estimated Cases of Avoided Lifetime Mortality and Morbidity Attributable to the Proposed Respirable Crystalline Silica Rule**

Health Outcome	Total Lifetime Avoided Cases [a]		
	MNM	Coal	Total
<b>Avoided Morbidity</b>			
Silicosis	2,566	244	2,809
<b>Avoided Morbidity Total (Net of Silicosis Fatalities)</b>	<b>2,566</b>	<b>244</b>	<b>2,809</b>
<b>Avoided Mortality</b>			
NMRD (net of silicosis mortality)	366	35	402
Silicosis	174	12	186
ESRD	139	12	150

Health Outcome	Total Lifetime Avoided Cases [a]		
	MNM	Coal	Total
Lung Cancer [b]	56	5	61
<b>Avoided Mortality Total</b>	<b>736</b>	<b>63</b>	<b>799</b>

[a] Cases include full-time-equivalent contract miners and assume compliance with the existing limits.

[b] Lung cancer estimates assume a 15-year lag between exposure and health effect.

**Table ES - 3. Estimated Cases of Avoided Mortality and Morbidity Attributable to the Proposed Respirable Crystalline Silica Rule over 60 Years (Regulatory Analysis Time Horizon)**

Health Outcome	Total Avoided Cases over 60 Years [a]		
	MNM	Coal	Total
<b>Avoided Morbidity</b>			
Silicosis	1,298.0	121.7	1,419.7
<b>Avoided Morbidity Total (Net of Silicosis Fatalities)</b>	<b>1,298.0</b>	<b>121.7</b>	<b>1,419.7</b>
<b>Avoided Mortality</b>			
NMRD (net of silicosis mortality)	186.8	16.4	203.2
Silicosis	94.8	8.1	102.9
ESRD	69.7	5.9	75.5
Lung Cancer [b]	26.0	2.3	28.2
<b>Avoided Mortality Total</b>	<b>377.3</b>	<b>32.6</b>	<b>409.9</b>

Numbers may not add up due to rounding.

[a] Cases include full-time-equivalent contract miners and assume compliance with the existing limits.

[b] Lung cancer estimates assume a 15-year lag between exposure and health effect.

**Table ES - 4. Estimated Benefits over 60 Years for the Proposed Respirable Crystalline Silica Rule Annualized at a 3 Percent Real Discount Rate (in Millions 2021 \$)**

Health Outcome	MNM	Coal	Total
<b>Avoided Morbidity (Not Preceding Mortality)</b>			
Silicosis (Net of Silicosis Mortality)	\$48.7	\$4.6	\$53.2
<b>Avoided Morbidity (Not Preceding Mortality) Total</b>	<b>\$48.7</b>	<b>\$4.6</b>	<b>\$53.2</b>
<b>Avoided Mortality</b>			
NMRD (Net of Silicosis Mortality)	\$48.5	\$4.2	\$52.8
Silicosis	\$25.9	\$2.2	\$28.1
ESRD	\$18.3	\$1.6	\$19.9
Lung Cancer	\$6.6	\$0.6	\$7.2
<b>Avoided Mortality Total</b>	<b>\$99.4</b>	<b>\$8.6</b>	<b>\$108.0</b>
<b>Avoided Morbidity (Preceding Mortality)</b>			
NMRD (Net of Silicosis Mortality)	\$6.3	\$0.5	\$6.9
Silicosis	\$3.7	\$0.3	\$4.0
ESRD	\$2.5	\$0.2	\$2.7
Lung Cancer	\$0.8	\$0.1	\$0.9
<b>Avoided Morbidity (Preceding Mortality) Total</b>	<b>\$13.3</b>	<b>\$1.2</b>	<b>\$14.5</b>
<b>Grand Total</b>	<b>\$161.4</b>	<b>\$14.3</b>	<b>\$175.7</b>

MSHA acknowledges that its benefit estimates are influenced by the underlying assumptions and that the long-time frame of this analysis (first 60 years) is a source of uncertainty. The main assumptions underlying these estimates of avoided mortality and morbidity include the following:

- Employment and production are held constant over the 60 years—the analysis period of the proposed rule.<sup>3</sup>
- Any miners currently exposed above the existing PELs are exposed to levels of respirable crystalline silica at existing standards (100  $\mu\text{g}/\text{m}^3$  for a full-shift exposure, calculated as an 8-hour TWA at MNM mines and 85.7  $\mu\text{g}/\text{m}^3$  for a full-shift exposure, calculated as an 8-hour TWA at coal mines).
- The proposed rule will result in miners being exposed at or below the proposed PEL (50  $\mu\text{g}/\text{m}^3$ ).
- Miners have identical employment and hence exposure tenures (45 years).
- The assumptions inherent in developing the exposure-response functions for the modeled health outcomes are reasonable throughout the exposure ranges relevant to this benefits analysis.

In addition to the above quantified health benefits, MSHA projects that there would be additional benefits from requiring approved respirators be selected, fitted, used, and maintained in accordance with ASTM F3387-19. The ASTM standard reflects developments in respiratory protection since MSHA issued its existing standards. These developments include OSHA's research and rulemaking on respiratory protection. ASTM F3387-19 also includes respiratory protection program elements: program administration; standard operating procedures (SOPs); medical evaluation; respirator selection; training; fit testing; respirator maintenance; and inspection and storage. Given the uncertainty about the current state of operator respiratory protection practices, MSHA did not quantify the benefits that would be realized by requiring approved respirators to be selected, fitted, used, and maintained in accordance with the requirements, as applicable, of ASTM F3387-19.

MSHA believes the proposed rule would lower exposures to respirable crystalline silica and respirable coal mine dust. MSHA expects that adverse health outcomes attributable to respirable coal mine dust exposure, such as Coal Workers' Pneumoconiosis (CWP), would also be reduced. However, the available exposure-response models do not account for exposures to both respirable crystalline silica and coal mine dust; therefore, it is difficult to estimate their separate effects. For example, exposures to respirable coal mine dust at or below the existing PEL, may still expose some miners, in certain occupations, to high concentrations of respirable crystalline silica. For these miners, MSHA anticipates that there would be additional unquantified benefits provided by the proposed rule. MSHA does quantify benefits from avoidance of 35 deaths from NMRD among coal miners over a 60-year period that includes 45

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<sup>3</sup> MSHA recognizes that it is impossible to predict economic factors over such a long period. Given known information and forecast limitations, MSHA believes this is a reasonable assumption.

years of working life (starting at age 21 and retiring at age 65) and 15 years of retirement (see Table ES – 2).

Finally, MSHA also expects that the proposed rule’s medical surveillance provisions would reduce mortality and morbidity from respirable crystalline silica exposure among MNM miners. The initial mandatory examination that assesses a new miner’s baseline pulmonary status, coupled with periodic examinations, would assist in the early detection of respirable crystalline silica related illnesses. Early detection of illness often leads to early intervention and treatment, which may slow disease progression and/or improve health outcomes. However, as noted, MSHA lacks data to quantify these additional benefits.

The net benefits of the proposed rule are the differences between the estimated benefits and costs. Table ES - 5 shows estimated net benefits using alternative discount rates of 0, 3, and 7 percent for benefits and costs. As is observed from the table, the choice of discount rate has a significant effect on annualized costs, benefits, and hence net benefits. While the net benefits of the proposed respirable crystalline silica rule vary considerably depending on the choice of discount rate used to annualize costs and benefits, total benefits exceed total costs under each discount rate considered. MSHA’s estimate of the net annualized benefits of the proposed rule, using a uniform discount rate for both costs and benefits of 3 percent, is \$118.2 million a year with the largest share (\$108.8 million; 92.0 percent) attributable to the MNM sector.

**Table ES - 5. Annualized Costs, Benefits, and Net Benefits of MSHA’s Proposed Respirable Crystalline Silica Rule (in Millions 2021 \$)**

Impact Category	MNM			Coal			Total		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
<b>Benefits</b>									
Mortality	\$160.0	\$99.4	\$49.4	\$13.8	\$8.6	\$4.3	\$73.8	\$108.0	\$53.8
Morbidity Preceding Mortality	\$19.6	\$13.3	\$7.5	\$1.7	\$1.2	\$0.7	\$21.3	\$14.5	\$8.2
Morbidity Not Preceding Mortality	\$67.5	\$48.7	\$31.3	\$6.3	\$4.6	\$2.9	\$73.8	\$53.2	\$34.2
<b>Total</b>	<b>\$247.1</b>	<b>\$161.4</b>	<b>\$88.2</b>	<b>\$21.8</b>	<b>\$14.3</b>	<b>\$7.9</b>	<b>\$268.9</b>	<b>\$175.7</b>	<b>\$96.2</b>
<b>Costs</b>									
Exposure Monitoring	\$27.3	\$28.7	\$30.9	\$3.3	\$3.4	\$3.5	\$30.6	\$32.0	\$34.3
Exposure Controls	\$4.8	\$4.9	\$5.0	\$0.8	\$0.9	\$0.9	\$5.6	\$5.7	\$5.9
Respiratory Protection	\$1.0	\$1.0	\$1.0	\$0.1	\$0.1	\$0.1	\$1.0	\$1.0	\$1.0
Medical Surveillance	\$17.5	\$17.4	\$17.2	--	--	--	\$17.5	\$17.4	\$17.2
ASTM Update	\$0.8	\$0.8	\$0.8	\$0.6	\$0.6	\$0.6	\$1.4	\$1.4	\$1.4
<b>Total</b>	<b>\$51.3</b>	<b>\$52.6</b>	<b>\$54.8</b>	<b>\$4.8</b>	<b>\$4.9</b>	<b>\$5.0</b>	<b>\$56.1</b>	<b>\$57.5</b>	<b>\$59.9</b>
<b>Net Benefits</b>	<b>\$195.8</b>	<b>\$108.8</b>	<b>\$33.4</b>	<b>\$17.0</b>	<b>\$9.4</b>	<b>\$2.9</b>	<b>\$212.8</b>	<b>\$118.2</b>	<b>\$36.3</b>

Note: Medical surveillance cost is the average cost under the assumed participation rate of 75 percent and 25 percent.

[a] For the purpose of simplifying the estimation of the monetized benefits of avoided illness and death, MSHA simply added the monetized benefits of morbidity preceding mortality to the monetized benefits of mortality at the time of death, and both would be discounted at that point. In theory, however, the monetized benefits of morbidity should be recognized (and discounted) at the onset of morbidity, as this is what a worker’s willingness to pay is presumed to measure—that is, the risk of immediate death or an immediate period of illness that a worker is willing to pay to avoid—a practice that would increase the present value of discounted morbidity benefits. A parallel tendency toward underestimation occurs with regard to morbidity not preceding mortality, since it implicitly assumes that the benefits occur at retirement. However, many, if not most, of the 2/0 or higher silicosis cases will have begun years before (with those classifications, in turn, preceded by a 1/0 classification). As a practical matter, however, the Agency lacks sufficient data at this time to refine the analysis in this way.

## 1 INTRODUCTION

The Preliminary Risk Analysis (PRA) has shown that miners exposed to respirable crystalline silica can face risk of injury and death from silicosis, lung cancer, nonmalignant respiratory diseases (NMRD), and end-stage renal disease (ESRD). The proposed rule addresses the risk of occupational exposure to respirable crystalline silica to protect miners.

The size of the mining industry, in terms of both employment and output, is difficult for economists to forecast given the uncertainties in future demand for various mining commodities, as well as uncertainties about technological change. Because of this uncertainty about the future size of the industry, MSHA has assumed a constant level of employment for all mining commodities in its forecasts for this analysis. Nevertheless, whether the industry contracts, or expands, for any of the mining commodities in the future, the relative ratio of benefits to costs will remain roughly the same because both the benefits and costs of the proposed rule are in proportion to the size of the industry. For example, if production and employment for one of the commodities expands by 50 percent, then both the benefits and costs of the rule will each expand by about 50 percent as well, and thus the benefits and costs will still be in relatively the same proportion to each other. Therefore, while the absolute size of the industry in the future remains somewhat uncertain, there will still be certainty in the general result as to whether the benefits of the rule will exceed its costs.

After carefully weighing the various potential advantages and disadvantages of using a regulatory approach to improve miners' current exposure from respirable crystalline silica, MSHA concludes that the proposed mandatory standards represent the best choice, consistent with its statutory obligations under the Mine Act. In addition, rulemaking is necessary to replace older existing standards with updated, clear, and consistent health standards.

This document presents the profile of mining industry, compliance cost estimates, benefit estimates, net benefits, economic feasibility, and regulatory alternatives.



## 2 MINERS AND THE MINING INDUSTRY

The proposed rule will affect mine operators and miners. This section provides information on the structure and economic characteristics of the metal and nonmetal (MNM) and coal mining industries including the number and types of mines by size. The section also presents the respirable crystalline silica exposure profile of all at-risk miners in the MNM and coal sectors. These data come from the U.S. Department of the Interior (DOI), U.S. Geological Survey (USGS); U.S. Department of Labor (DOL), Mine Safety and Health Administration (MSHA), Educational Policy and Development and Program Evaluation and Information Resources; DOL, Bureau of Labor Statistics (BLS), Occupational Employment and Wage Statistics (OES); U.S. Census Bureau, Statistics of U.S. Businesses (SUSB); and the Energy Information Administration (EIA).

The mining industry can be divided into two major sectors based on commodity: (1) metal and nonmetal (MNM) mines and (2) coal mines, with further distinction made regarding type of operation (e.g., underground mines or surface mines). The MNM mining sector is made up of metal mines (copper, iron ore, gold, silver, etc.) and nonmetal mines. Nonmetal mines can be categorized into four commodity groups: nonmetal (mineral) materials such as clays, potash, soda ash, salt, talc, and pyrophyllite; sand and gravel, including common sand and construction sand; stone including granite, limestone, dolomite, sandstone, slate, and marble; and crushed limestone.

MSHA tracks mine characteristics and maintains a database containing the number of mines by mine type and size, number of employees, and employee hours worked. MSHA also collects data on the number of independent contractor firms, their employees, and employee hours. While independent contractors are issued a unique MSHA contractor identification number, they may work at any mine.

MSHA categorizes mines by size based on employment. For purposes of this industry profile, MSHA has categorized mines into the following four groups for analysis purposes:<sup>4</sup> mines that employ: (1) 1-20 miners ( $\text{Emp} \leq 20$ ); (2) 21 to 100 miners ( $20 < \text{Emp} \leq 100$ ); (3) 101 to 500 miners ( $100 < \text{Emp} \leq 500$ ); and (4) 501 or more miners ( $500 > \text{Emp}$ ). Table 2-1 presents the number of MNM and coal mines, their employment, excluding contractors, and revenues by commodity type. All data are current as of 2019. The table presents four mine size categories based on miner employment: (1) 1-20 miners; (2) 21 to 100 miners; (3) 101 to 500 miners; and (4) 501 or more miners. In addition, it shows that, while the MNM sector has more than 10 times the number of mines than does coal, it only has roughly three times the number of miners. The MNM mining sector employs 169,070 workers, of which 150,928 are miners and 18,142 are office workers. There are 1,106 coal mines that reported production and that employ 52,966 workers, of which 51,573 are miners and 1,393 are office workers in 2019.

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<sup>4</sup> Miner employment is based on the information submitted quarterly through the MSHA Form 7000-2, excluding Subunit 99 – Office (professional and clerical employees at the mine or plant working in an office); [https://www.msha.gov/sites/default/files/Support Resources/Forms/7000-2\\_0.pdf](https://www.msha.gov/sites/default/files/Support%20Resources/Forms/7000-2_0.pdf)

Table 2-1. Profile of MNM and Coal Mines in 2019, by Mine Size

Mine Category	Range by Miner Employment	Tons (millions)		Revenues [a]		Number of Mines		Production Employees		Production Hours (thousands)		Total Employment	
		Millions	Percent	Millions in \$ 2019	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Metal	Emp <= 20	NA	NA	\$504.7	1.9%	157	56.1%	851	2.3%	1,433.8	1.9%	999	2.5%
Metal	20 < Emp <= 100	NA	NA	\$1,380.4	5.1%	39	13.9%	1,947	5.3%	3,921.3	5.1%	2,251	5.6%
Metal	100 < Emp <= 500	NA	NA	\$11,298.0	42.0%	62	22.1%	15,060	40.7%	32,094.2	42.0%	16,508	40.7%
Metal	500 > Emp	NA	NA	\$13,716.8	51.0%	22	7.9%	19,168	51.8%	38,965.3	51.0%	20,771	51.2%
Metal	<b>Total</b>	<b>NA</b>	<b>NA</b>	<b>\$26,900.0</b>	<b>100.0%</b>	<b>280</b>	<b>100.0%</b>	<b>37,026</b>	<b>100.0%</b>	<b>76,414.7</b>	<b>100.0%</b>	<b>40,529</b>	<b>100.0%</b>
Non-Metal	Emp <= 20	NA	NA	\$3,218.6	14.4%	645	71.9%	3,694	16.3%	6,397.5	14.4%	4,237	16.6%
Non-Metal	20 < Emp <= 100	NA	NA	\$8,957.7	40.1%	207	23.1%	8,921	39.3%	17,805.0	40.1%	10,065	39.3%
Non-Metal	100 < Emp <= 500	NA	NA	\$8,296.8	37.1%	42	4.7%	8,220	36.2%	16,491.4	37.1%	9,163	35.8%
Non-Metal	500 > Emp	NA	NA	\$1,872.3	8.4%	3	0.3%	1,845	8.1%	3,721.6	8.4%	2,134	8.3%
Non-Metal	<b>Total</b>	<b>NA</b>	<b>NA</b>	<b>\$22,345.4</b>	<b>100.0%</b>	<b>897</b>	<b>100.0%</b>	<b>22,680</b>	<b>100.0%</b>	<b>44,415.4</b>	<b>100.0%</b>	<b>25,599</b>	<b>100.0%</b>
Sand and Gravel	Emp <= 20	NA	NA	\$6,267.5	69.7%	5,879	96.7%	23,887	75.0%	39,673.3	69.7%	27,262	75.9%
Sand and Gravel	20 < Emp <= 100	NA	NA	\$2,284.3	25.4%	188	3.1%	6,703	21.1%	14,459.5	25.4%	7,320	20.4%
Sand and Gravel	100 < Emp <= 500	NA	NA	\$438.8	4.9%	10	0.2%	1,247	3.9%	2,777.6	4.9%	1,337	3.7%
Sand and Gravel	500 > Emp	NA	NA	\$0.0	0.0%	0	0.0%	0	0.0%	0.0	0.0%	0	0.0%
Sand and Gravel	<b>Total</b>	<b>NA</b>	<b>NA</b>	<b>\$8,990.7</b>	<b>100.0%</b>	<b>6,077</b>	<b>100.0%</b>	<b>31,837</b>	<b>100.0%</b>	<b>56,910.5</b>	<b>100.0%</b>	<b>35,919</b>	<b>100.0%</b>
Stone	Emp <= 20	NA	NA	\$3,653.3	28.5%	2,002	83.1%	11,198	31.7%	20,035.5	28.5%	12,563	31.5%
Stone	20 < Emp <= 100	NA	NA	\$5,623.9	43.8%	339	14.1%	14,779	41.9%	30,842.4	43.8%	16,824	42.2%
Stone	100 < Emp <= 500	NA	NA	\$3,357.2	26.2%	67	2.8%	8,762	24.8%	18,411.6	26.2%	9,896	24.8%
Stone	500 > Emp	NA	NA	\$200.4	1.6%	1	0.0%	539	1.5%	1,098.8	1.6%	602	1.5%
Stone	<b>Total</b>	<b>NA</b>	<b>NA</b>	<b>\$12,834.8</b>	<b>100.0%</b>	<b>2,409</b>	<b>100.0%</b>	<b>35,278</b>	<b>100.0%</b>	<b>70,388.3</b>	<b>100.0%</b>	<b>39,885</b>	<b>100.0%</b>
Crushed Limestone	Emp <= 20	NA	NA	\$5,836.3	45.8%	1,555	83.5%	11,771	48.8%	22,834.9	45.8%	13,495	49.7%
Crushed Limestone	20 < Emp <= 100	NA	NA	\$5,790.4	45.5%	293	15.7%	10,480	43.5%	22,655.5	45.5%	11,641	42.9%
Crushed Limestone	100 < Emp <= 500	NA	NA	\$1,102.4	8.7%	14	0.8%	1,856	7.7%	4,313.4	8.7%	2,002	7.4%
Crushed Limestone	500 > Emp	NA	NA	\$0.0	0.0%	0	0.0%	0	0.0%	0.0	0.0%	0	0.0%
Crushed Limestone	<b>Total</b>	<b>NA</b>	<b>NA</b>	<b>\$12,729.1</b>	<b>100.0%</b>	<b>1,862</b>	<b>100.0%</b>	<b>24,107</b>	<b>100.0%</b>	<b>49,803.8</b>	<b>100.0%</b>	<b>27,138</b>	<b>100.0%</b>
<b>MNM Total</b>	<b>Emp &lt;= 20</b>	<b>NA</b>	<b>NA</b>	<b>\$19,480.5</b>	<b>23.2%</b>	<b>10,238</b>	<b>88.8%</b>	<b>51,401</b>	<b>34.1%</b>	<b>90,375.0</b>	<b>30.3%</b>	<b>58,556</b>	<b>34.6%</b>
<b>MNM Total</b>	<b>20 &lt; Emp &lt;= 100</b>	<b>NA</b>	<b>NA</b>	<b>\$24,036.7</b>	<b>28.7%</b>	<b>1,066</b>	<b>9.2%</b>	<b>42,830</b>	<b>28.4%</b>	<b>89,683.7</b>	<b>30.1%</b>	<b>48,101</b>	<b>28.5%</b>
<b>MNM Total</b>	<b>100 &lt; Emp &lt;= 500</b>	<b>NA</b>	<b>NA</b>	<b>\$24,493.3</b>	<b>29.2%</b>	<b>195</b>	<b>1.7%</b>	<b>35,145</b>	<b>23.3%</b>	<b>74,088.3</b>	<b>24.9%</b>	<b>38,906</b>	<b>23.0%</b>
<b>MNM Total</b>	<b>500 &gt; Emp</b>	<b>NA</b>	<b>NA</b>	<b>\$15,789.5</b>	<b>18.8%</b>	<b>26</b>	<b>0.2%</b>	<b>21,552</b>	<b>14.3%</b>	<b>43,785.7</b>	<b>14.7%</b>	<b>23,507</b>	<b>13.9%</b>
<b>MNM Total</b>	<b>Total</b>	<b>NA</b>	<b>NA</b>	<b>\$83,800.0</b>	<b>100.0%</b>	<b>11,525</b>	<b>100.0%</b>	<b>150,928</b>	<b>100.0%</b>	<b>297,932.6</b>	<b>100.0%</b>	<b>169,070</b>	<b>100.0%</b>
Coal	Emp <= 20	16.6	2.3%	\$1,007.5	3.9%	707	63.9%	4,358	8.5%	9,077.4	7.7%	4,611	8.7%

Mine Category	Range by Miner Employment	Tons (millions)		Revenues [a]		Number of Mines		Production Employees		Production Hours (thousands)		Total Employment	
		Millions	Percent	Millions in \$ 2019	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Coal	20 < Emp <= 100	66.3	9.4%	\$3,225.6	12.6%	271	24.5%	11,814	22.9%	27,591.7	23.5%	12,145	22.9%
Coal	100 < Emp <= 500	366.8	51.9%	\$14,414.9	56.2%	116	10.5%	26,145	50.7%	59,897.7	51.0%	26,818	50.6%
Coal	500 > Emp	256.4	36.3%	\$7,001.6	27.3%	12	1.1%	9,256	17.9%	20,962.2	17.8%	9,392	17.7%
Coal	<b>Total</b>	<b>706.1</b>	<b>100.0%</b>	<b>\$25,649.6</b>	<b>100.0%</b>	<b>1,106</b>	<b>100.0%</b>	<b>51,573</b>	<b>100.0%</b>	<b>117,529.0</b>	<b>100.0%</b>	<b>52,966</b>	<b>100.0%</b>

NA = Not available

[a] Coal Revenues were calculated using MSHA Production Figures in Short Tons by Rank: 650.3 million tons Bituminous Coal, 53.2 million tons Lignite Coal, 2.6 million tons Anthracite Coal; and EIA price's per short ton by Coal Rank: EIA Annual Coal Report 2019; Table 31 Average Sales Price of Coal by State And Rank, 2019; US Total: \$58.93/ton Bituminous Coal, \$19.86/ton Lignite Coal, \$102.22/ton Anthracite Coal; [https://www.eia.gov/coal/annual/archive/0584\\_2019.pdf](https://www.eia.gov/coal/annual/archive/0584_2019.pdf). The revenues for MNM commodities are calculated by applying the proportion of revenues represented by each commodity among all MNM commodities in the 2017 SUSB data and applying that proportion to the 2019 production value for all industrial minerals reported by USGS.

## 2.1 Structure of the Mining Industry

### 2.1.1 MNM Mining Sector

The MNM mining sector is made up of metal mines (copper, iron ore, gold, silver, etc.) and nonmetal mines. In a 2012 study, Watts, *et al.* (2012) examined the trends in the MSHA metal and nonmetal dust data that was collected during 1974 – 2010. Their study data included nearly 147,000 respirable dust samples with a mass of at least 0.1 mg and a minimum of 1 percent quartz and represented roughly half of all respirable dust samples collected by MSHA. The other half of the samples collected did not meet the MSHA criteria for respirable quartz dust. The authors analyzed these data by location, commodity, and occupation.

For their analysis, Watts, *et al.* (2012) categorized the nonmetal mines into four commodity groups: nonmetal (mineral) materials such as clays, potash, soda ash, salt, talc, and pyrophyllite; sand and gravel, including industrial sands; stone including granite, limestone, dolomite, sandstone, slate, and marble; and crushed limestone.<sup>5</sup> MSHA uses the same categorization for this respirable crystalline silica rulemaking analysis. In 2019, the MNM mining sector employed 169,070 individuals, of which 150,928 were miners and 18,142 were office workers (Table 2-1). The breakdown of small and large mines is provided by commodity type below.

#### *Metal Mining*

There are 24 groups of metal commodities mined in the U.S. Metal mines represent about 2.4 percent (280 out of 11,525) of all MNM mines and employ roughly 24.5 percent of all MNM miners. Of these 280 mines, 157 (about 56 percent) employ 20 or fewer miners and 22 (7.9 percent) employ greater than 500 miners. Additionally, the 2019 MSHA data show that there are a total of 13,792 contract miners in the metal mining industry with a total of 18.9 million reported production hours.

#### *Non-Metal (mineral) Mining*

Thirty-five non-metal commodities are mined in the US, not including stone, and sand and gravel. Non-metal mines represent about 7.8 percent of all MNM mines and employ roughly 15 percent of all MNM miners. The majority (71.9 percent) of non-metal mines employ fewer than 20 miners and less than 1 percent employ more than 500 employees. According to

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<sup>5</sup> Watts et al. (2012) treated the sand and gravel and crushed limestone commodities separately for three reasons: 1) they qualified as individual “similarly exposed groups” based on the activities miners performed and the authors’ judgement about similarities of their expected exposures [pp. 721, 725 of article]; 2) “because of the large number of [silica exposure] samples collected in these two commodities” [pp. 724, 725], explained by 3) the fact that “over half [57.2 percent] of all active mines or mills [fell] into these two categories [p. 724].” Although Watts et al. was evaluating data collected 1993 through 2010, the same trend continues in MSHA’s 2006 through 2019 respirable crystalline silica dataset and in the information analyzed for this industry profile, which shows that 69 percent of MNM mines now fall into these two commodities.

the 2019 MSHA data, there are a total of 11,346 contract miners in the non-metal mining industry with a total of 14.5 million reported production hours.

### ***Sand and Gravel Mining***

Based on the number of mining operations, the sand and gravel subsector is the largest commodity group in the U.S. mining industry. Sand and gravel mines account for 52.7 percent of all MNM mines and employ 21.1 percent of all MNM miners. Nearly all (96.7 percent) of these mines employ fewer than 20 employees and the number of miners working in these mines comprise 15.8 percent of all MNM miners. In addition, the 2019 MSHA data show that there are a total of 7,512 contract miners in the sand and gravel mining industry with a total of 8.9 million reported production hours.

### ***Stone Mining***

The stone mining subsector includes eight different stone commodities. Seven of the eight are further classified as either dimension stone or crushed and broken stone. Stone mines make up 20.9 percent of all MNM mines and employ 23.4 percent of all MNM miners. The majority of these mines (83.1 percent) employ less than 20 miners (31.7 percent of all miners working in these stone mines). According to the 2019 MSHA data, there are a total of 18,559 contract miners in the stone mining industry with a total of 18.8 million reported production hours.

### ***Crushed Limestone***

Crushed Limestone mines make up 16.2 percent of all MNM mines and employ the about the same percentage (16.0 percent) of all MNM miners. Of the 1,862 crushed limestone mines, large majority (83.5 percent) employ fewer than 20 miners and there are no crushed limestone mines that employ over 500 miners. Additionally, the 2019 MSHA data show that there are a total of 9,605 contract miners in the crushed limestone mining industry with a total of 10.2 million reported production hours.

## **2.1.2 Coal Mining Sector**

As shown in Table 2-1, 1,106 coal mines had production in calendar year 2019. Of these 1,106 mines, 707 (63.9 percent) employed fewer than 20 miners, 271 (24.5 percent) between 21 to 100 miners, 116 (10.5 percent) between 101 and 500 miners, and the remaining 12 mines (1.1 percent) employed more than 500 miners. The overall coal mine employment in 2019 was 52,966, of which 51,573 were miners and the remaining 1,393 were office workers. Additionally, the 2019 MSHA data show that there are a total of 22,003 contract miners in the coal mining industry with a total of 28.0 million reported production hours.

## 2.2 Economic Characteristics of the Mining Industry

### 2.2.1 MNM Mining Sector

The value of all MNM mining output in 2019 was estimated at \$83.8 billion (U.S. Department of Interior, 2021). Metal mines, which include iron, gold, copper, silver, nickel, lead, zinc, uranium, radium, and vanadium mines, contributed \$26.9 billion. Production values for nonmetals, stone, sand and gravel, and crushed limestone are combined in to one commodity group titled industrial minerals in the USGS Mineral Commodity Summaries. Therefore, MSHA estimates the production value of each individual commodity by applying the proportion of revenues represented by each among all commodities in the 2017 USB and applying that proportion to the 2019 production value for all industrial minerals reported by USGS. This approach yields the following estimates: metal production was valued at \$26.9 billion, non-metal production at \$22.345 billion, stone mining at \$12.835 billion, sand and gravel at \$8.991 billion, and crushed limestone at \$12.729 billion.

### 2.2.2 Coal Mining Sector

The following three major commodity groups make up the US coal mining sector: bituminous, lignite, and anthracite. According to MSHA, bituminous operations represent approximately 92.1 percent of total coal production in short tons and 91.9 percent of coal miners. Anthracite operations represent 0.4 percent of coal production in short tons and 1.9 percent of coal miners. Lignite operations represent roughly 7.5 percent of total coal production in short tons and 6.2 percent of coal miners.

To estimate coal revenues in 2019, MSHA combines production estimates with prices per ton. Mine production data was taken from MSHA quarterly data and the coal price per ton was taken from the 2019 EIA Annual Coal Report. As shown in Table 2-1, total coal revenues in 2019 equaled \$25.6 billion.

## 2.3 Respirable Crystalline Silica Exposure Profile of Miners

Using the quarterly employment data submitted by mines and the Occupational Employment and Wage Statistics (OES) reported by the BLS, MSHA estimates the distribution of miners across different job categories. Table 2-2 and Table 2-3 present the distribution of 202,501 miners by job category across the MNM and coal sectors, respectively.

Table 2-2 shows that operators of haulage equipment (large and small) and mobile workers (i.e., laborers, electricians, mechanics, supervisors, and jackhammer operators) comprise the largest segment (79 percent) among all miners across the MNM sector. Table 2-3 shows that of the 51,573 coal miners, about 39 percent have the job title “miner” (9,228 surface and 10,653 underground combined), around 43 percent have the job title “large-powered haulage operator” (14,114 surface miners and 7,932 underground miners combined), and 11 percent have the job title “continuous mining machine operator.”

**Table 2-2. Estimated Number of Miners in MNM Sector in 2019, by Occupational Category**

Job Code	Job Description	Number of Miners	Percent
1	Drillers	2,841	1.9%
2	Stone Cutting Operators	6,345	4.2%
4	Conveyor Operators	0	0.0%
5	Truck Loading Station Tenders	5,550	3.7%
6	Crushing Equipment and Plant Operators	5,570	3.7%
7	Kiln, Mill, and Concentrator Workers	2,910	1.9%
8	Operators of Large Powered Haulage Equipment [a]	51,958	34.4%
9	Operators of Small Powered Haulage Equipment [b]	21,233	14.1%
10	Packaging Equipment Operators	2,277	1.5%
11	Mobile Workers [c]	46,497	30.8%
12	Miners in Other Occupations	5,747	3.8%
<b>MNM Total</b>		<b>150,928</b>	<b>100.0%</b>

[a] For example, trucks, front end loaders, bulldozers, and scalers.

[b] For example, bobcats and forklifts.

[c] The category includes laborers, electricians, mechanics, supervisors, and jackhammer operators.

**Table 2-3. Estimated Number of Miners in Coal Sector in 2019, by Occupational Category**

Job Code	Job Description	Number of Miners	Percent
1	Continuous Mining Machine Operators	5,811	11.3%
2	Underground Large Powered Haulage Operators	7,932	15.4%
3	Longwall Operators	569	1.1%
4	Underground Miners	10,653	20.7%
5	Roof Bolter Operators	2,565	5.0%
6	Surface Crusher Operators	289	0.6%
7	Surface Drills Operators	413	0.8%
8	Surface Large Powered Haulage Operators	14,114	27.4%
9	Surface Miners	9,228	17.9%
<b>Coal Total</b>		<b>51,573</b>	<b>100.00%</b>

MSHA did not have information on the types of jobs among the 82,278 contract miners of which 60,275 (73 percent) are in the MNM sector and the remaining 22,003 (27 percent) are in the coal sector. Thus, MSHA assumes that the distribution of contract miners across the different job categories mirrors that of the miners in the two sectors in the economic analysis. MSHA welcomes information on the types of jobs contract miners are likely to have in mines and invites input on how contract miners should be treated in the economic analysis.

Not all miners work full-time, i.e., 2,000 hours per year, and some miners work overtime during the course of a year. To account for the fact that miners may experience more or less than 2,000 hours of exposure per year, MSHA calculates the number of miner full-time equivalents (FTEs) by dividing the total number of hours by the number of miners reported for



each sector (Table 2-4).<sup>6</sup> In the MNM sector, there are 184,615 FTEs of which 148,966 (81 percent) are miner FTEs and the remaining 35,649 (19 percent) are contract miner FTEs. The shares of miner and contract miner FTEs are similar in the coal sector, with miner FTEs accounting for 81 percent (58,764 out of 72,768) and contract miner FTEs comprising 19 percent (14,004 out of 72,768) of total FTEs.

**Table 2-4. Miner and Contract Miner Full-time Equivalents (FTEs)**

Parameter	MNM	Coal	Total
Number of Contract Miners[a]	60,275	22,003	82,278
Number of Contract Miner Hours [a]	71,297,875	28,007,955	99,305,830
Contract Miner FTEs [b]	35,649	14,004	49,653
Number of Miners [c]	150,928	51,573	202,501
Number of Miner Hours [c]	297,932,646	117,528,968	415,461,614
Miner FTEs [d]	148,966	58,764	207,730
Miner and Contract Miner FTEs Combined [e]	184,615	72,768	257,383

[a] (Mine Safety and Health Administration, 2022a); (Mine Safety and Health Administration, 2022b)

[b] The figure is calculated by dividing the total number of contract miner hours by 2,000.

[c] From Table 2-2 and Table 2-3 above.

[d] Similar to the contract miner FTEs, the figure is calculated by dividing the total number of miner hours by 2,000.

[e] The figure is the sum of the calculated miner and contract miner FTEs.

In its Preliminary Risk Analysis (PRA), MSHA estimated the distribution of respirable dust samples in its MNM and coal exposure datasets by occupational category and exposure interval as presented in Table 2-5 and Table 2-6. The exposure intervals in the MNM sector are grouped into six ranges: Less than 25  $\mu\text{g}/\text{m}^3$ ;  $\geq 25 \mu\text{g}/\text{m}^3$  and  $\leq 50 \mu\text{g}/\text{m}^3$ ;  $> 50 \mu\text{g}/\text{m}^3$  and  $\leq 100 \mu\text{g}/\text{m}^3$ ;  $> 100 \mu\text{g}/\text{m}^3$  and  $\leq 250 \mu\text{g}/\text{m}^3$ ;  $> 250 \mu\text{g}/\text{m}^3$  and  $\leq 500 \mu\text{g}/\text{m}^3$ ; and greater than 500  $\mu\text{g}/\text{m}^3$ . In the coal sector, the exposure range of  $> 50 \mu\text{g}/\text{m}^3$  and  $\leq 100 \mu\text{g}/\text{m}^3$  is further separated into  $> 50 \mu\text{g}/\text{m}^3$  and  $\leq 85.7 \mu\text{g}/\text{m}^3$  and  $> 85.7 \mu\text{g}/\text{m}^3$  and  $\leq 100 \mu\text{g}/\text{m}^3$  to account for the conversion from

<sup>6</sup> In Section 3.1 of this analysis, the possibility of an exposure-response threshold is mentioned. The existence of a threshold could cause FTE-focused estimates to differ from what would be produced by evidence on the pattern of actual exposures. However, the Department doesn't anticipate this difference to be given the average duration of work hours among miners. The *NIOSH Survey of the Mining Population* (2012) indicates that the average working week for miners was 45.2 hours, and BLS *Current Employment Statistics Survey* (Jan 2021- Jan 2023) shows that employees in coal mining, metal mining, nonmetal mining, and stone mining average between 43 and 48 hours a week.



MRE measurement to ISO.<sup>7</sup> These frequencies represent the percentages of miners and miner FTEs in each job category currently exposed at levels within the indicated range.

Because exposure data associated with individual miners are not available, MSHA assumed the proportion of miners exposed to a given exposure range is equal to the proportion of samples in that range. Thus, MSHA applied the distribution of respirable dust samples in its MNM and coal exposure datasets to the miner population to derive the imputed exposure profile of miners and miner FTEs stratified by occupational category and exposure interval. Table 2-7 and Table 2-8 present the imputed exposure profile of miners and miner FTEs at risk from respirable crystalline silica exposure at all levels in 2019 in the MNM and coal sectors, respectively.

In the MNM sector, 14,323 miners (6 percent), including contract miners, currently have respirable crystalline silica exposures above the existing PEL of 100  $\mu\text{g}/\text{m}^3$ , 42,230 (17 percent) above the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ , and 83,833 (34 percent) above the proposed action level of 25  $\mu\text{g}/\text{m}^3$ . On an FTE basis, 11,769 miner FTEs (6 percent), including contract miner FTEs, have respirable crystalline silica exposures above the existing PEL of 100  $\mu\text{g}/\text{m}^3$ , 33,575 (18 percent) above the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ , and 65,943 (36 percent) above the proposed action level of 25  $\mu\text{g}/\text{m}^3$  (Table 2-7).

In the coal sector, 1,406 miners (2 percent), including contract miners, currently have respirable crystalline silica exposures above the existing PEL of 85.7  $\mu\text{g}/\text{m}^3$ , 4,080 (6 percent) above the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ , and 13,971 (19 percent) above the proposed action level of 25  $\mu\text{g}/\text{m}^3$ . On an FTE basis, the figures are similar with 1,391 miner FTEs (2 percent), including contract miner FTEs, having respirable crystalline silica exposures above the existing PEL of 85.7  $\mu\text{g}/\text{m}^3$ , 4,035 (6 percent) above the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ , and 13,818 (19 percent) above the proposed action level of 25  $\mu\text{g}/\text{m}^3$  (Table 2-8).

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<sup>7</sup> As discussed in the PRA, the existing PEL for coal is 100  $\mu\text{g}/\text{m}^3$  MRE, measured as a time-weighted average (TWA). When this figure is converted to International Organization for Standardization (ISO) from MRE it becomes 85.7  $\mu\text{g}/\text{m}^3$  ISO, measured as a TWA. The current PEL for MNM as well as the proposed PEL for both coal and MNM is 50  $\mu\text{g}/\text{m}^3$  ISO, measured, not at a time weighted average but as an 8-hour time weighted average. There is no single conversion factor that can be applied when adjusted from a time weighted average to an 8-hour time weighted average. This means it is not possible to express the current Coal PEL as a single ISO 8-hour time weighted average figure. Given this MSHA has chosen, when referring to coal's existing PEL, to express it as the approximate value of 85.7  $\mu\text{g}/\text{m}^3$  ISO, as measured as an 8-hour time weighted average. ISO concentration values (measured as 8-hour time-weighted average) were used as the exposure metric when calculating risk in both the baseline scenario (i.e., full compliance with the current PEL) and the proposed PEL of 50  $\mu\text{g}/\text{m}^3$  scenario. As such, exposures were deemed "noncompliant" if they exceeded 85.7  $\mu\text{g}/\text{m}^3$  measured as an ISO 8-hour time-weighted average.

**Table 2-5. Percentage Distribution of Respirable Crystalline Silica Exposures in the MNM Industry from 2005 to 2019, by Occupational Category and Exposure Interval**

Job Code	Job Description	Number of Samples [a]	Percentage of Samples in ISO Concentration Ranges, $\mu\text{g}/\text{m}^3$						Total
			$\leq 25$ $\mu\text{g}/\text{m}^3$	$> 25$ to $\leq 50$ $\mu\text{g}/\text{m}^3$	$> 50$ to $\leq 100$ $\mu\text{g}/\text{m}^3$	$> 100$ to $\leq 250$ $\mu\text{g}/\text{m}^3$	$> 250$ to $\leq 500$ $\mu\text{g}/\text{m}^3$	$> 500$ $\mu\text{g}/\text{m}^3$	
1	Drillers	2,092	67.9%	16.8%	10.2%	3.8%	0.9%	0.4%	100.0%
2	Stone Cutting Operators	2,446	32.3%	20.9%	27.4%	13.9%	4.0%	1.4%	100.0%
4	Conveyor Operators	215	55.8%	23.3%	9.8%	8.8%	1.9%	0.5%	100.0%
5	Truck Loading Station Tenders	453	66.7%	12.8%	13.5%	6.4%	0.4%	0.2%	100.0%
6	Crushing Equipment and Plant Operators	11,565	58.7%	20.8%	13.4%	5.8%	1.0%	0.2%	100.0%
7	Kiln, Mill, and Concentrator Workers	1,802	59.1%	19.4%	14.6%	4.6%	1.6%	0.7%	100.0%
8	Operators of Large Powered Haulage Equipment [b]	17,016	77.2%	14.0%	6.6%	2.0%	0.2%	0.0%	100.0%
9	Operators of Small Powered Haulage Equipment [c]	1,110	58.7%	19.4%	15.0%	5.4%	1.0%	0.5%	100.0%
10	Packing Equipment Operators	2,980	56.0%	18.3%	16.3%	7.4%	1.3%	0.6%	100.0%
11	Mobile Workers [d]	15,216	61.2%	18.9%	12.6%	5.8%	1.1%	0.4%	100.0%
12	Miners in Other Occupations	2,874	74.1%	13.7%	8.0%	3.0%	0.9%	0.3%	100.0%
<b>MNM Total</b>		<b>57,769</b>	<b>64.7%</b>	<b>17.6%</b>	<b>11.6%</b>	<b>4.8%</b>	<b>1.0%</b>	<b>0.3%</b>	<b>100.0%</b>

Source: MSHA MSIS respirable crystalline silica data for the MNM industry, January 1, 2005, through December 31, 2019 (version 20220812). Also see PRA Table 5 for a breakdown by MNM commodity.

[a] Personal samples collected using ISO-compliant sampling methods and calculated as an 8-hour equivalent time-weighted average (8-hour TWA). Samples were collected using an air flow rate of 1.7 L/min and reported as 8-hour TWAs.

[b] For example, trucks, front end loaders, bulldozers, and scalers.

[c] For example, bobcats and forklifts.

[d] The category includes laborers, electricians, mechanics, supervisors, and jackhammer operators.

**Table 2-6. Percentage Distribution of Respirable Crystalline Silica Exposures as ISO 8-hour TWA in the Coal Industry from 2016 to 2021, by Occupational Category and Exposure Interval**

Job Code	Job Description	Number of Samples [a]	Percentage of Samples in ISO Concentration Ranges, 8-hour TWA, $\mu\text{g}/\text{m}^3$							Total
			$\leq 25$ $\mu\text{g}/\text{m}^3$	$> 25$ to $\leq 50$ $\mu\text{g}/\text{m}^3$	$> 50$ to $\leq 85.7$ $\mu\text{g}/\text{m}^3$	$> 85.7$ to $\leq 100$ $\mu\text{g}/\text{m}^3$	$> 100$ to $\leq 250$ $\mu\text{g}/\text{m}^3$	$> 250$ to $\leq 500$ $\mu\text{g}/\text{m}^3$	$> 500$ $\mu\text{g}/\text{m}^3$	
1	Continuous Mining Machine Operators	9,910	68.1%	23.9%	5.8%	0.7%	1.5%	0.1%	0.0%	100.0%
2	Underground Large Powered Haulage Operators	21,777	82.4%	14.3%	2.6%	0.2%	0.4%	0.0%	0.0%	100.0%
3	Longwall Operators	3,176	55.6%	27.0%	11.2%	2.0%	3.9%	0.3%	0.0%	100.0%
4	Underground Miners	3,926	86.5%	10.1%	2.4%	0.3%	0.6%	0.1%	0.0%	100.0%
5	Roof Bolter Operators	14,306	61.3%	29.3%	7.6%	0.7%	1.0%	0.0%	0.0%	100.0%
6	Surface Crusher Operators	631	93.2%	4.4%	2.1%	0.2%	0.2%	0.0%	0.0%	100.0%
7	Surface Drills Operators	1,762	57.8%	24.0%	10.2%	1.7%	5.1%	1.0%	0.2%	100.0%
8	Surface Large Powered Haulage Operators	5,313	80.3%	11.8%	4.1%	0.8%	2.5%	0.3%	0.1%	100.0%
9	Surface Miners	2,326	90.4%	7.1%	1.9%	0.1%	0.5%	0.0%	0.0%	100.0%
<b>Coal Total</b>		<b>63,127</b>	<b>73.8%</b>	<b>19.3%</b>	<b>5.0%</b>	<b>0.6%</b>	<b>1.2%</b>	<b>0.1%</b>	<b>0.0%</b>	<b>100.0%</b>

Source: MSHA MSIS respirable crystalline silica data for the coal industry, August 1, 2016, through July 31, 2021 (version 20220617). Also see PRA Table 9.

[a] Personal samples presented in terms of ISO concentrations, normalized to 8-hour time-weighted averages (8-hour TWA). The samples were originally collected for the entire duration of each miner's work shift, using an air flow rate of 2 L/min.

**Table 2-7. Imputed Respirable Crystalline Silica Exposure Profile of Miners and Miner FTEs in the MNM Industry in 2019, by Occupational Category and Exposure Interval**

Job Code	Job Description	Number of Miners [a]	Miners in ISO Concentration Ranges, $\mu\text{g}/\text{m}^3$					
			$\leq 25$ $\mu\text{g}/\text{m}^3$	$> 25$ to $\leq 50$ $\mu\text{g}/\text{m}^3$	$> 50$ to $\leq 100$ $\mu\text{g}/\text{m}^3$	$> 100$ to $\leq 250$ $\mu\text{g}/\text{m}^3$	$> 250$ to $\leq 500$ $\mu\text{g}/\text{m}^3$	$> 500$ $\mu\text{g}/\text{m}^3$
1	Drillers	4,610	3,132	774	469	174	42	20
2	Stone Cutting Operators	10,295	3,329	2,151	2,820	1,435	417	143
4	Conveyor Operators	0	0	0	0	0	0	0
5	Truck Loading Station Tenders	9,006	6,004	1,153	1,213	577	40	20
6	Crushing Equipment and Plant Operators	9,038	5,308	1,882	1,210	523	95	20
7	Kiln, Mill, and Concentrator Workers	4,722	2,791	915	689	218	76	34
8	Operators of Large Powered Haulage Equipment [b]	84,305	65,091	11,806	5,534	1,660	183	30
9	Operators of Small Powered Haulage Equipment [c]	34,451	20,236	6,673	5,152	1,862	341	186
10	Packing Equipment Operators	3,694	2,070	677	602	275	47	22
11	Mobile Workers [d]	75,444	46,180	14,294	9,475	4,343	833	317
12	Miners in Other Occupations	9,326	6,915	1,278	743	276	81	32
<b>MNM Total</b>		<b>244,890</b>	<b>161,057</b>	<b>41,603</b>	<b>27,908</b>	<b>11,343</b>	<b>2,155</b>	<b>825</b>
Job Code	Job Description	Number of Miner FTEs [a]	Miner FTEs in ISO Concentration Ranges, $\mu\text{g}/\text{m}^3$					
			$\leq 25$ $\mu\text{g}/\text{m}^3$	$> 25$ to $\leq 50$ $\mu\text{g}/\text{m}^3$	$> 50$ to $\leq 100$ $\mu\text{g}/\text{m}^3$	$> 100$ to $\leq 250$ $\mu\text{g}/\text{m}^3$	$> 250$ to $\leq 500$ $\mu\text{g}/\text{m}^3$	$> 500$ $\mu\text{g}/\text{m}^3$
1	Drillers	3,476	2,232	677	392	134	28	14
2	Stone Cutting Operators	7,761	3,007	1,442	1,879	960	331	142
4	Conveyor Operators	0	0	0	0	0	0	0
5	Truck Loading Station Tenders	6,789	4,641	929	774	414	21	10
6	Crushing Equipment and Plant Operators	6,813	3,846	1,428	983	454	83	19
7	Kiln, Mill, and Concentrator Workers	3,560	2,204	646	486	150	51	23
8	Operators of Large Powered Haulage Equipment [b]	63,555	46,748	9,954	5,052	1,632	156	13
9	Operators of Small Powered Haulage Equipment [c]	25,972	15,689	4,886	3,579	1,378	246	194
10	Packing Equipment Operators	2,785	1,695	446	396	190	37	20
11	Mobile Workers [d]	56,875	33,952	10,921	7,465	3,493	787	256
12	Miners in Other Occupations	7,030	4,659	1,039	798	380	86	70
<b>MNM Total</b>		<b>184,615</b>	<b>118,672</b>	<b>32,369</b>	<b>21,805</b>	<b>9,185</b>	<b>1,825</b>	<b>759</b>

[a] The figure includes both miners and contract miners in the MNM sector.

[b] For example, trucks, front end loaders, bulldozers, and scalars.

[c] For example, bobcats and forklifts.

[d] The category includes laborers, electricians, mechanics, supervisors, and jackhammer operators.

**Table 2-8. Imputed Respirable Crystalline Silica Exposure Profile of Miners and Miner FTEs in the Coal Industry in 2019, by Occupational Category and Exposure Interval**

Job Code	Job Description	Number of Miners [a]	Number of Miners in ISO Concentration Ranges, 8-hour TWA, $\mu\text{g}/\text{m}^3$						
			$\leq 25$ $\mu\text{g}/\text{m}^3$	$> 25$ to $\leq 50$ $\mu\text{g}/\text{m}^3$	$> 50$ to $\leq 85.7$ $\mu\text{g}/\text{m}^3$	$> 85.7$ to $\leq 100$ $\mu\text{g}/\text{m}^3$	$> 100$ to $\leq 250$ $\mu\text{g}/\text{m}^3$	$> 250$ to $\leq 500$ $\mu\text{g}/\text{m}^3$	$> 500$ $\mu\text{g}/\text{m}^3$
1	Continuous Mining Machine Operators	8,290	5,647	1,979	479	56	120	9	0
2	Underground Large Powered Haulage Operators	11,316	9,322	1,616	299	27	49	4	0
3	Longwall Operators	811	451	219	91	16	32	2	0
4	Underground Miners	15,199	13,147	1,541	372	43	85	12	0
5	Roof Bolter Operators	3,659	2,243	1,073	280	27	36	1	0
6	Surface Crusher Operators	412	384	18	8	1	1	0	0
7	Surface Drills Operators	589	340	141	60	10	30	6	1
8	Surface Large Powered Haulage Operators	20,135	16,175	2,376	830	171	500	68	15
9	Surface Miners	13,164	11,897	928	255	17	62	6	0
<b>Coal Total</b>		<b>73,576</b>	<b>59,605</b>	<b>9,892</b>	<b>2,673</b>	<b>366</b>	<b>916</b>	<b>107</b>	<b>17</b>
Job Code	Job Description	Number of Miner FTEs [a]	Number of Miner FTEs in ISO Concentration Ranges, 8-hour TWA, $\mu\text{g}/\text{m}^3$						
			$\leq 25$ $\mu\text{g}/\text{m}^3$	$> 25$ to $\leq 50$ $\mu\text{g}/\text{m}^3$	$> 50$ to $\leq 85.7$ $\mu\text{g}/\text{m}^3$	$> 85.7$ to $\leq 100$ $\mu\text{g}/\text{m}^3$	$> 100$ to $\leq 250$ $\mu\text{g}/\text{m}^3$	$> 250$ to $\leq 500$ $\mu\text{g}/\text{m}^3$	$> 500$ $\mu\text{g}/\text{m}^3$
1	Continuous Mining Machine Operators	8,199	5,585	1,958	473	55	119	9	0
2	Underground Large Powered Haulage Operators	11,192	9,219	1,598	296	26	49	4	0
3	Longwall Operators	802	446	216	90	16	32	2	0
4	Underground Miners	15,032	13,003	1,524	368	42	84	11	0
5	Roof Bolter Operators	3,619	2,218	1,061	277	27	36	1	0
6	Surface Crusher Operators	407	380	18	8	1	1	0	0
7	Surface Drills Operators	582	337	139	59	10	30	6	1
8	Surface Large Powered Haulage Operators	19,914	15,997	2,350	821	169	495	67	15
9	Surface Miners	13,020	11,766	918	252	17	62	6	0
<b>Coal Total</b>		<b>72,768</b>	<b>58,951</b>	<b>9,783</b>	<b>2,644</b>	<b>362</b>	<b>906</b>	<b>106</b>	<b>17</b>

[a] The figure includes both miner and contract miner FTEs in the coal sector.

### 3 BENEFIT ANALYSIS

In this section, MSHA estimates the benefits of the proposed respirable crystalline silica rule. To develop estimates of the benefits, the following sections forecast the number of silica-related diseases prevented because of the proposed rule over a regulatory analysis time horizon of 60 years and estimate monetized benefits of the prevented diseases. Additionally, MSHA discusses the non-quantified benefits of the proposed rule's updated standards for respiratory protection in MNM and coal mines. MSHA invites comments on any aspect of the data and methods used in this section.

#### 3.1 Estimation of the Lifetime Number of Silica-related Diseases Avoided

For economic analysis purposes, MSHA estimates the benefits associated with avoided cases of disease (both morbidity and mortality) attributable to the proposed PEL of  $50 \mu\text{g}/\text{m}^3$  for the following health outcomes identified in the PRA:

- Non-fatal cases of silicosis,
- Fatal cases of non-malignant respiratory disease (NMRD) (excluding silicosis),
- Fatal cases of silicosis,
- Fatal cases of end-stage renal disease (ESRD), and
- Fatal cases of lung cancer.

Avoided lifetime cases of respirable crystalline silica related diseases are calculated as the difference between estimated lifetime cases under the existing limits of  $100 \mu\text{g}/\text{m}^3$  for MNM and  $85.7 \mu\text{g}/\text{m}^3$  for coal<sup>8</sup> to those under the proposed PEL of  $50 \mu\text{g}/\text{m}^3$ . MSHA applied the exposure-response relationships developed in the PRA (PRA Table 2) to the imputed exposure profile presented in Table 2-7 and Table 2-8 above to determine risks associated with various exposure levels for each of the respirable crystalline silica-related diseases.

More specifically, after distributing the miner population (stratified by occupational category) to exposure groups based on the proportion of samples occurring in each exposure

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<sup>8</sup> As discussed in the PRA, the existing PEL for coal is  $100 \mu\text{g}/\text{m}^3$  MRE, measured as a full-shift time-weighted average (TWA). To calculate risks consistently for both coal and MNM miners, the PRA converts the MRE full-shift TWA concentrations experienced by coal miners to ISO 8-hour TWA concentrations (see Section 4 of the PRA for a full explanation). Note that exposures at TWA  $100 \mu\text{g}/\text{m}^3$  MRE and SWA  $85.7 \mu\text{g}/\text{m}^3$  ISO are only equivalent when the sampling duration is 480 minutes (eight hours). However, for the sake of simplicity, this analysis approximates exposures at the existing coal exposure limit of  $100 \text{ MRE } \mu\text{g}/\text{m}^3$  as  $85.7 \mu\text{g}/\text{m}^3$  ISO for comparison purposes. Thus, ISO concentration values (measured as an 8-hour time-weighted average) were used as the exposure metric when calculating risk under in both the baseline scenario (i.e., full compliance with the existing standards) and the proposed PEL of  $50 \mu\text{g}/\text{m}^3$  scenario. To simulate compliance among coal miners, exposures were capped at  $85.7 \mu\text{g}/\text{m}^3$  measured as an ISO 8-hour time-weighted average, which is approximately equal to the existing coal PEL, when calculating risks to coal miners in the baseline scenario.

interval, MSHA first calculated the median exposure of MSHA inspection samples in each exposure interval. Assuming full compliance with the existing limits (100  $\mu\text{g}/\text{m}^3$  for MNM miners and 85.7  $\mu\text{g}/\text{m}^3$  for coal miners), MSHA then assigned the existing limits to those groups with exposures in excess of the existing limits and the median exposures to those with exposures below the existing limits. Under the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ , MSHA projects that miners in those strata with exposures above 50  $\mu\text{g}/\text{m}^3$  under the existing limits will have exposures at 50  $\mu\text{g}/\text{m}^3$  after the final rule promulgation and the exposures of those miners that were below 50  $\mu\text{g}/\text{m}^3$  under the existing limits will remain at their median levels. Table 3-1 presents the median exposures of miners under the existing limits and the proposed PEL, by sector and exposure interval. Estimating risks and cases for each such group, and subsequently aggregating across all groups, yields overall estimates for lifetime risk and lifetime cases among MNM and coal miners under each scenario as MSHA presents in its PRA.

**Table 3-1. Median Exposures of Miners, by Sector and Exposure Interval**

Exposure Interval	From MSHA Exposure Datasets		Under Existing Limits (100 $\mu\text{g}/\text{m}^3$ for MNM and 85.7 $\mu\text{g}/\text{m}^3$ for Coal)		Under the Proposed PEL of 50 $\mu\text{g}/\text{m}^3$	
	MNM	Coal	MNM	Coal	MNM	Coal
$\leq 25 \mu\text{g}/\text{m}^3$	7.0	12.3	7.0	12.3	7.0	12.3
$> 25$ to $\leq 50 \mu\text{g}/\text{m}^3$	35.0	33.3	35.0	33.3	35.0	33.3
$> 50$ to $\leq 85.7 \mu\text{g}/\text{m}^3$	69.0	60.4	69.0	60.4	50.0	50.0
$> 85.7$ to $\leq 100 \mu\text{g}/\text{m}^3$		92.4		85.7		50.0
$> 100$ to $\leq 250 \mu\text{g}/\text{m}^3$	138.0	126.9	100.0	85.7	50.0	50.0
$> 250$ to $\leq 500 \mu\text{g}/\text{m}^3$	322.0	288.3	100.0	85.7	50.0	50.0
$> 500 \mu\text{g}/\text{m}^3$	613.0	666.5	100.0	85.7	50.0	50.0

In the PRA, to examine the lifetime effect of simply changing the PEL, MSHA compares the number of various kinds of cases of respirable crystalline silica-related disease that would occur if miners are exposed for an entire working life at or below the proposed PEL of 50  $\mu\text{g}/\text{m}^3$  to the number of cases that would occur at levels of exposure at or below the existing limits (100  $\mu\text{g}/\text{m}^3$  for MNM and 85.7  $\mu\text{g}/\text{m}^3$  for coal) using a life table methodology (see Appendix B of PRA). Risk estimates for morbidity and mortality due to occupational exposure to respirable crystalline silica are presented in terms of lifetime excess risk per 1,000 exposed miners. Lifetime risks and cases are estimated over a 60-year period that includes 45 years of working life (starting at age 21 and retiring at age 65) and 15 years of retirement. This approach is to properly account for adverse health impacts resulting from cumulative exposure to respirable crystalline silica that may manifest during a miner's working years as well as retirement years even after silica exposure ceases. The assumptions of a 45-year "working life" (constituting 45 years of exposure) and a 15-year retirement are established by precedent as documented in the PRA (73 FR 11292). The annual exposure duration is scaled by a weighted average FTE ratio<sup>9</sup>

<sup>9</sup> FTEs was chosen as the unit of measurement for the benefits analysis to account for health benefits because health benefits are a function of hours exposed. Miners who work less than full time are exposed less than average exposure are therefore at lower risk, while those who consistently work overtime are exposed more than average exposure and at higher risk. Using FTEs adjusts for exposure hours by standardizing miner hours.



for both contract miners and production employees. Table 3-2 below presents the estimated lifetime risks per 1,000 exposed miners at exposure levels equal to the existing limits, the proposed PEL and the differences in lifetime risks post rule promulgation for each of the respirable crystalline silica related diseases.

**Table 3-2. Incremental Reduction in Lifetime Excess Risk per 1,000 Miners Exposed to Respirable Crystalline Silica Under the Proposed Rule, by Exposure Interval and Health Outcome**

Health Outcome	Exposure Interval	Under Existing Limits (100 µg/m³ for MNM and 85.7 µg/m³ for Coal)		Under the Proposed PEL of 50 µg/m³		Incremental Reduction in Lifetime Risk Attributable to the Proposed Rule	
		MNM	Coal	MNM	Coal	MNM	Coal
Morbidity							
Silicosis	≤ 25 µg/m³	10.1	12.8	10.1	12.8	0.0	0.0
	> 25 to ≤ 50 µg/m³	26.3	28.8	26.3	28.8	0.0	0.0
	> 50 to ≤ 85.7 µg/m³	81.3	79.5	43.6	54.2	37.6	25.2
	> 85.7 to ≤ 100 µg/m³		189.9		54.2		135.7
	> 100 to ≤ 250 µg/m³	206.7	189.9	43.6	54.2	163.1	135.7
	> 250 to ≤ 500 µg/m³	206.7	189.9	43.6	54.2	163.1	135.7
	> 500 µg/m³	206.7	189.9	43.6	54.2	163.1	135.7
Mortality							
NMRD	≤ 25 µg/m³	4.0	7.9	4.0	7.9	0.0	0.0
	> 25 to ≤ 50 µg/m³	19.6	21.1	19.6	21.1	0.0	0.0
	> 50 to ≤ 85.7 µg/m³	38.2	37.8	27.9	31.5	10.3	6.4
	> 85.7 to ≤ 100 µg/m³		53.1		31.5		21.6
	> 100 to ≤ 250 µg/m³	54.7	53.1	27.9	31.5	26.8	21.6
	> 250 to ≤ 500 µg/m³	54.7	53.1	27.9	31.5	26.8	21.6
	> 500 µg/m³	54.7	53.1	27.9	31.5	26.8	21.6
Silicosis	≤ 25 µg/m³	2.5	2.5	2.5	2.5	0.0	0.0
	> 25 to ≤ 50 µg/m³	4.8	5.0	4.8	5.0	0.0	0.0
	> 50 to ≤ 85.7 µg/m³	9.4	9.4	5.9	8.1	3.5	1.3
	> 85.7 to ≤ 100 µg/m³		14.0		8.1		5.9
	> 100 to ≤ 250 µg/m³	14.3	14.0	5.9	8.1	8.4	5.9
	> 250 to ≤ 500 µg/m³	14.3	14.0	5.9	8.1	8.4	5.9
	> 500 µg/m³	14.3	14.0	5.9	8.1	8.4	5.9
ESRD	≤ 25 µg/m³	12.9	16.8	12.9	16.8	0.0	0.0
	> 25 to ≤ 50 µg/m³	23.2	23.7	23.2	23.7	0.0	0.0
	> 50 to ≤ 85.7 µg/m³	28.9	28.8	26.1	27.1	2.9	1.7
	> 85.7 to ≤ 100 µg/m³		32.2		27.1		5.1
	> 100 to ≤ 250 µg/m³	32.5	32.2	26.1	27.1	6.5	5.1
	> 250 to ≤ 500 µg/m³	32.5	32.2	26.1	27.1	6.5	5.1
	> 500 µg/m³	32.5	32.2	26.1	27.1	6.5	5.1

Health Outcome	Exposure Interval	Under Existing Limits (100 $\mu\text{g}/\text{m}^3$ for MNM and 85.7 $\mu\text{g}/\text{m}^3$ for Coal)		Under the Proposed PEL of 50 $\mu\text{g}/\text{m}^3$		Incremental Reduction in Lifetime Risk Attributable to the Proposed Rule	
		MNM	Coal	MNM	Coal	MNM	Coal
Lung Cancer	$\leq 25 \mu\text{g}/\text{m}^3$	0.4	0.7	0.4	0.7	0.0	0.0
	$> 25$ to $\leq 50 \mu\text{g}/\text{m}^3$	1.8	2.0	1.8	2.0	0.0	0.0
	$> 50$ to $\leq 85.7 \mu\text{g}/\text{m}^3$	3.7	3.6	2.6	3.0	1.1	0.7
	$> 85.7$ to $\leq 100 \mu\text{g}/\text{m}^3$		5.3		3.0		2.3
	$> 100$ to $\leq 250 \mu\text{g}/\text{m}^3$	5.5	5.3	2.6	3.0	2.8	2.3
	$> 250$ to $\leq 500 \mu\text{g}/\text{m}^3$	5.5	5.3	2.6	3.0	2.8	2.3
	$> 500 \mu\text{g}/\text{m}^3$	5.5	5.3	2.6	3.0	2.8	2.3

For example, Table 3-2 shows that the lifetime excess risk of silicosis morbidity for MNM miners is 206.7 in 1,000 at 100-250  $\mu\text{g}/\text{m}^3$  exposure interval under the existing limit of 100  $\mu\text{g}/\text{m}^3$ , compared to the general population. This lifetime excess risk is lowered to 43.6 in 1,000 miners in this exposure interval, if the existing limit is dropped to the proposed level of 50  $\mu\text{g}/\text{m}^3$ . Then the estimated reduction of risk attributable to the proposed rule for MNM miners in this exposure interval is 163.1, which is the difference between 206.7 and 43.6. Given that there currently are 9,185 MNM miner FTEs in this exposure interval (Table 2-7), the proposed PEL would cut the risk by 163.1 in 1,000 miners and reduce the number of expected lifetime cases in the future by 1,498 ( $=163.1 \times 9.185$ ) from 1,898 ( $=206.7 \times 9.185$ ) to 400 ( $43.6 \times 9.185$ ) among the group with a current exposure profile of 100-250  $\mu\text{g}/\text{m}^3$ .

The number of avoided cases over a hypothetical working life of exposure for the current population at a lower PEL is then equal to the difference between the number of cases at levels of exposure at or below the existing PEL for that population and the number of cases at the lower proposed PEL. This approach represents a steady-state comparison based on what would hypothetically happen to miners who received a specific average level of occupational exposure to respirable crystalline silica during an entire working life. Table 3-3 presents the avoided lifetime cases for miners after the final rule promulgation for each of the respirable crystalline silica-related diseases by exposure interval as a corollary to Table 3-2. Table 3-4 presents a summary by health outcome.

**Table 3-3. Estimated Cases of Avoided Lifetime Cases Among Miners Exposed to Respirable Crystalline Silica Under the Proposed Rule, by Exposure Interval and Health Outcome**

Health Outcome	Exposure Interval	Under Existing Limits (100 µg/m³ for MNM and 85.7 µg/m³ for Coal)		Under the Proposed PEL of 50 µg/m³		Avoided Lifetime Cases Attributable to the Proposed Rule	
		MNM	Coal	MNM	Coal	MNM	Coal
Morbidity							
Silicosis (Excluding Silicosis Deaths) [a]	≤ 25 µg/m³	905.7	610.5	905.7	610.5	0.0	0.0
	> 25 to ≤ 50 µg/m³	695.7	232.3	695.7	232.3	0.0	0.0
	> 50 to ≤ 85.7 µg/m³	1,568.1	185.4	822.9	122.0	745.2	63.3
	> 85.7 to ≤ 100 µg/m³		63.7		16.7		47.0
	> 100 to ≤ 250 µg/m³	1,767.2	159.4	346.6	41.8	1,420.6	117.5
	> 250 to ≤ 500 µg/m³	351.2	18.6	68.9	4.9	282.4	13.7
	> 500 µg/m³	146.1	2.9	28.7	0.8	117.5	2.1
Morbidity Total (Excluding Silicosis Deaths) [a]	≤ 25 µg/m³	905.7	610.5	905.7	610.5	0.0	0.0
	> 25 to ≤ 50 µg/m³	695.7	232.3	695.7	232.3	0.0	0.0
	> 50 to ≤ 85.7 µg/m³	1,568.1	185.4	822.9	122.0	745.2	63.3
	> 85.7 to ≤ 100 µg/m³		63.7		16.7		47.0
	> 100 to ≤ 250 µg/m³	1,767.2	159.4	346.6	41.8	1,420.6	117.5
	> 250 to ≤ 500 µg/m³	351.2	18.6	68.9	4.9	282.4	13.7
	> 500 µg/m³	146.1	2.9	28.7	0.8	117.5	2.1
Mortality							
NMRD (Excluding Silicosis Deaths) [b]	≤ 25 µg/m³	178.3	319.1	178.3	319.1	0.0	0.0
	> 25 to ≤ 50 µg/m³	478.2	156.8	478.2	156.8	0.0	0.0
	> 50 to ≤ 85.7 µg/m³	628.7	75.2	479.2	61.8	149.5	13.5
	> 85.7 to ≤ 100 µg/m³		14.2		8.5		5.7
	> 100 to ≤ 250 µg/m³	371.1	35.4	201.8	21.2	169.3	14.2
	> 250 to ≤ 500 µg/m³	73.8	4.1	40.1	2.5	33.6	1.7
	> 500 µg/m³	30.7	0.6	16.7	0.4	14.0	0.3
Silicosis	≤ 25 µg/m³	291.7	144.9	291.7	144.9	0.0	0.0
	> 25 to ≤ 50 µg/m³	156.7	49.4	156.7	49.4	0.0	0.0
	> 50 to ≤ 85.7 µg/m³	203.9	24.7	128.4	21.4	75.5	3.3
	> 85.7 to ≤ 100 µg/m³		5.1		2.9		2.2
	> 100 to ≤ 250 µg/m³	131.3	12.7	54.1	7.3	77.2	5.4
	> 250 to ≤ 500 µg/m³	26.1	1.5	10.8	0.9	15.3	0.6
	> 500 µg/m³	10.9	0.2	4.5	0.1	6.4	0.1

Health Outcome	Exposure Interval	Under Existing Limits (100 $\mu\text{g}/\text{m}^3$ for MNM and 85.7 $\mu\text{g}/\text{m}^3$ for Coal)		Under the Proposed PEL of 50 $\mu\text{g}/\text{m}^3$		Avoided Lifetime Cases Attributable to the Proposed Rule	
		MNM	Coal	MNM	Coal	MNM	Coal
ESRD	$\leq 25 \mu\text{g}/\text{m}^3$	1,535.3	990.2	1,535.3	990.2	0.0	0.0
	$> 25$ to $\leq 50 \mu\text{g}/\text{m}^3$	749.9	232.2	749.9	232.2	0.0	0.0
	$> 50$ to $\leq 85.7 \mu\text{g}/\text{m}^3$	631.0	76.3	568.6	71.8	62.4	4.5
	$> 85.7$ to $\leq 100 \mu\text{g}/\text{m}^3$		11.7		9.8		1.8
	$> 100$ to $\leq 250 \mu\text{g}/\text{m}^3$	298.9	29.2	239.5	24.6	59.4	4.6
	$> 250$ to $\leq 500 \mu\text{g}/\text{m}^3$	59.4	3.4	47.6	2.9	11.8	0.5
	$> 500 \mu\text{g}/\text{m}^3$	24.7	0.5	19.8	0.4	4.9	0.1
Lung Cancer	$\leq 25 \mu\text{g}/\text{m}^3$	42.1	41.8	42.1	41.8	0.0	0.0
	$> 25$ to $\leq 50 \mu\text{g}/\text{m}^3$	58.7	19.1	58.7	19.1	0.0	0.0
	$> 50$ to $\leq 85.7 \mu\text{g}/\text{m}^3$	80.1	9.6	57.2	7.9	22.9	1.7
	$> 85.7$ to $\leq 100 \mu\text{g}/\text{m}^3$		1.9		1.1		0.8
	$> 100$ to $\leq 250 \mu\text{g}/\text{m}^3$	50.1	4.8	24.1	2.7	26.1	2.1
	$> 250$ to $\leq 500 \mu\text{g}/\text{m}^3$	10.0	0.6	4.8	0.3	5.2	0.2
	$> 500 \mu\text{g}/\text{m}^3$	4.1	0.1	2.0	0.0	2.2	0.0
Mortality Total	$\leq 25 \mu\text{g}/\text{m}^3$	2,047.4	1,496.1	2,047.4	1,496.1	0.0	0.0
	$> 25$ to $\leq 50 \mu\text{g}/\text{m}^3$	1,443.5	457.5	1,443.5	457.5	0.0	0.0
	$> 50$ to $\leq 85.7 \mu\text{g}/\text{m}^3$	1,543.7	185.8	1,233.3	162.8	310.4	23.0
	$> 85.7$ to $\leq 100 \mu\text{g}/\text{m}^3$		32.8		22.3		10.5
	$> 100$ to $\leq 250 \mu\text{g}/\text{m}^3$	851.5	82.1	519.5	55.8	332.0	26.3
	$> 250$ to $\leq 500 \mu\text{g}/\text{m}^3$	169.2	9.6	103.3	6.5	66.0	3.1
	$> 500 \mu\text{g}/\text{m}^3$	70.4	1.5	43.0	1.0	27.4	0.5

[a] The estimated number of silicosis mortality is subtracted from the estimated number of silicosis morbidity cases.

[b] NMRD net mortality is the difference between the estimated NMRD and silicosis deaths.

**Table 3-4. Estimated Cases of Lifetime Avoided Morbidity and Mortality Attributable to the Proposed Rule**

Health Outcome	Total Lifetime Avoided Cases [a]			Long-run Average Total Cases Avoided per Year [b]		
	MNM	Coal	Total	MNM	Coal	Total
<b>Avoided Morbidity</b>						
Silicosis (Excluding Silicosis Deaths)	2,566	244	2,809	42.8	4.1	46.8
<b>Avoided Morbidity Total (Excluding Silicosis Deaths)</b>	<b>2,566</b>	<b>244</b>	<b>2,809</b>	<b>42.8</b>	<b>4.1</b>	<b>46.8</b>
<b>Avoided Mortality</b>						
NMRD (Excluding Silicosis Deaths)	366	35	402	6.1	0.6	6.7
Silicosis	174	12	186	2.9	0.2	3.1
ESRD	139	12	150	2.3	0.2	2.5
Lung Cancer [c]	56	5	61	0.9	0.1	1.0
<b>Avoided Mortality Total</b>	<b>736</b>	<b>63</b>	<b>799</b>	<b>12.3</b>	<b>1.1</b>	<b>13.3</b>

Numbers may not add up due to rounding. The health outcomes are ordered from largest to smallest based on total lifetime avoided cases. Also see PRA Table 17 and PRA Table 18.

[a] Cases include full-time-equivalent contract miners and assume compliance with the existing limits.

[b] Average over 60 years for all health outcomes.

[c] Lung cancer estimates assume a 15-year lag between exposure and health effect.

MSHA estimates the number of non-fatal silicosis cases reaching the severe levels of 2/1 and above in accordance with how the International Labour Organization (ILO) classifies the opacities observed on chest radiographs by their characteristics such as size, shape, and profusion on a scale of 1 through 3 (3 = most severe).<sup>10</sup> Based on a study by Buchanan *et al.* (2003) of a cohort of coal miners (as discussed in the PRA), MSHA estimates that the proposed PEL of 50 µg/m<sup>3</sup> would prevent 2,995 lifetime cases of moderate-to-severe silicosis (registering 2/1 or more, using the ILO method for assessing severity) among the working population, or about 49.9 cases of moderate-to-severe silicosis prevented annually on a long-run average basis. After subtracting the fatal silicosis cases from these totals, an estimate of 2,809 avoided non-fatal silicosis cases over the 60-year period is obtained, or about 46.8 cases per year on a long-run average basis.

Following Park *et al.* (2002), as discussed in the Agency's PRA, MSHA also estimates that the proposed PEL of 50 µg/m<sup>3</sup> would prevent an estimated 588 NMRD lifetime fatalities, with a long-term average of about 9.8 cases avoided per year. Of these 588 cases, 186 are attributable to silicosis and the remainder (402) to other types of NMRD or 6.7 cases per year on a long-run average basis. Based on findings shown in Mannetje *et al.* (2002a), MSHA estimates that a total

<sup>10</sup> The International Labour Organization (ILO) Classification of Radiographs of Pneumoconioses is a standardized system to classify the opacities seen on chest radiographs (ILO 1980, 2002, 2011, and 2022). The ILO system grades the size, shape, and profusion of opacities in the lung. Profusion scores for simple pneumoconiosis are graded 1, 2, or 3, with 3 being the most severe, and for complicated pneumoconiosis, A, B, or C, with C being the most severe. Category 0 is a normal film (ILO 2002 and 2011; Wagner *et al.*, 1993; NIOSH 2014b).

of about 186 silicosis lifetime fatalities would be avoided in both the MNM and coal mine sectors or about 3.1 silicosis fatalities per year on a long-run average basis.

MSHA also finds that miners with significant exposures to respirable crystalline silica are at elevated risk of ESRD. Based on Steenland *et al.* (2002a), MSHA estimates that the proposed PEL of 50  $\mu\text{g}/\text{m}^3$  would prevent 150 cases of ESRD over the lifetime of the current miner population, or about 2.5 cases annually on a long-run average basis.

Combining the four major fatal health endpoints—for NMRD, silicosis, ESRD, and lung cancer—MSHA estimates that the proposed PEL would prevent 799 premature fatalities over the lifetime among a future population of MNM and coal miners equal in size to the current MNM and coal miner population. This is the equivalent of an average of 13.3 cases avoided annually, given a 45-year working life of exposure to the proposed PEL and following miners 15 years into retirement as summarized in Table 3-4.

In summary, the avoided lifetime morbidity and mortality estimates presented in Table 3-4 reflect the future steady-state once the proposed rule is fully effective. These numbers represent the difference between lifetime health outcomes expected to occur after both 45 years of employment under the existing limits (from 21 through 65 years of age) and 15 years of retirement (up to 80 years of age) to those under the proposed PEL after it is full effective. The first group of miners that would experience the avoided lifetime fatalities and illnesses is the population living 60 years after promulgation of the proposed rule, which would only contain miners exposed under the proposed rule. To calculate benefits associated with the proposed rulemaking, the economic analysis monetizes avoided deaths and cases while accounting for the fact that, during the first 60 years following promulgation, miners would have fewer avoided lifetime fatalities and illnesses because they would be exposed under both the existing standards and the proposed PEL (see Section 3.2 for further discussion).

The Agency notes that these estimates represent reductions in the number of silica-related diseases over a working life of constant exposure for miners who are employed in occupations in which they are exposed to respirable crystalline silica for their entire working lives, from ages 21 through 65. In other words, miners are assumed not to enter or exit jobs with respirable crystalline silica exposure mid-career or switch to other exposure groups during their working lives. MSHA did not have any miner demographics or labor force participation patterns and requests information that may help refine this assumption.

MSHA's risk estimates are based on application of exposure-response models derived from several individual epidemiological studies as well as the pooled cohort studies of Steenland *et al.* (2001a) and Mannerje *et al.* (2002b). MSHA recognizes that there is uncertainty around any of the point estimates of risk derived from any single study. In its PRA, MSHA has made efforts to characterize some of the more important sources of uncertainty to the extent that available data permit. This specifically includes: characterizing statistical uncertainty by reporting the confidence intervals around each of the risk estimates; quantitatively evaluating the impact of uncertainties in underlying exposure data used in the cohort studies; and exploring the use of alternative exposure-response model forms. MSHA believes that these



efforts reflect much, but not necessarily all, of the uncertainties associated with the approaches taken by investigators in their respective risk analyses.

Another source of uncertainty involves the degree to which MSHA's risk estimates reflect the risk of disease among miners with widely varying exposure patterns. Some miners may be exposed to fairly high concentrations of respirable crystalline silica only intermittently, while others may experience more regular and constant exposure. Risk models employed in the quantitative assessment are based on a cumulative exposure metric, which is the product of average daily respirable crystalline silica concentration and duration of miner exposure for a specific job. Consequently, these models predict the same risk for a given cumulative exposure regardless of the pattern of exposure, reflecting a miner's long-term average exposure without regard to variances in exposure. Although the Agency believes that the results of its risk assessment are broadly relevant to all occupational exposure situations involving respirable crystalline silica, MSHA acknowledges that differences exist in the relative toxicity of respirable crystalline silica present in different work settings. This may be due to factors such as differences in the crystal structure of respirable crystalline silica (i.e., polymorphs), the presence of mineral or metal impurities on particle surfaces, whether the particles have been freshly fractured or are aged, and size distribution of particles. However, in its PRA, MSHA preliminarily concludes that the estimates from the studies and analyses relied upon are fairly representative of a wide range of work settings reflecting differences in respirable crystalline silica polymorphism, surface properties, and impurities.

Additionally, as discussed in the PRA, the exposure datasets on which the risk analysis is based may contain some upward bias, the magnitude of which cannot be quantified. In some but not all cases, MSHA inspectors sample specific jobs they suspect to have the highest exposures. Consequently, the exposure profiles developed from these datasets may distribute a larger proportion of samples into higher exposure intervals, thereby potentially inflating the number of miners assigned to higher exposure intervals. This bias could result in an overestimation of the avoided cases and corresponding benefits. However, MSHA believes the impact of this bias may be counteracted by other potential biases (e.g., the healthy worker survivor bias, also discussed in the PRA) that are likely causing underestimation of the avoided cases and corresponding benefits.

MSHA has a high degree of confidence in the risk estimates associated with exposure to the existing limits and the proposed PEL. MSHA acknowledges there is greater uncertainty in the risk estimates for the proposed action level of  $25 \mu\text{g}/\text{m}^3$  than exists at the existing limit ( $100 \mu\text{g}/\text{m}^3$ ) and the proposed PEL ( $50 \mu\text{g}/\text{m}^3$ ), particularly given some evidence of a threshold for silicosis between the proposed PEL and action level. However, MSHA believes that a precise estimate of the risk for exposures below the proposed action level is not necessary to further inform the Agency's regulatory action.

## 3.2 Estimating the Stream of Benefits Over Time

Risk assessments in the occupational environment are generally designed to estimate the risk of an occupation-related illness over the course of an individual worker's lifetime. As demonstrated previously in this section, the current occupational exposure profile for a particular substance for the current cohort of miners can be matched against the expected profile after the proposed standard takes effect (i.e., after 60 years have elapsed from the final rule promulgation), creating a "steady-state" estimate of benefits. However, in order to annualize the benefits for the period of time after the respirable crystalline silica rule takes effect but before the steady state is reached, it is necessary to create a timeline of benefits for an entire active workforce over that period.

Prior to implementation of the proposed PEL, all living miners accruing lifetime cases (both working miners and retired miners) are assumed to have the same exposure histories characterized by exclusive exposure under the existing limits. As such, their survival probabilities and risks are homogeneous for a given disease. Similarly, 60 years after promulgation of the proposed PEL, all living miners accruing lifetime cases (both working miners and retired miners) will have identical exposure histories characterized by exclusive exposure under the proposed PEL. However, during the 60 years immediately following promulgation, miners with exposure under the existing limits will gradually be replaced by miners with exposure under the proposed PEL. During this initial 60-year period, the different miner cohorts possess heterogeneities that change from one year to the next as older cohorts reach the end of their life and are replaced by newer cohorts. Specifically, different miner cohorts will have a different number of years of exposure under the existing limits and under the proposed PEL. During this initial 60-year period following promulgation, the cases avoided per year will gradually increase to the long-run averages, i.e., "steady-state" values, discussed in the preceding section and presented in Table 3-4.

To characterize the magnitude of benefits before the steady state is reached, MSHA uses the underlying risk models to calculate the yearly reduction in lifetime risk of cases of respirable crystalline silica related disease, starting from the year of the final rule promulgation and extending to 60 years in the future, when all the miners currently working or retired through the age of 80 will enjoy the full benefits of the reduced exposure. In the case of lung cancer, the function representing the decline in the number of respirable crystalline silica-related cases as a result of the proposed rule is similar, but the underlying mortality modes specifies a 15-year lag before any reduction in cancer cases would be achieved.

### 3.2.1 Methodology for Estimating Annual Cases Avoided over Initial 60 Years Following Promulgation

Below MSHA describes the methodology for calculating the number of cases in each of the 60 years immediately following the final rule promulgation, which is the regulatory time horizon chosen for the analysis. During these years, miner cohorts are defined by a mixture of exposures under the existing limits and the proposed PEL. As this 60-year period progresses, annual cases avoided will increase gradually to the steady-state values presented in Table 3-4 of

Section 3.1. Upon reaching the steady-state values in Table 3-4, annual cases avoided will be constant because all miner cohorts will be homogeneous with identical lifetime risks. A detailed explanation of this life table approach is provided in Appendix B of the PRA. The approach described here refers to the quantities defined in that section, including the survival  $S_t$ , the disease-specific death risk  $r_t$ , the disease-specific hazard  $h_t$ , and the all-cause death hazard  $d_t$ .

In MSHA's PRA, lifetime risks and lifetime cases are estimated for each group with exposure levels of  $\leq 25 \mu\text{g}/\text{m}^3$ ,  $>25$  to  $\leq 50 \mu\text{g}/\text{m}^3$ ,  $>50$  to  $\leq 85.7 \mu\text{g}/\text{m}^3$  (coal only),  $>50$  to  $\leq 100 \mu\text{g}/\text{m}^3$  (MNM only),  $>100$  to  $\leq 250 \mu\text{g}/\text{m}^3$ ,  $>250$  to  $\leq 500 \mu\text{g}/\text{m}^3$ , and  $>500 \mu\text{g}/\text{m}^3$ . While all of these groups experience risk, the reduction in risk is exclusively attributable to miners exposed to concentrations of respirable crystalline silica that exceed the proposed PEL of  $50 \mu\text{g}/\text{m}^3$ . Under the assumption of full compliance with the existing limits, there are two such groups who experience risk reductions due to the proposed PEL: (1) miners who are currently exposed to the limit of  $100 \mu\text{g}/\text{m}^3$  for MNM or  $85.7 \mu\text{g}/\text{m}^3$  for coal, and (2) miners who are currently exposed to levels between  $50 \mu\text{g}/\text{m}^3$  and  $100 \mu\text{g}/\text{m}^3$  for MNM, or between  $50 \mu\text{g}/\text{m}^3$  and  $85.7 \mu\text{g}/\text{m}^3$  for coal. The first group experiences an exposure reduction from  $100 \mu\text{g}/\text{m}^3$  to  $50 \mu\text{g}/\text{m}^3$  in the case of MNM, and from  $85.7 \mu\text{g}/\text{m}^3$  to  $50 \mu\text{g}/\text{m}^3$  in the case of coal. The second group experiences an exposure reduction from  $69.0 \mu\text{g}/\text{m}^3$  to  $50 \mu\text{g}/\text{m}^3$  in the case of MNM, and  $60.4 \mu\text{g}/\text{m}^3$  to  $50 \mu\text{g}/\text{m}^3$  in the case of coal. (As discussed and presented in Appendix B of the PRA,  $69.0 \mu\text{g}/\text{m}^3$  is the median exposure value for MNM samples in the exposure interval  $>50$  to  $\leq 100 \mu\text{g}/\text{m}^3$ , and  $60.4 \mu\text{g}/\text{m}^3$  is the median exposure value for coal samples in the exposure interval  $>50$  to  $\leq 85.7 \mu\text{g}/\text{m}^3$ .) In each of the 60 analysis years following promulgation, annual cases avoided are estimated for both affected exposure groups. The total cases avoided in a given year is the sum each of avoided cases in these two groups in the manner described below.

Life tables are used to calculate lifetime risks. As described on p. 83 of Vaeth and Pierce (1990), "[c]alculation of excess lifetime risks usually requires rather complicated life-table computation." After assessing the life table approach used by OSHA to calculate risks in the *Occupational Exposure to Respirable Crystalline Silica -- Review of Health Effects Literature and Preliminary Quantitative Risk Assessment*, MSHA adopted a similar method to that of OSHA in the accompanying PRA. (See, for example, the methodological description in Section II.B *Lung Cancer Risk Estimates* on pp. 269-280.) A detailed description of the life table methodology is provided in Appendix B of the PRA.

Briefly, each group of miners that enters the workforce at age 21 in a given calendar year represents a distinct generation cohort. Sixty such cohorts are alive at any given time, each having entered the workforce at the age of 21 during a different calendar year. At any single point in time, 45 of these surviving cohorts are still working, and 15 are retired. Each cohort is assumed to have a fixed initial size  $n \approx \frac{N}{45}$  which decreases gradually as time passes in accordance with the decreasing survival  $S_t$ . Under the proposed PEL, all of these 60 living miner cohorts would experience reduced risks.

The population of interest, for which risks and benefits are calculated in this section and in the PRA, is current working miners including contract miners. Presently, this corresponds to 257,383 total miner FTEs (72,768 coal miner FTEs and 184,615 MNM miner FTEs). The population for which a steady state is reached is larger,  $257,383 \times 60/45 = 343,177$  FTEs, because it also encompasses retired miner FTEs. For a yearly analysis, the full population of 60 cohorts must be included who are required in order to eventually achieve a steady state composed of homogeneous cohorts over time. As such, in this analysis, risks across the full population of 60 cohorts must be considered in order to determine annual cases avoided at the steady state. However, the goal is to quantify lifetime benefits only for *working* miners. As such, benefits are only ultimately counted for a fraction (45/60) of the full steady-state population. This same fraction is applied to the estimated annual cases avoided across all 60 cohorts. The scaling factor of 45/60 reduces the annual cases to an average value for the population of interest: a group of 343,177 working miner FTEs for each of the 60 years following promulgation. This scaling factor accounts for the fact that, during any given year, the methodology below sums the risk reduction across the 60 cohorts that eventually reach steady state.

As presented in Appendix B of the PRA, the number of cases avoided in year  $t$  among a single cohort of initial size  $n$  is:

$$c_t = n \times r_t \quad (1)$$

where  $c_t$  is the cases avoided and  $r_t$  is the disease-specific death risk in year  $t$ . During the steady state under the proposed PEL, all 60 cohorts with surviving members have identical life tables characterized by exposure at the proposed PEL. Prior to that time, the population will be composed of individuals belonging to 60 different miner cohorts each possessing a different set of exposure histories. In general, older cohorts will have had fewer years under the proposed PEL, and younger cohorts will have had more years under the proposed PEL.

Accordingly, a superscripted  $i$  can be used to index the 60 different cohorts. The total cases that occur in a single year across all cohorts are:

$$\sum_i c_t^{(i)} = \sum_i n \times r_t^{(i)} \quad (2)$$

The total cases that would have occurred in a single year if the existing PEL had remained in effect are:

$$\sum_i \tilde{c}_t^{(i)} = \sum_i n \times \tilde{r}_t^{(i)} \quad (3)$$

where  $\tilde{c}_t^{(i)}$  and  $\tilde{r}_t^{(i)}$  are the expected cases and disease-specific risks under the existing PEL in year  $t$ .

During early years following implementation, some miner cohorts will contain surviving members who retired before the proposed PEL took effect. These retired miners would receive no benefit from the proposed PEL because  $r_t^{(i)} = \tilde{r}_t^{(i)}$  at all years  $t$  in the cohort's life table. That is, for these older, previously retired miners, the life table would contain 45 years of exposure under the existing PEL. On the other hand, some young cohorts would have entered the workforce after the proposed PEL took effect, giving them reduced cases during each year of their life table. For these younger cohorts, the life table contains 45 years of exposure under the proposed PEL. As an intermediate example (for illustrative purposes), a miner who began working 5 years before the PEL took effect would possess 5 years of higher exposure at (e.g.,  $100 \mu\text{g}/\text{m}^3$  under the existing limit (during ages 21 through 25,) followed by 40 years of reduced exposure at  $50 \mu\text{g}/\text{m}^3$ , and 15 years of retirement associated with lower cumulative exposure over their life. This miner would receive benefits during the ages of 26 through 80.

For any miner cohort  $i$ , the cases avoided in a selected year  $t$  is the difference in expected cases under the existing limits  $\tilde{c}_t^{(i)}$  and expected cases under the proposed PEL  $c_t^{(i)}$ :

$$\Delta c_t^{(i)} = \tilde{c}_t^{(i)} - c_t^{(i)} \quad (4)$$

Summing  $\Delta c_t^{(i)}$  across all surviving miner cohorts in a given year  $t$  yields the cases avoided  $\Delta c_t$  in that year  $t$ :

$$\Delta c_t = \sum_i \Delta c_t^{(i)} \quad (5)$$

Substituting Eq. 4 and Eq. 1 into Eq. 5 yields:

$$= \sum_i (\tilde{c}_t^{(i)} - c_t^{(i)}) \quad (6)$$

$$= \sum_i n \times \tilde{r}_t^{(i)} - \sum_i n \times r_t^{(i)} \quad (7)$$

$$= n \left( \sum_i \tilde{r}_t^{(i)} - \sum_i r_t^{(i)} \right) \quad (8)$$

$$= \frac{N}{45} \left( \sum_i \tilde{r}_t^{(i)} - \sum_i r_t^{(i)} \right) \quad (9)$$

Eq. 9 gives the avoided lifetime cases in year  $t$  across all 60 cohorts. To reduce the value to the sub-population of interest, a scaling factor of 45/60 is applied:

$$\Delta c'_t = \frac{N}{45} \left( \sum_i \tilde{r}_t^{(i)} - \sum_i r_t^{(i)} \right) \times \frac{45}{60} = \frac{N}{60} \left( \sum_i \tilde{r}_t^{(i)} - \sum_i r_t^{(i)} \right) \quad (10)$$

Importantly,  $N$  in this formula represents the size of a single exposure group. For MNM,  $N = 11,796$  for the exposure group over  $100 \mu\text{g}/\text{m}^3$ , and  $N = 21,805$  for the exposure group  $>50$  to  $\leq 100 \mu\text{g}/\text{m}^3$ . For coal,  $N = 1,391$  for the exposure group over  $85.7 \mu\text{g}/\text{m}^3$ , and  $N = 2,644$  for the exposure group  $>50$  to  $\leq 85.7 \mu\text{g}/\text{m}^3$ . Applying Eq. 10 to both groups (either for MNM or for coal) and summing the cases avoided  $\Delta c'_t$  gives the total cases avoided in year  $t$ . For example, among MNM miners, the total cases avoided in year  $t$  is:

$$(\Delta c'_t)_{\text{total}} = (\Delta c'_t)_{>100 \frac{\mu\text{g}}{\text{m}^3}} + (\Delta c'_t)_{50-100 \frac{\mu\text{g}}{\text{m}^3}} \quad (11)$$

Eq. 10 and Eq. 11 were used to calculate the total number of cases avoided during each of the 60 years immediately following promulgation of the proposed PEL. To perform this calculation, a separate life table was constructed for each distinct miner cohort containing surviving members during any of the 60 years following promulgation of the proposed PEL. MSHA presents an example using abbreviated life tables that demonstrates the manner in which number of cases avoided in a single year was estimated in Appendix B of the PRA.

Table 3-5 presents the estimated cases of avoided morbidity and mortality during the 60 years following promulgation of the proposed PEL, which is the regulatory analysis time horizon for this rule.

**Table 3-5. Estimated Cases of Avoided Mortality and Morbidity Attributable to the Proposed Respirable Crystalline Silica Rule over 60 Years (Regulatory Analysis Time Horizon) Following Rule Promulgation**

Health Outcome	Total Avoided Cases over 60 Years [a]		
	MNM	Coal	Total
<b>Avoided Morbidity</b>			
Silicosis	1,298.0	121.7	1,419.7
<b>Avoided Morbidity Total (Net of Silicosis Fatalities)</b>	<b>1,298.0</b>	<b>121.7</b>	<b>1,419.7</b>
<b>Avoided Mortality</b>			
NMRD (net of silicosis mortality)	186.8	16.4	203.2
Silicosis	94.8	8.1	102.9
ESRD	69.7	5.9	75.5
Lung Cancer [b]	26.0	2.3	28.2
<b>Avoided Mortality Total</b>	<b>377.3</b>	<b>32.6</b>	<b>409.9</b>

Numbers may not add up due to rounding. The health outcomes are ordered from largest to smallest based on total avoided cases.

[a] Cases include full-time-equivalent contract miners and assume compliance with the existing limits.

[b] Lung cancer estimates assume a 15-year lag between exposure and health effect.

### 3.2.2 Monetizing the Benefits of the Proposed Rule

MSHA also provides estimates of the monetary value of the benefits associated with the proposed rule.

### *Placing a Monetary Value on Individual Silica-Related Fatalities Avoided*

For this rule, MSHA uses a VSL estimate of \$11.8 million for the year 2021 based on estimates originally developed by the U.S. Department of Transportation (2022). For each year beyond 2021, MSHA adjusts this VSL value to account for growth in real income. Assuming a constant rate of income growth,  $g$ , and a constant income elasticity  $\eta$ , MSHA calculates the VSL in year,  $t$ , as:

$$VSL_t = VSL_{2021} \times (1 + g)^{(t-2021)} \times \eta \quad (12)$$

According to the DOT guidelines for regulatory impact analysis (RIA), DOT agencies are recommended to use an income elasticity assumption of 1 ( $\eta = 1$ ) in their analyses (U.S. Department of Transportation, 2022). MSHA estimates the rate of income growth using data on the real gross domestic product per capita,  $\overline{GDP}$ , from 1971 through 2021 by the U.S. Bureau of Economic Analysis (BEA) as:

$$g = \left( \frac{\overline{GDP}_{2021}}{\overline{GDP}_{1971}} \right)^{\frac{1}{(2021-1971)}} - 1 = \left( \frac{\$58,624}{\$24,640} \right)^{\frac{1}{50}} - 1 = 1.75\% \quad (13)$$

Thus, for each year beyond 2021, MSHA calculates the VSL for year  $t$  as:

$$VSL_t = VSL_{2021} \times (1.0175)^{(t-2021)} \quad (14)$$

### *Placing a Monetary Value on Individual Silica-Related Diseases Avoided*

In addition to the benefits that are based on the implicit value of fatalities avoided, workers also place an implicit value on occupational injuries or illnesses avoided, which reflect their willingness to pay to avoid monetary costs (for medical expenses and lost wages) and quality-of-life losses as a result of occupational illness. Silicosis, lung cancer, NMRD, and ESRD can adversely affect miners for years or even decades in non-fatal cases, or before ultimately proving fatal.

Consistent with Buchanan *et al.* (2003), MSHA estimates the total number of moderate-to-severe silicosis cases prevented by the proposed rule, as measured by 2/1 or more severe x-rays (based on the ILO rating system). However, while radiological evidence of moderate-to-severe silicosis is evidence of significant material impairment of health or functional capacity, placing a precise monetary value on this condition is difficult, in part because the severity of symptoms may vary significantly among miners. For that reason, for this preliminary analysis, the Agency employs a broad range of valuation, which should encompass the range of severity these miners may encounter.

Using the WTP-approach and previous estimates of valuations of non-fatal, but permanently disabling injuries, OSHA previously identified the value of silica-related morbidity (both for cases preceding death and for non-fatal cases) in its rulemaking ranging from \$64,000 to \$5.2 million in 2012 dollars. MSHA used the reported GDP implicit price deflator index to

inflate the midpoint of the range, \$2.63 million, from 2012 dollars to 2021 dollars. The reported GDP implicit price deflator indices for 2012 and 2021 are 100.0 and 118.49, respectively, based on data from the BEA (U.S. Bureau of Economic Analysis, 2022). This results in a GDP implicit price adjustment factor,  $s$ , of

$$s = \frac{(118.49 - 100.000)}{100.000} = 0.183 \quad (15)$$

Using this adjustment factor, MSHA computes the average value of each avoided silicosis morbidity case,  $VM_{avg}$ , in 2021 dollars as:

$$VM_{avg} = \$2.63 \text{ million} \times (1 + s) = \$2.63 \text{ million} \times (1 + 0.183) = \$3.12 \text{ million} \quad (16)$$

This valuation is applied to non-fatal silicosis cases as well as to silica-related fatalities to account for the social costs of morbidity before death. To simplify the calculation of the monetized benefits of avoided illness and death, MSHA adds the monetized benefits of morbidity preceding mortality to the monetized benefits of mortality at the time of death, at which point both are discounted. In theory, however, the monetized benefits of morbidity should be recognized (and discounted) at the onset of morbidity, as this is what a worker's WTP is presumed to measure—that is, the risk of *immediate* death or an *immediate* period of illness that a miner is willing to pay to avoid. For this reason, the present value of discounted morbidity benefits has some tendency toward underestimation in this analysis. A parallel underestimate occurs with regard to morbidity not preceding mortality, since it implicitly assumes that the benefits occur at or before retirement, as per the Buchanan *et al.* (2003) model, but many, if not most, of the 2/0 or higher silicosis cases will have begun years before (with those classifications, in turn, preceded by a 1/0 classification). As a practical matter, however, the Agency lacks sufficient data currently to refine the analysis in this way. The Agency is interested in public input on the issue of valuing the cost to society of non-fatal cases of moderate-to-severe silicosis, as well as the morbidity associated with other related diseases of the lung, and with renal disease.

### ***Summary of Monetized Benefits***

Table 3-6 presents the estimated annualized (over the first 60 years) undiscounted benefits from each of these components of the valuation. As shown, the full monetized benefits, undiscounted, for the proposed PEL of  $50 \mu\text{g}/\text{m}^3$  is estimated at \$268.9 million annually. The total value of benefits is dominated by mortality (\$173.8 million). Also, the analysis illustrates that most of the morbidity benefits are related to silicosis cases that are not ultimately fatal in the MNM sector with \$67.5 million related to morbidity preceding mortality. Comparable benefits (i.e., morbidity not preceding mortality) for the coal sector are \$6.3 million.



**Table 3-6. Estimated Annualized Undiscounted Monetized Benefits of the Silica Proposal for Avoided Morbidity and Mortality (in 2021 \$ millions)**

Health Outcome	MNM	Coal	Total
Avoided Mortality	\$160.0	\$13.8	\$173.8
Avoided Morbidity (Preceding Mortality)	\$19.6	\$1.7	\$21.3
Avoided Morbidity (Not Preceding Mortality)	\$67.5	\$6.3	\$73.8
<b>Total</b>	<b>\$247.1</b>	<b>\$21.8</b>	<b>\$268.9</b>

### *Adjustment to Monetized Benefits*

MSHA’s estimates of the monetized benefits of the proposed rule is based on the imputed value of each avoided fatality and each avoided silica-related disease. As previously discussed, these, in turn, derive from a miner’s WTP to avoid a fatality of \$11.8 million and of \$3.12 million avoided morbidity associated with a silica-related disease in 2021 dollars. However, two related factors suggest that the VSL will tend to increase over time.

Economic theory suggests that the value of reducing life-threatening and health-threatening risks—and correspondingly the willingness of individuals to pay to reduce these risks—will increase as real per capita income increases. With increased income, an individual’s health and life becomes more valuable relative to other goods because, unlike other goods, they are without close substitutes and in relatively fixed or limited supply. Expressed differently, as income increases, consumption will increase but the marginal utility of consumption will decrease. In contrast, added years of life (in good health) is not subject to the same type of diminishing returns—implying that an effective way to increase lifetime utility is by extending one’s life and maintaining one’s good health.

Second, real per capita income has broadly been increasing throughout U.S. history, including recent periods. Based on the predicted increase in real per capita income in the United States over time and the expected resulting increase in the value of avoided fatalities and diseases, MSHA adjusted its estimates of the future benefits of the proposed rule to reflect the anticipated increase in their value over time. As discussed in Section 3.2.2 above, for each year beyond 2021, MSHA inflated the VSL value to account for growth in real income using the formula specified in Eq. 14.

### **3.2.3 Discounting of Monetized Benefits**

As previously noted, the estimated stream of benefits arising from the proposed silica rule is not constant from year to year, both because of the 45-year delay after the rule takes effect until all active workers obtain reduced silica exposure over their entire working lives and because of, in the case of lung cancer, a 15-year latency period between reduced exposure and a reduction in the probability of disease. Thus, an appropriate discount rate is needed to reflect the timing of benefits over the 60-year period after the rule takes effect and to allow conversion to an equivalent steady stream of annualized benefits.

### *Alternative Discount Rates for Annualizing Benefits*

Following OMB (2003) guidelines, MSHA estimates the annualized benefits of the proposed rule using discount rates of 3 percent and 7 percent. Consistent with the Agency’s

own practices in recent proposed and final rules, MSHA also estimates, for benchmarking purposes, undiscounted benefits—that is, benefits using a zero percent discount rate.

The rate of time preference approach is intended to measure the tradeoff between current consumption and future consumption, or in the context of the proposed rule, between current benefits and future benefits. The *individual* rate of time preference is influenced by uncertainty about the availability of the benefits at a future date and whether the individual will be alive to enjoy the delayed benefits. By comparison, the *social* rate of time preference takes a broader view over a longer time horizon—ignoring individual mortality and the riskiness of individual investments (which can be accounted for in a range of discount rates).

The usual method for estimating the social rate of time preference is to calculate the post-tax real rate of return on long-term, risk-free assets, such as U.S. Treasury securities. According to data from the U.S. Department of the Treasury, the daily treasury real long-term rates have ranged from -0.64 to 4.4 percent over the 2000-2021 period (U.S. Department of the Treasury, 2022).

In accordance with OMB Circular A-4 (2003), MSHA presents benefits estimates using discount rates of 3 percent and 7 percent. The Agency is interested in any evidence, theoretical or applied, that would inform the application of different discount rates to the costs and benefits of a regulation.

### *Summary of Annualized Benefits under Alternative Discount Rates*

Table 3-7 presents MSHA’s estimates of the sum of the annualized benefits of the proposed rule, using alternative discount rates,  $r$ , of 0, 3, and 7 percent, with a breakout between the MNM and Coal mining sectors. To calculate annualized benefits, MSHA first calculated the present value,  $PV$ , of the stream of benefits over the rule horizon of 60 years as:

$$PV = V_{t=0} + \frac{V_{t=1}}{(1+r)} + \frac{V_{t=2}}{(1+r)^2} + \frac{V_{t=3}}{(1+r)^3} + \dots + \frac{V_{t=60}}{(1+r)^{60}} = \sum_{t=0}^{60} \frac{V_t}{(1+r)^t} \quad (17)$$

where the value of benefits,  $V$ , due to total cases of avoided fatalities,  $FT$ , and avoided morbidity,  $MOR$ , in year  $t$  is:

$$V_t = (VSL_t \times FT_t) + (VM_{avg} \times MOR_t) \quad (18)$$

MSHA then annualizes the stream of benefits over 60 years as:

$$Annualized\ Benefits = \begin{cases} PV & \text{if } r = 0 \\ PV \times \frac{r \times (1+r)^{60}}{(1+r)^{60} - 1} & \text{if } r > 0 \end{cases} \quad (19)$$

Given that the stream of benefits extends out 60 years, the value of future benefits is sensitive to the choice of discount rate. From Table 3-7, the undiscounted total benefits are

estimated at \$268.9 million annually. The annualized benefits are \$175.7 million if the discount rate is 3 percent. Using a 7 percent discount rate, the annualized benefits fall to \$96.2 million. As can be seen, going from undiscounted benefits to a 7 percent discount rate has the effect of cutting the annualized benefits of the proposed rule over 60 percent.

**Table 3-7. Annualized Benefits over 60 Years for a Proposed PEL of 50 µg/m<sup>3</sup> by Discount Rate (in 2021 \$ Million)**

Health Outcome	MNM			Coal			Total		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
<b>Avoided Morbidity (Not Preceding Mortality)</b>									
Silicosis (Excluding Silicosis Deaths)	\$67.5	\$48.7	\$31.3	\$6.3	\$4.6	\$2.9	\$73.8	\$53.2	\$34.2
<b>Avoided Morbidity (Not Preceding Mortality) Total</b>	<b>\$67.5</b>	<b>\$48.7</b>	<b>\$31.3</b>	<b>\$6.3</b>	<b>\$4.6</b>	<b>\$2.9</b>	<b>\$73.8</b>	<b>\$53.2</b>	<b>\$34.2</b>
<b>Mortality</b>									
NMRD (Excluding Silicosis Deaths)	\$80.3	\$48.6	\$22.5	\$7.1	\$4.2	\$1.9	\$87.4	\$52.8	\$24.4
Silicosis	\$38.7	\$25.9	\$15.0	\$3.2	\$2.2	\$1.4	\$41.9	\$28.1	\$16.4
ESRD	\$29.6	\$18.3	\$9.2	\$2.5	\$1.6	\$0.8	\$32.1	\$19.9	\$9.9
Lung Cancer	\$11.4	\$6.6	\$2.8	\$1.0	\$0.6	\$0.2	\$12.4	\$7.2	\$3.0
<b>Avoided Mortality Total</b>	<b>\$160.0</b>	<b>\$99.4</b>	<b>\$49.5</b>	<b>\$13.8</b>	<b>\$8.6</b>	<b>\$4.3</b>	<b>\$173.8</b>	<b>\$108.0</b>	<b>\$53.8</b>
<b>Avoided Morbidity (Preceding Mortality)</b>									
NMRD (Excluding Silicosis Deaths)	\$9.7	\$6.3	\$3.3	\$0.9	\$0.5	\$0.3	\$10.6	\$6.9	\$3.6
Silicosis	\$4.9	\$3.7	\$2.5	\$0.4	\$0.3	\$0.2	\$5.4	\$4.0	\$2.7
ESRD	\$3.6	\$2.5	\$1.4	\$0.3	\$0.2	\$0.1	\$3.9	\$2.7	\$1.5
Lung Cancer	\$1.3	\$0.8	\$0.4	\$0.1	\$0.1	\$0.0	\$1.5	\$0.9	\$0.4
<b>Avoided Morbidity (Preceding Mortality) Total</b>	<b>\$19.6</b>	<b>\$13.3</b>	<b>\$7.6</b>	<b>\$1.7</b>	<b>\$1.2</b>	<b>\$0.7</b>	<b>\$21.3</b>	<b>\$14.5</b>	<b>\$8.2</b>
<b>Grand Total</b>	<b>\$247.1</b>	<b>\$161.4</b>	<b>\$88.3</b>	<b>\$21.8</b>	<b>\$14.3</b>	<b>\$7.9</b>	<b>\$268.9</b>	<b>\$175.7</b>	<b>\$96.2</b>

Taken as a whole, the Agency's best preliminary estimate of the total annualized benefits of the proposed rule—using a 3 percent discount rate with no adjustment for the increasing value of health benefits over time—is \$175.7 million. Of these benefits, \$108.0 million (61.5 percent) are attributable to mortality cases avoided, \$53.2 million (30.3 percent) are for silicosis morbidity (not preceding mortality) cases avoided, and the remaining \$13.9 million (8.3 percent) are for morbidity preceding mortality cases avoided. Table 3-8 shows the annualized undiscounted benefits as derived over the 60 years after the silica rule becomes effective including the assumed factors for increasing monetized benefits in response to increases in per capita income over time.

**Table 3-8. Stream of Benefits over 60 Years Post Rule Promulgation for a PEL of 50 µg/m<sup>3</sup> Accounting for Income Growth**

Year After Rule Promulgation	Total Number of Avoided Cases (MNM and Coal Combined)		Value of Avoided Cases by Year (MNM and Coal Combined) in 2021 \$ Million			
	Avoided Mortality	Avoided Silicosis Morbidity	Avoided Mortality	Avoided Morbidity (Preceding Mortality)	Avoided Morbidity	Total
Year 1	0.0770	0.7692	\$0.94	\$0.24	\$2.40	<b>\$3.58</b>
Year 2	0.1613	1.5326	\$2.01	\$0.50	\$4.78	<b>\$7.29</b>
Year 3	0.2773	2.2657	\$3.51	\$0.86	\$7.07	<b>\$11.44</b>
Year 4	0.3237	3.0738	\$4.17	\$1.01	\$9.59	<b>\$14.76</b>
Year 5	0.4377	3.8078	\$5.73	\$1.37	\$11.88	<b>\$18.97</b>
Year 6	0.5395	4.5681	\$7.19	\$1.68	\$14.25	<b>\$23.12</b>
Year 7	0.6635	5.3464	\$9.00	\$2.07	\$16.67	<b>\$27.74</b>
Year 8	0.8047	6.1515	\$11.10	\$2.51	\$19.18	<b>\$32.79</b>
Year 9	0.9583	6.8847	\$13.45	\$2.99	\$21.47	<b>\$37.91</b>
Year 10	1.1240	7.6502	\$16.05	\$3.51	\$23.86	<b>\$43.41</b>
Year 11	1.3090	8.4297	\$19.02	\$4.08	\$26.29	<b>\$49.39</b>
Year 12	1.5124	9.2324	\$22.36	\$4.72	\$28.79	<b>\$55.87</b>
Year 13	1.7332	9.9660	\$26.07	\$5.41	\$31.08	<b>\$62.56</b>
Year 14	1.9704	10.7349	\$30.16	\$6.14	\$33.48	<b>\$69.78</b>
Year 15	2.2231	11.5098	\$34.63	\$6.93	\$35.90	<b>\$77.45</b>
Year 16	2.5298	12.2756	\$40.09	\$7.89	\$38.28	<b>\$86.26</b>
Year 17	2.8364	13.0168	\$45.74	\$8.85	\$40.60	<b>\$95.18</b>
Year 18	3.1429	13.8173	\$51.57	\$9.80	\$43.09	<b>\$104.46</b>
Year 19	3.4493	14.5982	\$57.58	\$10.76	\$45.53	<b>\$113.87</b>
Year 20	3.7558	15.3568	\$63.80	\$11.71	\$47.89	<b>\$123.40</b>
Year 21	4.0621	16.1021	\$70.21	\$12.67	\$50.22	<b>\$133.09</b>
Year 22	4.3683	16.9077	\$76.82	\$13.62	\$52.73	<b>\$143.17</b>
Year 23	4.6744	17.6925	\$83.64	\$14.58	\$55.18	<b>\$153.40</b>
Year 24	4.9804	18.4748	\$90.68	\$15.53	\$57.62	<b>\$163.83</b>
Year 25	5.2865	19.2573	\$97.94	\$16.49	\$60.06	<b>\$174.48</b>
Year 26	5.5920	20.0638	\$105.41	\$17.44	\$62.57	<b>\$185.42</b>
Year 27	5.8971	20.8057	\$113.11	\$18.39	\$64.89	<b>\$196.38</b>
Year 28	6.2017	21.6131	\$121.03	\$19.34	\$67.40	<b>\$207.78</b>
Year 29	6.5060	22.3951	\$129.19	\$20.29	\$69.84	<b>\$219.32</b>

Year After Rule Promulgation	Total Number of Avoided Cases (MNM and Coal Combined)		Value of Avoided Cases by Year (MNM and Coal Combined) in 2021 \$ Million			
	Avoided Mortality	Avoided Silicosis Morbidity	Avoided Mortality	Avoided Morbidity (Preceding Mortality)	Avoided Morbidity	Total
Year 30	6.8099	23.1984	\$137.59	\$21.24	\$72.35	<b>\$231.18</b>
Year 31	7.1126	23.9406	\$146.22	\$22.18	\$74.66	<b>\$243.06</b>
Year 32	7.4140	24.7502	\$155.09	\$23.12	\$77.19	<b>\$255.39</b>
Year 33	7.7143	25.5377	\$164.19	\$24.06	\$79.64	<b>\$267.89</b>
Year 34	8.0134	26.3053	\$173.54	\$24.99	\$82.04	<b>\$280.57</b>
Year 35	8.3114	27.0891	\$183.15	\$25.92	\$84.48	<b>\$293.55</b>
Year 36	8.6063	27.8986	\$192.96	\$26.84	\$87.01	<b>\$306.81</b>
Year 37	8.8979	28.6894	\$202.99	\$27.75	\$89.47	<b>\$320.21</b>
Year 38	9.1866	29.4606	\$213.24	\$28.65	\$91.88	<b>\$333.77</b>
Year 39	9.4722	30.2533	\$223.72	\$29.54	\$94.35	<b>\$347.61</b>
Year 40	9.7548	31.0687	\$234.43	\$30.42	\$96.89	<b>\$361.74</b>
Year 41	10.0311	31.8775	\$245.29	\$31.28	\$99.42	<b>\$375.99</b>
Year 42	10.3013	32.6686	\$256.30	\$32.13	\$101.88	<b>\$390.31</b>
Year 43	10.5654	33.4796	\$267.47	\$32.95	\$104.41	<b>\$404.84</b>
Year 44	10.8236	34.3119	\$278.81	\$33.75	\$107.01	<b>\$419.57</b>
Year 45	11.0759	35.0843	\$290.30	\$34.54	\$109.42	<b>\$434.26</b>
Year 46	11.3183	35.8578	\$301.84	\$35.30	\$111.83	<b>\$448.97</b>
Year 47	11.5509	36.6323	\$313.44	\$36.02	\$114.24	<b>\$463.70</b>
Year 48	11.7740	37.4080	\$325.08	\$36.72	\$116.66	<b>\$478.46</b>
Year 49	11.9877	38.1847	\$336.77	\$37.39	\$119.08	<b>\$493.24</b>
Year 50	12.1922	38.9624	\$348.51	\$38.02	\$121.51	<b>\$508.05</b>
Year 51	12.3809	39.7416	\$360.10	\$38.61	\$123.94	<b>\$522.65</b>
Year 52	12.5542	40.5222	\$371.53	\$39.15	\$126.37	<b>\$537.06</b>
Year 53	12.7126	41.3042	\$382.80	\$39.65	\$128.81	<b>\$551.26</b>
Year 54	12.8566	42.0875	\$393.91	\$40.10	\$131.26	<b>\$565.26</b>
Year 55	12.9865	42.8721	\$404.86	\$40.50	\$133.70	<b>\$579.06</b>
Year 56	13.0939	43.6587	\$415.35	\$40.84	\$136.16	<b>\$592.34</b>
Year 57	13.1799	44.4472	\$425.39	\$41.10	\$138.62	<b>\$605.11</b>
Year 58	13.2454	45.2374	\$434.99	\$41.31	\$141.08	<b>\$617.38</b>
Year 59	13.2916	46.0295	\$444.14	\$41.45	\$143.55	<b>\$629.15</b>

Year After Rule Promulgation	Total Number of Avoided Cases (MNM and Coal Combined)		Value of Avoided Cases by Year (MNM and Coal Combined) in 2021 \$ Million			
	Avoided Mortality	Avoided Silicosis Morbidity	Avoided Mortality	Avoided Morbidity (Preceding Mortality)	Avoided Morbidity	Total
Year 60	13.3192	46.8232	\$452.86	\$41.54	\$146.03	<b>\$640.42</b>
Discount Rate = 0%	PV		<b>\$10,429.1</b>	<b>\$1,278.4</b>	<b>\$4,427.5</b>	<b>\$16,135.0</b>
	Annualized Value		<b>\$173.82</b>	<b>\$21.31</b>	<b>\$73.79</b>	<b>\$268.92</b>
Discount Rate = 3%	PV		<b>\$2,988.77</b>	<b>\$400.50</b>	<b>\$1,473.49</b>	<b>\$4,862.76</b>
	Annualized Value		<b>\$107.99</b>	<b>\$14.47</b>	<b>\$53.24</b>	<b>\$175.71</b>
Discount Rate = 7%	PV		<b>\$754.92</b>	<b>\$115.33</b>	<b>\$480.22</b>	<b>\$1,350.46</b>
	Annualized Value		<b>\$53.77</b>	<b>\$8.21</b>	<b>\$34.21</b>	<b>\$96.19</b>

As previously mentioned, MSHA has not attempted, at this point, to estimate the monetary value of less severe silicosis cases, measured at 1/0 to 1/2 on the ILO scale. The Agency believes the economic loss to miners with less severe cases of silicosis could be substantial, insofar as they may be accompanied by a life of medical surveillance and lung damage, and potentially may require a change in career. However, many of these effects can be difficult to isolate and measure in economic terms, particularly in those cases where there is no obvious effect at this stage of disease on physiological function or performance. The Agency invites public comment on this issue.

### **3.2.4 Unquantified Benefits of Medical Surveillance Among MNM Miners**

Medical surveillance programs are useful in identifying workers who have or who are developing work-related illnesses (Wilken, et al., 2012). Such programs also help assess the magnitude of a given occupational health or injury and its temporal trend (i.e., whether the problem is increasing or decreasing) (Fine, 1999). At present, there are medical surveillance requirements for both surface and underground coal miners that include conducting a series of medical examinations (e.g., chest x-ray, spirometry, symptom assessment). These medical examinations are mandatory for miners who begin work at a coal mine for the first time. Further, for those miners already working at coal mines, voluntary medical examinations are available every five years. The medical surveillance provision of the proposed respirable crystalline silica rule institutes similar requirements for MNM miners that include an initial series of mandatory medical examinations when a miner begins work in the MNM mining industry for the first time and periodic voluntary examinations thereafter. MSHA believes that the initial series of mandatory examinations that assesses a miner's baseline pulmonary status coupled with periodic examinations would assist in the early detection of respirable crystalline silica related illnesses. Early detection of illness often leads to early intervention and treatment, which may slow disease progression and/or improve health outcomes. Thus, MSHA expects that the proposed rule's medical surveillance provisions would reduce mortality and morbidity from respirable crystalline silica exposure among MNM miners. However, MSHA is unable to quantify the magnitude of these expected reductions because it is not possible for MSHA to estimate: 1) the reduced rates of mortality and morbidity that would be attributable to the proposed rule, and 2) the extent to which miners would be inclined to get medical examinations at their own time and expense, in lieu of the medical surveillance program (the baseline scenario), which would then reduce the benefits of the proposed rule in comparison to the baseline.

In addition to the above direct benefits, the proposed rule's medical surveillance requirement would also have an indirect benefit by promoting greater awareness among MNM miners of the potential hazard of respirable crystalline silica exposure. Increasing awareness may encourage MNM miners to be more cautious and diligent in their work, and mine operators to be more cognizant of MSHA's safety and health standards in general. Again, such benefits would be difficult for MSHA to quantify with any reasonable degree of confidence.

### 3.2.5 Unquantified Benefits Associated with Pneumoconiosis Among Coal Miners

MSHA's 2014 coal dust rule quantified benefits among coal miners related to reduced cases of coal workers' pneumoconiosis (CWP), NMRD, and progressive massive fibrosis (PMF) due to lower exposure limits for RCMD. In the 2010 quantitative risk analysis (QRA) (Kogut, 2010), MSHA estimated the reduction in excess risks of CWP, NMRD, and PMF due to (a) lowering the exposure limit for RCMD from 2.0 mg/m<sup>3</sup> (and 1.0 mg/m<sup>3</sup> for Part 90 miners) to the equivalent of 1.5 mg/m<sup>3</sup> on each 8-hour shift (and 0.5 mg/m<sup>3</sup> for Part 90 miners) and (b) changing the basis for determinations of noncompliance from the average of 5 samples to a single sample. MSHA also estimated additional reductions in risk based on changes to the sampling strategies and a revised definition of normal product shift. Risk reductions were calculated both through age 73 and through age 85.

Other changes implemented in the 2014 coal dust rule were estimated to reduce risk of CWP, NMRD, and PMF. Basing noncompliance on a single sample rather than the average of 5 samples removes the ability of a mine operator to dilute the average concentration with abnormally low measurements—and this would apply not only to the concentration of RCMD but also to the concentration of respirable crystalline silica. The 2014 rule changed to full-shift sampling and adjusted the definition of normal production shift, which allowed MSHA to identify more instances where the respirable crystalline silica concentration exceeded the exposure limit.

In the 2010 coal dust QRA, risk was calculated for three ranks of respirable coal mine dust: low, medium, and high. Coal rank is a measure of the coal's moisture and carbon content, with high rank dust having less than 4 percent of moisture in the air-dried coal or more than 84 percent of carbon (dry ash-free coal). The largest reductions in NMRD risk were predicted among miners in occupations exposed to high rank RCMD; MSHA noted that equal changes in exposure levels were expected to produce substantially greater improvement for high rank coal dust miners (17 fewer deaths per 1,000 exposed miners) than for low/medium rank coal dust miners (7 fewer deaths per 1,000 exposed miners).

MSHA believes the proposed rule would likely lower not only respirable crystalline silica concentrations, but also levels of RCMD. As a result, MSHA believes the proposed rule would provide additional reductions in CWP, NMRD, and PMF beyond those conferred by the 2014 coal dust rule. In the 2014 final rule, NIOSH emphasized the important role respirable crystalline silica plays in causing these diseases, stating that, "in concentrating on this particular exposure-response relationship with coal mine dust, we must not forget that [coal] miners today are being exposed to excess silica levels, particularly in thinner seam and small mines, and that this situation could well get worse as the thicker seams are mined out. Hence, since silica is more toxic than mixed coal dust, tomorrow's [coal] miners could well be at greater risk, despite a reduction in the mixed coal mine dust standard." However, exposure-response relationships based on respirable crystalline silica exposure are not available for CWP. While additional reductions in total coal dust would be expected due to the proposed rule, these reductions cannot be quantified as the reductions depend on the particular control measures



that mine operators implement. The benefits quantified here may underestimate the true benefits, as MSHA does not account for expected reductions in CWP.

Another reason MSHA believes the proposed rule will provide additional benefits beyond those ascribed in the 2014 coal dust rule is that high concentrations of respirable crystalline silica and high rank RCMD are not always correlated. The coal exposure data suggest some miners may be exposed to higher concentrations of respirable crystalline silica despite experiencing compliant exposure levels of RCMD. For these miners in particular, the proposed rule provides additional benefits.

Given these challenges, and the fact that some benefits associated with reduced CWP deaths were already ascribed to the 2014 coal dust rule, MSHA is not estimating benefits to coal miners due to further reductions in CWP mortality expected under this proposed rule. The proposed rule does quantify the benefits of avoided deaths and illnesses, among coal miners, from NMRD, as a result of the proposed PEL. Among coal miners, MSHA estimates 35 lifetime avoided deaths from NMRD (See Table 3-4.). MSHA believes that some additional benefits would be conferred to coal miners under the proposed rule. Coal inspection data suggest that high respirable crystalline silica exposures may still occur when overall dust mass is low. Miners exposed to these conditions would likely receive additional benefits under the proposed rule beyond those estimated in the 2014 coal dust rule. Other miners may also receive additional benefits, particularly if they are in occupations for which respirable crystalline silica concentrations have increased over time.

### **3.2.6 Unquantified Benefits of Updated Standards for Respiratory Protection**

In this action, MSHA is proposing to revise the Agency's regulations by incorporating by reference ASTM International's respiratory protection standard, F3387-19, *Standard Practice for Respiratory Protection* (ASTM F3387-19), published in 2019 which would replace the existing standard, the American National Standards Institute (ANSI) Z88.2-1969, *Practices for Respiratory Protection* (ANSI Z88.2-1969), published by ANSI in 1969. Under this proposed rule, MSHA would require that operators establish a respiratory protection program in writing, that includes minimally acceptable program elements: program administration; standard operating procedures; medical evaluations; respirator selection; training; fit testing; and maintenance, inspection, and storage.

Beyond the minimum, MSHA proposes to provide mine operators with flexibility to select the provisions in ASTM F3387-19 that are applicable to the conditions of their mines and respirator use by their miners. In MSHA's experience, the need for and actual use of respirators varies among mines for different reasons, including the type of commodity mined or processed and the mining method and controls used. At some mines, miners may not use or may only rarely use respirators. At other mines, miners may use respirators more frequently. Recognizing these differences, MSHA would allow mine operators to comply with the provisions in ASTM F3387-19 that they deem are relevant and appropriate for their mining operations and conditions.

The primary benefit resulting from MSHA's updated standards for respiratory protection in MNM and coal mines would be to reduce miners' inhalation of airborne hazards while the miners perform activities for which they are required to wear respirators as a temporary measure. The benefit would be realized through several key improvements of the ASTM F3387-19 standard such as a more clearly defined respiratory protection practices framed by standard operating procedures (SOPs), clearer guidance on medical evaluations, clearly established fit test methods and frequencies, improved training, and strengthened program evaluation provisions. Quantitative estimates of these benefits are difficult to estimate because of uncertainties regarding the current state of operator respiratory protection programs.

MSHA currently regulates the use of respiratory protection in coal mines under 30 CFR § 72.710 *Selection, Fit, Use, and Maintenance of Approved Respirators*, in surface and underground MNM mines at § 56.5005 and § 57.5005 (both titled *Control of Exposure to Airborne Contaminants*). All three standards would be updated for consistency. In addition to updating the 50-year-old ANSI Z88.2-1969 standard currently incorporated in these standards, MSHA is including the 2019 ASTM standard's provisions as part of the proposed Part 60 Respirable Crystalline Silica (§ 60.14 *Respiratory Protection*) in this action.

The sections that follow provide a qualitative discussion of the benefits of the ASTM F3387-19 standard's key improvements compared to the ANSI Z88.2-1969 standard.

### ***Respiratory Protection Program Clarifications***

While both the ASTM F3387-19 and ANSI Z88.2-1969 standards provide for written respiratory protection programs, ASTM F3387-19 provides additional clarification on the required content of the respiratory protection programs by specifying that mine operators develop written SOPs for more, defined elements of the program. Such clarification would help mine operators improve the existing respiratory protection practices or develop new respiratory protection programs.

Greskevitch, *et al.* (2007), reporting on a 2001-2002 NIOSH and the BLS survey of 40,002 establishments (including between 2,250 and 2,500 mining establishments), provided a more detailed description of RPP deficiencies in the industry. This survey identified significant program weaknesses among mining establishments that reported respirator use. For instance, the survey found that 80.8 percent of mining establishments that used air-purifying gas/vapor filters did not have written change-out schedules; 61 percent were using an "improper method for setting air pressure to control airflow on airline respirators," or they did not know which methods they used; 54.3 percent were either unaware of or did not have "written procedures to periodically evaluate the effectiveness of respirator use;" 51.3 percent did not have a "written program for deciding how respirators are used;" and 38.8 percent did not have or were not aware of "written procedures or schedules for respirator maintenance." The authors concluded that "[w]ritten procedures and staff training are important for maintaining the quality of respirator programs," and that "[p]roperly written documentation helps assure continuity in decision making for all aspects of a respiratory protection program" (Greskevitch, *et al.*, 2007).

ASTM F3389-19 includes provisions for written SOPs addressing specific program elements, including each of the key program deficiencies identified by Greskevitch, *et al.* (2007). This clear delineation of program elements would benefit operators by removing ambiguity so that operators know what to include in their programs and would ensure consistent and effective RPPs across the mining industry. Such RPPs would provide better miner protection through reduced inhalation exposures by ensuring that miners work environments are assessed and the miners are provided with the correct type of respiratory protection based on that assessment. For example, NIOSH certifies three levels of respirator particle filters under 42 CFR 84, with the highest efficiency filter (P100, filters at least 99.97 percent of airborne particles and is strongly resistant to oil) more protective for miners than the lowest (N95, filters at least 95 percent of airborne particles and is not resistant to oil) (National Institute for Occupational Safety and Health, 2019). MSHA has observed some mine operators providing miners with this least protective level of respiratory protection. In proposed § 60.14, MSHA would require mine operators to provide high efficiency filters to miners temporarily exposed to respirable crystalline silica above the PEL. A comprehensive written respiratory protection program would help ensure miner work environments are considered in respirator selection, a sufficient supply of high efficiency particulate filters is readily available, and supervisors and miners recognize when to replace particulate filters.

The standard's provision that SOPs be made available to workers would further ensure that the program requirements are accessible to the miners who will be wearing the respirators. Removing ambiguity regarding required program content will also assist operators with compliance efforts.

### ***Medical Evaluation Clarification***

The ASTM F3387-19 standard provides detailed information and clear instruction to RPP administrators on the information (e.g., type of respirator to be used and frequency and duration of use) that they would provide to physicians or other licensed healthcare professionals (PLHCPs) to assist them in determining an employee's medical suitability for respirator use. The standard also identifies management responsibilities to provide the PLHCP with supplemental information before the PLHCP makes a recommendation concerning an employee's ability to use a respirator. While some PLHCPs may request this information as standard practice, clearly defining the information ensures consistency and allows RPP program administrators to collect the information and provide it to PLHCPs in an efficient manner, to ensure that all PLHCPs have the information needed to make informed assessments on miner health and their ability to perform assigned tasks while wearing the required respirator. More informed medical evaluations would benefit both miners and operators by helping to improve miner health and reduce workplace illnesses.

ASTM F3387-19 also allows the use of licensed healthcare professionals to perform the medical evaluations rather than limiting this task to physicians, as specified in the ANSI Z88.2-1969. This flexibility would improve operators' ability to obtain qualified healthcare services near their mines.

### *Defined Fit Test Frequencies*

While ANSI Z88.2-1969 requires that respirator users be fit tested on the make and model of the respirator, significant advances in assessing respirator fit, including the development of qualitative and quantitative fit testing protocols, have been made since the ANSI Z88.2-1969 standard was published. Due to variability in face size characteristics among individuals, different sizes of respirator facepieces are now available which contrasts with the ANSI Z88.2-1969 standard, which generally took a one-size-fits-all approach. ASTM F3387-19 standard provides for a qualitative fit test or quantitative fit test to determine proper fit of tight-fitting facepiece respirators. Employees would be fit tested with the same make, model, style, and size of respirator that will be used. To accommodate different facial types, a variety of sizes, models, and styles would be provided to the wearer. Fit testing would be done prior to initial use of the respirator, whenever a different respirator facepiece (i.e., size, style, model, or make) is used, and at least annually thereafter. Additional fit tests would be done whenever an employee reports or the employer, PLHCP, supervisor, or program administrator makes visual observations of changes in the employee's physical condition that could affect respirator fit under 29 CFR. 1910.134 (Occupational Safety and Health Administration, 1997). The analysis noted that studies advocate annual fit testing to ensure that miners receive optimal protection from the respirator and wearers are comfortable with the respirator fit. ASTM F3387-19 provisions for annual or more frequent fit tests would allow operators to routinely assess the continued quality of user respirator fits, identify situations where poor respirator fits have developed, and make respirator changes as needed to ensure the continued protection of respirator wearers.

### *Strengthened Training Requirements*

Employee training is an important part of a RPP and is essential for correct respirator use. The ANSI Z88.2-1969 standard contains basic minimal training requirements. It requires that respirator users be instructed and trained “in the proper use of respirators and their limitations.” The ASTM F3387-19 standard provides comprehensive guidance, including specific competencies for respirator trainers and users and training for respirator wearers, supervisors, and persons issuing respirators. Among these provisions are trainer qualification to ensure consistent training as well as an annual training for users. Annual training ensures users remain familiar and knowledgeable about workplace respiratory hazards and how to properly use, maintain and store their respirators.

The strengthened training provisions of ASTM F3387-19 would help address training deficiencies in the mining industry resulting in more effective and complete RPP implementation and reduced miner inhalation exposures.

### *Strengthened Respiratory Protection Program Evaluation Requirements*

ASTM F3387-19 includes several provisions that strengthen respiratory protection program evaluation. Specifically, ASTM F3387-19 provides for an annual written audit of all aspects of the respiratory protection program by the program administrator as well as an

additional periodic audit conducted by a knowledgeable person not directly associated with the RPP. In addition, the standard outlines the specific elements of the program to be evaluated. In discussing weaknesses observed during a 2001-2002 NIOSH and BLS survey of mining establishments, Greskevitch, *et al.* (2007) also noted the importance of periodic evaluation of written respiratory protection programs to ensure proper respiratory protection program implementation and respirator use. Evaluation provisions, coupled with the respiratory protection program clarifications discussed above, would ensure the ongoing effectiveness of mines' respiratory protection programs. In addition, strengthened evaluation provisions would help ensure better miner protection through reduced inhalation exposures when miners must wear respirators as a temporary measure of protection (i.e., during non-routine activities and while engineering controls are being implemented).

## 4 COSTS OF COMPLIANCE

MSHA proposes to establish a new, lower PEL for exposure to respirable crystalline silica for all MNM and coal mines. MSHA's existing standards, established in the early 1970s, help protect miners from the most dangerous levels of exposure to respirable crystalline silica. However, scientific understanding of respirable crystalline silica toxicity has advanced, and the National Institute for Occupational Safety and Health (NIOSH) has recommended a respirable crystalline silica exposure level of 50 µg/m<sup>3</sup> for workers. In 2016, the Occupational Safety and Health Administration (OSHA) established a permissible exposure level (PEL) of 50 µg/m<sup>3</sup> in all industry sectors that it regulates.

To provide miners with this same level of protection as workers in other industries, MSHA proposes to lower its existing exposure limits to 50 µg/m<sup>3</sup> for respirable crystalline silica in MNM and coal mines. The proposed PEL would be expressed as a full shift exposure, calculated as an 8-hour time-weighted average (TWA). A uniform proposed PEL for all MNM and coal mines would also eliminate the existing respirable dust standard when quartz is present for coal mines, which, due to its complexity, can create both compliance and enforcement challenges.

Under the proposed rule, mine operators would be required to: conduct exposure monitoring (§ 60.12); implement exposure controls (§ 60.11); provide respiratory protection during corrective actions (§ 60.13 and 60.14); make periodic medical examinations available to MNM miners (§ 60.15); and revise or develop existing respiratory protection programs and practices in accordance with the ASTM F3387-19 (§§ 56.5005, 57.5005, and 72.710), as applicable. Therefore, mine operators would incur the following incremental costs (using a 3 percent discount rate):

- Aggregate annualized costs of \$57.6 million in 2021 dollars.
- These costs are attributable to the following provisions of the proposed rule:
  - Exposure Monitoring (\$32.0 million, 56 percent of total)
  - Exposure Controls (\$5.75 million, 10 percent of total)
  - Respiratory Protection (\$1.03 million, 2 percent of total)
  - Medical Surveillance (\$17.4 million, 30 percent of total), and
  - ASTM Update (\$1.4 million, 2 percent of total).
- Annualized compliance costs attributed by commodity comprise:
  - Metal/Nonmetal: \$52.7 million (92 percent of total)
  - Coal: \$4.9 million (8 percent of total)
- Annualized compliance costs are expected to comprise about 0.05 percent (3 percent real discount rate) of annual industry revenues, well below the 1 percent

threshold that represents a presumption of no significant economic impacts to the industry.

In the remainder of this section, MSHA presents in detail the methods and data used to estimate the expected compliance costs of the proposed rule. Section 4.1 provides an overview of MSHA's approach to estimating costs. Section 4.2 describes the components of and rationale for the requirements to comply with the proposed PEL under 30 CFR Part 60; this includes exposure monitoring, engineering and administrative controls, additional respiratory protection needed by miners, and medical surveillance for MNM miners. Section 4.3 analyzes the changes in respiratory protection practices by updating from the 1969 ANSI standard to the 2019 ASTM standard and estimates the costs associated with the update. Finally, the Economic Feasibility of the proposed rule is presented in Section 6.

#### **4.1 Overview of Cost Estimation**

As described in the Technological Feasibility analysis, MSHA identified measures that would allow mines to reduce respirable crystalline silica dust concentrations from the existing PEL of 100  $\mu\text{g}/\text{m}^3$  for MNM and the existing exposure limit of 85.7  $\mu\text{g}/\text{m}^3$  for Coal to the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ . Those measures include:

- Conducting periodic sampling to ensure the mine meets the requirements of the proposed rule and to identify potential control failures so the mine operator can undertake corrective action.
- Selecting engineering controls such as the purchase of services and new equipment to clean or ventilate dust from work areas.
- Improving maintenance and repair of existing dust controls.
- Implementing administrative controls that will reduce miners' exposure to respirable crystalline silica dust.
- Providing respiratory protection to miners who did not need it at the existing PEL but might need it – at least temporarily – at the proposed PEL.
- Requiring MNM operators to make specified medical examinations available for all their miners.
- Updating respiratory protection practices from the current 1969 ANSI standard to the proposed 2019 ASTM standard.

### 4.1.1 Methodology

For each of the types of costs described above, MSHA will overview the cost estimation methodology and discuss how those costs might differ across the two mining sectors:

- Metal/Nonmetal
- Coal

After determining the steps likely necessary to comply with each provision of the proposed rule, MSHA estimates the costs incurred by a typical mine to comply with the provision. These could include one-time costs to purchase and install an engineering control, provide equipment expected to last multiple years (e.g., respirators), or devise and implement an administrative control. MSHA also estimates recurring costs such as the operating and maintenance (O&M) costs for using the engineering control, or the value of the labor hours and supplies used to perform periodic exposure monitoring. MSHA will aggregate costs by multiplying the average cost per mine by the number of mines expected to incur that cost. These costs are then added together over all control categories for each of the two major mining sectors to estimate industry cost totals.

#### 4.1.1.1 Cost Annualization

It is not appropriate to compare one dollar in cost incurred today with one dollar in benefits accrued 20 or more years from now because of the time value of money (i.e., the value of one dollar today is worth more than the value of one dollar a year from now). To ensure costs and benefits can be compared on a level playing field, MSHA annualizes costs and benefits. Cost annualization takes a series of costs (or benefits) incurred over time and converts them to a sequence of equal annual costs with the same present value as the original costs. One example of this concept is converting the purchase price of a house into a series of monthly mortgage payments; the sequence of equal monthly payments of principal and interest over 30 years has the same present value as the initial purchase price of the house.

Annualized costs (and benefits) are expressed as equal values per year over the analytic period and are convenient metrics for long-term analysis because they are immune to annual variations in cost while still accounting for the time value of money.

Different provisions of the proposed rule will result in mines incurring different patterns of compliance costs. The cost of complying with each provision will depend on the particular combination of one-time versus recurring costs, the timing of those costs, and the frequency at which controls might need to be replaced. To aggregate those costs for comparison with the estimated benefits of the proposed rule, MSHA uses a method called “cost annualization.” In addition to variation in the pattern or timing of compliance costs, the value of the broader costs and benefits of the rule also vary substantially over time. The most significant variation is that although mine operators begin incurring costs as soon as the rule is promulgated, the benefit



attributable to the reduction in exposure to respirable crystalline silica dust may not become fully apparent until 60 years following promulgation.

To compare costs with benefits that accrue over 60 years, MSHA annualizes costs using 3 percent and 7 percent real discount rates as specified in OMB guidance. The analytic period over which costs are annualized largely depends on the type of cost considered. For example, it is analytically convenient to match the analytic period for one-time costs for durable goods, machinery and structures to their expected service life to account for O&M costs over the entire life. If the services of such products, machinery or structures are needed for longer than their original service life, the analytic period may be doubled to account for replacement cost and continuing operating costs. MSHA set the analytic period for cost components primarily comprised of labor (e.g., increased maintenance and repair costs; administrative costs) at 10-years. Capital costs use a 30-year analytic period. Because exposure sampling costs require initial baseline sampling that is not repeated, MSHA set the analytic period at 60 years. The analytic period for Medical Surveillance costs is set at 20 years due to the expected working life of a miner. However, while different analytic periods are used to accommodate the different timings at which one-time costs are incurred, the resulting costs can be compared because taking their present value accounts for differences in timing, then annualizing results in a series of equal annual payments that are equal in each year of the analytic period regardless of when the underlying costs are incurred.

Benefits of the proposed rule are annualized over a 60-year period because (a) the types of diseases caused by exposure to respirable crystalline silica dust take significant time to develop before they become apparent, and (b) this is the period of time after which benefits will have reached their full effect because miners who are already working at promulgation and thus receive less than the full benefit of working under the proposed PEL (e.g., a miner who has worked 20 years under the existing PEL will have only received the benefit of working 25 years at the lower exposure limit) before retiring. Therefore, the overall analytic period for the proposed rule is 60 years.

Annualized costs and benefits can be directly compared to determine the net annualized benefit. This implicitly assumes all costs repeat in the same pattern over the 60-year period. For example, if the expected service life of a structure's ventilation system is 30 years, the capital costs to replace the ventilation system would be incurred again following the initial 30-year period (e.g., the mine replaces the ventilation system in years 1 and 31). But the annualized cost of two ventilation systems purchased once every 30 years over 60 years will be approximately equal to the annualized cost of one ventilation system lasting 30 years (excluding inflation) and can thus be compared to benefits annualized over the 60-year period. To the extent that a purchased control needs to be replaced less frequently than the analytic period (e.g., the

ventilation system lasts 40 years instead of the expected 30 years), this method overestimates annualized costs of the rule.<sup>11</sup>

In this section, MSHA presents: the exposure monitoring; engineering and administrative controls; control maintenance and repair; respiratory protection measures; medical surveillance requirements that will assist mines in meeting the mandatory health standards proposed in 30 CFR Part 60 (Respirable Crystalline Silica); and the estimated cost mines would incur to apply these measures.

#### **4.1.1.2 Labor Costs**

For each type of measure discussed below, MSHA will justify its inclusion based on utility and describe its major cost components. In general, the measures specified for the two mining sectors do not differ in either their justification or their cost structure.

However, costs for each sector will vary for several reasons. First, aggregate costs will vary because of differences in the number of mines in each sector that must adopt new practices and methods to reach the proposed PEL. Second, average hourly wages vary between sectors, even for miners in the same occupation or who perform the same tasks. Third, the prevalence of certain occupations and tasks varies between sectors, so more miners in MNM mining, for example, might need more protection than those in an equivalent occupation or task in Coal mining.

Many of the measures described below are primarily – but not completely – based on the time miners need to perform specified tasks. These measures include exposure monitoring, new engineering controls, increased maintenance and repair of existing engineering controls, administrative controls, and respiratory protection measures. In general, MSHA uses fully loaded hourly wage rates to value the time spent on these activities. MSHA’s source for unburdened wage rates is the BLS’s Occupational Employment and Wage Statistics (OEWS) statistics for the mining industry.<sup>12</sup> Unburdened wage rates are loaded to account for the employer cost of providing employee benefits (U.S. Bureau of Labor Statistics, 2021b) and overhead (U.S. Department of Labor, 2019). In total, the unburdened rate is multiplied by 1.663 (= 1.493 benefit multiplier + 0.17 overhead multiplier) to estimate the loaded wage.

In general, the labor cost of performing certain activities (e.g., checklist for equipment operators) is estimated using sources such as MSHA’s experience and knowledge; the

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<sup>11</sup> The principles described here apply to all analytic periods used in this analysis. However, to match a 60-year analytic period for benefits, the implicit repeating pattern of costs would apply six times for a control with an analytic period of 10 years but would only apply three times if the analytic period is 20 years and twice if the analytic period is 30 years.

<sup>12</sup> Bureau of Labor Statistics (BLS): Occupational Employment and Wage Statistics (OEWS). National industry-specific and by ownership. May 2021. Downloaded from <https://www.bls.gov/oes/tables.htm> on April 29, 2022. Three North American Industry Classification System (NAICS) codes are relevant to this analysis: 212100: Coal Mining; 212200: Metal Ore Mining; 212300: Nonmetallic Mineral Mining and Quarrying. OEWS wage rates are expressed in 2021 dollars and hence do not need to be adjusted for inflation.

Technological Feasibility and Economic Analyses for OSHA’s Silica rule (2013c); NIOSH’s Best Practices for Dust Control in Coal Mining (NIOSH, 2021a) and industry and manufacturer representatives through conversations or peer-reviewed and gray publications.<sup>13</sup>

These sources are also used to estimate the value of multipliers which are in turn used to estimate, for example, the cost of parts for equipment repairs relative to the cost of time mine operators spend on labor for maintenance and repairs; or the costs of preparing signage, informational posters, and training materials relative to the labor costs to identify opportunities for administrative controls and preparing procedures to implement those controls.

In addition, these sources are used to estimate variation in hours and costs over time. For example, it is likely that the opportunities to identify effective administrative controls will decrease over time simply because as opportunities are identified, there will be fewer new opportunities to find in following years, and those are likely to have less effect on miners’ exposure to respirable crystalline silica dust. Thus, it is likely that the labor hours mine operators assign to administrative controls will decrease over time.

In addition to the references listed above, market research on current prices is used to estimate the costs for engineering controls and other equipment (e.g., respirators). To the extent that prices may not be current, MSHA updates those prices to 2021 dollars using the Bureau of Economic Analysis’s GDP Implicit Price Deflator.<sup>14</sup>

MSHA invites comments on the values selected for the cost estimates presented here, as well as additional data to support alternative cost estimates. The Agency is interested in receiving the data and information on potential control-related costs such as engineering and administrative controls and their maintenance and repair.

## **4.2 Costs and Measures to Meet the Proposed Permissible Exposure Limit under 30 CFR Part 60**

### **4.2.1 Compliance Costs for Exposure Monitoring Requirements**

Under 30 CFR part 60, the proposed rulemaking for exposure to respirable crystalline silica dust lowers the PEL for all MNM and coal mines (§ 60.10). The proposed rule also establishes requirements for exposure monitoring (§ 60.11 through § 60.16) that must be met for mine operators to comply with the rule. In this section, MSHA presents its analysis and estimate of costs attributable to exposure monitoring under the proposed rule.

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<sup>13</sup> Gray literature generally consists of publications such as reports, working papers, white papers and evaluations prepared by subject matter experts in academia, government agencies, and industry that has not been subject to a formal peer-review process.

<sup>14</sup> Gross Domestic Product: Implicit Price Deflator, Index 2012=100, Annual, Seasonally Adjusted. Downloaded from <https://fred.stlouisfed.org/series/GDPDEF#0> on May 12, 2022.

### Affected Mines

MSHA first presents a tabulation of mines affected by exposure monitoring requirements in Table 4-1Table 4-. The difference between this table and the tabulation in the industry profile is that it further characterizes active mines by the number of quarters in which they were active in 2019 (reporting at least 520 miners' hours in any quarter of 2019). All active mines are required to conduct exposure monitoring; however, MSHA believes these costs will vary with mine size and quarters in operation.

As shown in Table 4- a total of 12,631 mines in all commodities were active for at least 3 months in 2019; over 70 percent of those mines (8,849 of 12,631) were active for the entire year in 2019, and 86 percent of mines (8,849 + 2,110)/12,631) were active for six months or more. Roughly equal percentages of Coal (85 percent) and MNM mines (87 percent) were active for 3 or 4 quarters in 2019. Thus, there is little difference by commodity type between the percentages of mines that were active for at least six months. The primary difference between mines that opened at least six months a year and those that opened less than six months a year is mine size. A total of 1,672 mines of all types were active for only one or two quarters in 2019; of these, only seven mines employed more than 20 miners (0.4 percent). The remaining 1,665 mines employed 20 or fewer miners (including contractors). Both mine size and quarters of activity affect the number of samples taken, and thus the cost of compliance.

**Table 4-1. Mines and Miners, Activity by Quarter, by Commodity, 2019**

Commodity and Mine Size	Total		Active 4 Quarters		Active 3 Quarters	
	Mines	Miners Including Contractors	Mines	Miners Including Contractors	Mines	Miners Including Contractors
All Mines						
Miners ≤ 20	10,945	75,737	7,203	64,330	2,077	7,505
20 < Miners ≤ 100	1,337	78,170	1,298	76,208	33	1,592
100 < Miners ≤ 500	311	87,768	310	87,599	0	0
500 < Miners	38	43,104	38	43,104	0	0
<b>Total</b>	<b>12,631</b>	<b>284,779</b>	<b>8,849</b>	<b>271,240</b>	<b>2,110</b>	<b>9,097</b>
MNM						
Miners ≤ 20	10,238	69,520	6,764	59,495	1,978	6,817
20 < Miners ≤ 100	1,066	61,316	1,047	60,359	15	726
100 < Miners ≤ 500	195	50,469	194	50,299	0	0
500 < Miners	26	29,899	26	29,899	0	0
<b>Total</b>	<b>11,525</b>	<b>211,203</b>	<b>8,031</b>	<b>200,052</b>	<b>1,993</b>	<b>7,544</b>
Coal						
Miners ≤ 20	707	6,217	439	4,835	99	688
20 < Miners ≤ 100	271	16,854	251	15,849	18	866
100 < Miners ≤ 500	116	37,299	116	37,299	0	0
500 < Miners	12	13,205	12	13,205	0	0
<b>Total</b>	<b>1,106</b>	<b>73,576</b>	<b>818</b>	<b>71,188</b>	<b>117</b>	<b>1,554</b>
	Active 2 Quarters		Active 1 Quarter			
All Mines						
Miners ≤ 20	1,087	2,776	578	1,127		
20 < Miners ≤ 100	2	140	4	230		

Commodity and Mine Size	Total		Active 4 Quarters		Active 3 Quarters	
	Mines	Miners Including Contractors	Mines	Miners Including Contractors	Mines	Miners Including Contractors
100 < Miners ≤ 500	0	0	1	170		
500 < Miners	0	0	0	0		
<b>Total</b>	<b>1,089</b>	<b>2,916</b>	<b>583</b>	<b>1,526</b>		
MNM						
Miners ≤ 20	1,004	2,344	492	864		
20 < Miners ≤ 100	0	0	4	230		
100 < Miners ≤ 500	0	0	1	170		
500 < Miners	0	0	0	0		
<b>Total</b>	<b>1,004</b>	<b>2,344</b>	<b>497</b>	<b>1,264</b>		
Coal						
Miners ≤ 20	83	432	86	263		
20 < Miners ≤ 100	2	140	0	0		
100 < Miners ≤ 500	0	0	0	0		
500 < Miners	0	0	0	0		
<b>Total</b>	<b>85</b>	<b>572</b>	<b>86</b>	<b>263</b>		

### *Estimated Cost by Monitoring Requirement*

There are five types of exposure monitoring required under the proposed rule:

- Baseline sampling based on a representative fraction of miners (§ 60.12(a)).
- Periodic sampling of a representative fraction of miners. If the most recent sampling results are at or above the action level but below the PEL (§ 60.12(b)); periodic monitoring continues until two consecutive sample results demonstrate that miners' exposures are below the proposed action level.
- Corrective action is performed after a sample result demonstrates that the proposed PEL has been exceeded. The mine operator first undertakes corrective actions to reduce exposure, then conducts sampling until the results demonstrate miners' exposures are at or below the proposed PEL (§ 60.12(c)).
- Semi-annual evaluations to ensure that production, processes, engineering or administrative controls, or other factors that may reasonably be expected to result in new or increased respirable crystalline silica exposures have not changed in a way that might increase miners' exposures (§ 60.12(d)).
- If the semi-annual evaluations conducted under § 60.12(d) find that increased exposures are likely, additional sampling must be conducted to ensure exposures remain at or below the proposed action level (§ 60.12 (e)).

MSHA selected the specified monitoring (sampling and evaluation) frequencies because it believes that it is necessary for mine operators to establish a baseline for any miner who is reasonably expected to be exposed to respirable crystalline silica. In addition, sampling in coal mines is currently conducted quarterly and over time has helped mine operators correlate a wide range of conditions to miner exposure levels. Further, periodic sampling will allow mine operators to see longer evidence of exposure trends more rapidly than would semi-annual or annual sampling. This will help mine operators more quickly identify areas where sampling can be discontinued and also more rapidly identify areas where more work is needed to keep exposures from approaching or unwittingly exceeding the proposed PEL. Thus, the periodic feedback provided by this monitoring frequency will better protect miner health than would other more extended sampling frequencies.

MSHA estimates sampling costs as a function of several factors: miners' and samplers' time and hourly wage; the number of samples necessary to meet the proposed requirements; the laboratory costs for analyzing the samples; and clerical costs for recording the results.

Exposure sampling costs time, which is valued at the hourly wage of the person wearing the sampling equipment and the person conducting the sampling. MSHA assumes that in MNM mines, sample preparation and collection is performed by an industrial hygienist (IH). The IH may be an in-house specialist or an external consultant. The IH consultant is assumed to charge

\$1,500 per day, including travel and report preparation costs. The time for the in-house IH is valued at their loaded average hourly wage. Because not all mines have an IH on staff MSHA assumes that half of MNM mines hire a contract IH, while the others use an on-staff IH for sampling (see Table 4-2). Coal miners, however, have a provision (30 CFR § 70.205) by which the miners themselves, if certified through training, can prepare the sampling equipment, fit it to the miner, collect the sample, ship the sample to the laboratory, and record the necessary information. MSHA assumes coal mines use trained miners. Thus, the average labor cost for coal mine sampling is less than 40 percent of that for MNM mines.

In addition, other activities associated with sampling cost include mine labor time. First, each sampled miner is assumed to lose one half hour of work time to be equipped with a sampling device, valued at the average loaded hourly wage of mine “Extraction Workers” (Standard Occupational Code 47-5000). Second, recordkeeping time takes 15 minutes per sample and is valued at the average loaded hourly wage of mine “Occupational Health and Safety Specialists” (Standard Occupational Code 19-5011). Third, MSHA assumes it takes two hours to prepare an evaluation; again, this time is valued at the average loaded hourly wage of mine “Occupational Health and Safety Specialists.” Loaded hourly wage rates are presented in Table 4-2.

Where several miners perform the same tasks on the same shift and in the same work area, the mine operator may sample a representative fraction (at least two) of these miners to meet the sampling requirements. MSHA requires that mines sample a representative group of miners who are expected to have the highest exposure to respirable crystalline silica. Based on the stratification of mines by size, MSHA assumes that a sample comprising at least 50 percent of miners at mines that employ 20 or fewer miners (including contract workers) will be necessary to collect a representative sample. In mines with 20 to 100 miners, a minimum 25 percent of miners will need to be sampled for the sample to be representative, while a minimum 10 percent sample should be representative at mines employing at least 100 miners. MSHA also assumes the personnel conducting sampling can collect 2, 3, and 4 samples per day at small, medium, and large mines, respectively.

These assumptions are also used to estimate the costs of periodic sampling for miners with exposures at or above the action level of  $25 \mu\text{g}/\text{m}^3$ . However, not all mines operate year-round; therefore, MSHA adjusted sampling costs for mines that operate fewer than four quarters per year. Each mine is assumed to undertake sampling with a frequency equal to the number of quarters the mine is open; those open only two quarters per year, for example, are assumed to sample twice during a calendar year.

In addition, MSHA accounts for sampling that might be performed for purposes of ensuring corrective actions sufficiently reduce miners’ exposure to respirable crystalline silica or evaluating whether exposure levels might have changed or remain below the proposed action level. MSHA assumes that additional sampling comprising 2.5 percent of miners accounts for corrective and/or evaluation sampling. This percentage is relatively small because mine operators are already performing a significant amount of periodic sampling that can be used for

these purposes, as well as any sampling performed by MSHA inspectors. However, some additional sampling might be needed to supplement these sources, hence the additional estimated sampling costs for these two categories.

MSHA believes that periodic sampling will decline over time, but not entirely disappear. Periodic sampling is required when results are at or below the proposed PEL but above the proposed action level of  $25 \mu\text{g}/\text{m}^3$  (§ 60.12(b)). Although reducing the exposure below the proposed action level is costly for mine operators, repeated sampling is also costly. Thus, mine operators have a financial incentive to reduce exposures not just below the proposed PEL but the proposed action level also.

MSHA assumes that mine operators will reduce the percentage of samples exceeding the proposed action level from their current level to about 15 percent of samples exceeding the proposed action level. Because there are no data on the pattern this reduction might take, MSHA assumes the decline will be linear.

Finally, mine operators are required to conduct evaluations at least semi-annually to evaluate any changes in production, processes, engineering or administrative controls, or other factors that may reasonably be expected to result in new or increased respirable crystalline silica exposures. MSHA assumes that mines operating only two quarters or less per year will conduct the evaluation once per year, while mines operating more than two quarters per year will perform this evaluation twice per year. Preparing the evaluation will require two hours of an IH specialist's time.

Table 4-2 summarizes how the costs of each of the types of monitoring measures are estimated. In addition, the table summarizes the definitions of each component used in the calculations.

**Table 4-2. Estimated Unit Monitoring Costs in 2021 Dollars**

Monitoring Cost Calculations Components [a]	
Baseline sampling = Number of baseline samples × price per sample where: Baseline samples = number of miners × percent of miners needed for representative sample by mine size Price per Sample = Sampling labor cost + lost work time + recording time + laboratory fees	
Periodic sampling of miners at or above the action level ( $>25 \mu\text{g}/\text{m}^3$ ) but at or below the PEL ( $\leq 50 \mu\text{g}/\text{m}^3$ ) = Number of periodic samples × price per sample where: Periodic samples = Number of miners with sample results above $25 \mu\text{g}/\text{m}^3$ × percent of miners needed for representative sample by mine size × number of quarters mine in operation Price per Sample = Sampling labor cost + lost work time + recording time + laboratory fees	
Corrective actions sampling plus Semiannual evaluation sampling = Number of corrective actions and evaluation samples × price per sample where: Corrective action and evaluation samples = Number of miners with sample results at or above $50 \mu\text{g}/\text{m}^3$ ×	



Monitoring Cost Calculations Components [a]		
2.5 percent sampled Price per Sample = Sampling labor cost + lost work time + recording time + laboratory fees		
Semi-Annual evaluation = Number of mines × cost per evaluation × frequency of evaluation where: Cost per evaluation = hours per evaluation × inhouse loaded IH wage		
Labor cost		
<u>Sampling labor cost</u> Metal Mine Nonmetal Mine Coal Mine	\$1,029* per day sampling \$966* \$343  * Average of cost of independent IH contractor (\$1,500 per day) and inhouse IH	Preparing and setting up sampling equipment; collecting samples; sending samples to laboratory; recording results
<u>Lost work time</u> Metal Mine Nonmetal Mine Coal Mine	\$24 per miner sampled \$19 \$23	30 minutes of “Extraction Worker” valued at loaded hourly wage
<u>Recordkeeping time</u> Metal Mine Nonmetal Mine Coal Mine	\$17 per sample \$15 \$19	15 minutes of IH valued at loaded hourly wage
<u>Semi-annual evaluation</u> Metal Mine Nonmetal Mine Coal Mine	\$139 per evaluation \$123 \$152	2 hours of IH valued at loaded hourly wage
Other costs and parameter		
Laboratory fees \$140 per sample		

[a] Throughout this table, miners refer to both miners and contractors.

Table 4-3 shows that of the 122,000 samples expected to be taken in the first year following promulgation, about 85 percent (= 103,000 ÷ 122,000) in the MNM sector. In years six through 20, about 80 percent (= 45,400 ÷ 56,500) will be in the MNM sector. The relatively large reduction in MNM sector samples is attributable to the much larger percentage of miners with samples exceeding the proposed action level in year 1, and thus a larger decrease over the five-year adjustment period.<sup>15</sup>

The estimated 122,000 samples in year 1 include 70,500 baseline samples, 44,150 periodic samples, and 7,100 corrective and process evaluation samples. Baseline sampling, from 284,800 miners working 12,600 mines in year 1 is expected to fall to 1,400 samples at 250

<sup>15</sup> Analysis of the MNM Silica Exposure and Coal Silica Exposure Data suggests that MNM mines will need to decrease samples exceeding the proposed action level from about 35 percent to 15 percent in six years, while Coal mines will need to decrease samples from about 19 percent to 15 percent in the same period. [Mine Safety and Health Administration [MSHA]. 2022a. MNM Silica Exposure Data. MSHA MSIS respirable crystalline silica data for the MNM Industry, 2005 through 2019 and Mine Safety and Health Administration [MSHA]. 2022b. Coal Silica Exposure Data MSHA MSIS respirable crystalline silica data for the Coal Industry, August 2016 through July 2021.]

miners per year for every year subsequent to year 1 because baseline sampling will only be performed by new mines. MSHA projects that about 2 percent of mines in any given year will be new entrants to the mining industry, although the total number of mines in each year remains roughly constant.

Periodic sampling, which is carried out when a previous sample was at or above the action level but at or below the PEL, is projected to increase from 44,150 in year 1 (from 88,600 miners in 12,600 mines) to 78,800 in year 2 (because only a half year of periodic monitoring occurs in year 1), then decline steadily to 41,000 by year 6 due to the implementation of engineering control maintenance repair and administrative controls. As illustrated in Table 4-4, the number of periodic samples is expected to decline by about 12 percent over all mine types per year<sup>16</sup> due to the assumed decline in miners and contractors with exposure levels at or above the action level from year 2 to year 6. Post evaluation and corrective sampling are assumed to remain constant at 14,100 samples per year since these samples are independent from the periodic sampling and MSHA sampling that are expected to form the primary source of quantitative data necessary to characterize exposure at a mine site.

**Table 4-3. Estimated Number of Samples Taken by Type and Year**

Cost Type	Year 1			Years 6 - 60*		
	Mines	Miners	Samples	Mines	Miners	Samples
All Mines						
Baseline sampling [a]	12,631	284,779	70,498	253	5,696	1,410
Periodic Sampling [b]		88,660	44,151		42,717	40,963
Corrective action & Process change sampling		88,660	7,064		42,717	14,128
<b>Total</b>	<b>NA</b>	<b>NA</b>	<b>121,713</b>	<b>NA</b>	<b>NA</b>	<b>56,500</b>
Metal/Nonmetal						
Baseline sampling [a]	11,525	211,203	58,126	231	4,224	1,163
Periodic Sampling [b]		74,689	39,590		31,680	33,757
Corrective action & Process change sampling		74,689	5,235		31,680	10,470
<b>Subtotal</b>	<b>NA</b>	<b>NA</b>	<b>102,951</b>	<b>NA</b>	<b>NA</b>	<b>45,390</b>
Coal						
Baseline sampling [a]	1,106	73,576	12,373	22	1,472	247
Periodic Sampling [b]		13,971	4,561		11,036	7,205
Corrective action & Process change sampling		13,971	1,829		11,036	3,658
<b>Subtotal</b>	<b>NA</b>	<b>NA</b>	<b>18,762</b>	<b>NA</b>	<b>NA</b>	<b>11,111</b>

[a] For years 2 - 60 MSHA assumes that 2% of mines will be new and therefore undertake initial monitoring, but with no net growth, the total number of mines will remain constant.

[b] Periodic monitoring of miners above the action level ( $>25 \mu\text{g}/\text{m}^3$ ); periodic sampling declines at the linear rates specified in Table 1-2 from year 1 to year 6.

<sup>16</sup> Calculated as the Compound Annual Growth Rate (CAGR) of periodic samples taken over 5 years.

**Table 4-4. Reduction in Periodic Samples by Year and Sector**

Type of Sample	Number of Samples by Year					
	Year 1	Year 2 [a]	Year 3	Year 4	Year 5	Years 6-60
Periodic Sampling						
<b>All Mines</b>	<b>44,151</b>	<b>78,834</b>	<b>69,366</b>	<b>59,898</b>	<b>50,430</b>	<b>40,963</b>
Metal/Nonmetal	39,590	70,096	61,011	51,927	42,842	33,757
Coal	4,561	8,738	8,355	7,972	7,588	7,205
All types of samples						
<b>All Mines</b>	<b>121,713</b>	<b>94,371</b>	<b>84,904</b>	<b>75,436</b>	<b>65,968</b>	<b>56,500</b>
Metal/Nonmetal	102,951	81,728	72,644	63,559	54,474	45,390
Coal	18,762	12,643	12,260	11,877	11,494	11,111

[a] Following year 1, baseline sampling declines to about 1,400 samples per year attributable to new mines opening; corrective and evaluation sampling remain constant at about 14,100 samples per year.

Table 4-5 presents estimated total annualized monitoring costs by type of monitoring and mining sector. Overall, all five types of monitoring are projected to cost mine operators an average of about \$32.0 million (3 percent real discount rate) per year over 60 years. Almost 90 percent are expected to be incurred by MNM mines while almost 10 percent are expected to be incurred by Coal mines. By type of monitoring, at \$1.9 million per year, initial monitoring composes about 6 percent of monitoring costs, while periodic monitoring of miners at or above the action level (\$21.7 million per year) accounts for nearly 68 percent of monitoring costs.

**Table 4-5. Total Annualized Sampling Costs by Commodity, 2021 (in millions of dollars)**

Cost Type	Total Cost over 60 Years	Annualized Costs			Percent Annualized Costs [c]
		0% Real Discount Rate	3% Real Discount Rate	7% Real Discount Rate	
All Mines					
Baseline sampling [a]	\$75.5	\$1.3	\$1.9	\$3.0	5.9%
Periodic Sampling	\$1,252.0	\$20.9	\$21.7	\$23.1	67.9%
Corrective action & Process change sampling	\$331.9	\$5.5	\$5.5	\$5.4	17.1%
Process change evaluations [b]	\$176.3	\$2.9	\$2.9	\$2.9	9.1%
<b>Total</b>	<b>\$1,835.7</b>	<b>\$30.6</b>	<b>\$32.0</b>	<b>\$34.3</b>	<b>100.0%</b>
Metal/Nonmetal					
Baseline sampling [a]	\$68.1	\$1.1	\$1.7	\$2.7	5.3%
Periodic Sampling	\$1,134.1	\$18.9	\$19.8	\$21.1	61.8%
Corrective action & Process change sampling	\$277.1	\$4.6	\$4.6	\$4.5	14.3%
Process change evaluations [b]	\$157.9	\$2.6	\$2.6	\$2.6	8.1%
<b>Subtotal</b>	<b>\$1,637.2</b>	<b>\$27.3</b>	<b>\$28.7</b>	<b>\$30.9</b>	<b>89.5%</b>
Coal					
Baseline sampling [a]	\$7.4	\$0.1	\$0.2	\$0.3	0.6%

Cost Type	Total Cost over 60 Years	Annualized Costs			Percent Annualized Costs [c]
		0% Real Discount Rate	3% Real Discount Rate	7% Real Discount Rate	
Periodic Sampling	\$117.9	\$2.0	\$2.0	\$2.0	6.2%
Corrective action & Process change sampling	\$54.8	\$0.9	\$0.9	\$0.9	2.8%
Process change evaluations [b]	\$18.4	\$0.3	\$0.3	\$0.3	\$0.0
<b>Subtotal</b>	<b>\$198.5</b>	<b>\$3.3</b>	<b>\$3.4</b>	<b>\$3.5</b>	<b>10.5%</b>

[a] Periodic sampling of miners above action level ( $> 25 \mu\text{g}/\text{m}^3$ ).

[b] Semi-annual evaluation.

[c] At the 3 percent real discount rate.

## 4.2.2 Control Measures

To estimate the cost of control measures, MSHA focuses on two major categories of controls:

- Engineering controls:
  - Purchasing new services and new equipment to clean or ventilate dust from work areas
  - Increased frequency of dust control maintenance and repair
- Administrative controls to reduce dust exposure.

In addition, to meet the requirements of 30 CFR Part 60, mine operators may have to provide some miners with respiratory protection. Respiratory protection is discussed below.

The assumptions and parameters used to estimate the costs of controls in this section can be considered those for a “typical” mine. As such, estimated costs are not distinguished by mine size; for at least some control categories, cost per mine may be lower for mines that are smaller than average or higher for mines that are larger than average.

### *Affected Mines*

MSHA expects that the cost of engineering and administrative controls will primarily be a function of the number of mines potentially affected by the rule, or more precisely, by the number of mines with a high likelihood of incurring costs to reach compliance with the proposed PEL. Although any operating mine might potentially be affected by this rulemaking because mines are under the jurisdiction of MSHA and are in the scope of this rulemaking, MSHA focuses the analysis on mines that are highly likely to incur costs under this rule; that is, mines that are expected to be affected by the rule.<sup>17</sup>

<sup>17</sup> The term mine means a 'coal or other mine,' as defined in section 3 of the Federal Mine Safety and Health Act of 1977 (30 U.S.C. 802), that is subject to the provisions of such Act (30 U.S.C. 801 et seq.).

MSHA uses data from its silica exposure datasets (MSHA 2022a, MSHA 2022b) to estimate the number of mines most likely to incur costs under this rule using the methodology described here. In addition to other criteria, this estimate is based on an analysis of individual mines, which is possible given that all inspection samples in the exposure datasets are identified by a Mine ID unique to the mine at which the sample was taken. Thus, MSHA can distinguish specific mines that have samples exceeding the proposed PEL. The exposure datasets contain five years of sample data for coal mines and 15 years of data for MNM mines (because MNM mines are sampled less frequently than coal mines, more years of data were included in the MNM dataset to make the number of observations roughly equal to the coal dataset). For most mines, the dataset includes multiple sample results as well as results from multiple inspections. The method of identifying affected mines, explained below, accounts for changes over time, whereby a previously noncompliant mine became compliant in more recent years.

To estimate the number of affected mines that would incur costs, MSHA analyzes MNM mines that were active in the 2015 – 2019 period, and Coal mines that were active in the August 2016 – July 2021 period. Mines that closed prior to 2015 (2016 for coal mines) are excluded because they may not be representative of mines still in production, especially in regard to respirable crystalline silica concentrations and/or respirable crystalline silica controls. MSHA designates mines as active in the five-year period if they had at least one three-month period during which they employed at least one full-time equivalent miner (FTE; i.e., 520 hours were worked in that quarter, whether by one or multiple miners).

After first identifying the subset of MNM mines that were active in the 2015 – 2019 period and Coal mines that were active in the August 2016 – July 2021, MSHA examines each mine’s sampling results from the most recent day on which one or more samples were taken.<sup>18</sup> If the result from just one sample on that day exceeds the proposed PEL, MSHA assumes that mine would incur compliance costs under the proposed rule. Using only the most recent day of historical data, MSHA resolves the potential difficulty of interpreting changes in exposure concentrations over time.

This approach relies on two assumptions: (1) a mine operator will use the most recent available data to determine if action is required to comply with the proposed rule, and (2) regardless of the number of sampling results available for that day, a single result that exceeds the proposed PEL will require the mine operator to take action and incur costs to reduce the likelihood of respirable crystalline silica exposure to its miners. Thus:

- A mine is expected to incur costs to meet the proposed PEL if it had a single sample result from the most recent day for which sample results were available

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<sup>18</sup> Although the mine must be active in the most recent five-year period contained in the dataset, the most recent sample(s) used to assess a mine’s likelihood of incurring costs did not need to be taken within that same five-year period. In one instance, for example, the most recent sample result dated from 2005, despite the mine having been active during the most recent five-year period. See: MSHA: Proposed Method for Estimating Mine Entities Affected by MSHA’s Proposed RCS Rule, July 25, 2022.

that exceeded the proposed PEL. Such a mine is described as “affected” by the rulemaking.

- A mine that had no sample results exceeding the proposed PEL on the most recent day for which sample results were available is assumed not to incur compliance costs under the proposed PEL.<sup>19</sup>

Using these criteria, MSHA tabulates the estimated number of affected mines by commodity. Table 4-6 presents the estimated number of affected mines and total mines by commodity, the number of miners employed in affected mines, and the average employment per affected mine. MSHA estimates 1,226 mines of 12,631 total (9.7 percent) are likely to incur costs under the proposed rule. Of total affected mines, nearly 1,100 are MNM, while 130 are Coal mines. Although less than 10 percent of mines are affected, nearly 16 percent of miners and contractors work in affected mines (44,937 miners out of 284,778 total). Because of this, affected mines are larger, employing more miners (i.e., 36.7 miners per mine compared to an average of 22.5).

**Table 4-6. Estimated Number of Affected Mines by Commodity, 2019**

Mine Sector	Number of Mines			Number of Miners Including Contractors			Average Miners Including Contractors per Mine	
	Affected as Percent of Total			In Affected Mines			Affected as Percent of Total	
	Affected	Total	Percent of Total	Affected	Total	Percent of Total	Affected	Total
<b>Total</b>	<b>1,226</b>	<b>12,631</b>	<b>9.7%</b>	<b>44,937</b>	<b>284,778</b>	<b>15.8%</b>	<b>36.7</b>	<b>22.5</b>
Metal/ Nonmetal	1,096	11,525	9.5%	30,823	211,202	14.6%	28.1	18.3
Coal	130	1,106	11.8%	14,114	73,576	19.2%	108.6	66.5

### *Engineering Controls*

MSHA expects that a subset of mines affected by this rule will incur costs because they will be required to adopt additional control measures, such as engineering or administrative controls, to reduce respirable crystalline silica exposures below the proposed PEL of 50 µg/m<sup>3</sup>. MSHA determined the subset of mines that may require additional control measures based on mine size (the number of employees at a mine) and an analysis of citations for violations of the existing PEL. As mine size correlates well with the amount of respirable crystalline silica dust produced and historical mine citations document how mines implement controls to reduce respirable crystalline silica exposure, MSHA is able to estimate the characteristics and number

<sup>19</sup> A mine might not have sample results exceeding the proposed PEL for two reasons. First, samples might have been taken at the mine but the results did not exceed the proposed PEL. Second, the mine might have not been sampled because in the judgement of MSHA inspector any samples would be well below the existing PEL and therefore sampling was unnecessary. In both cases, MSHA assumed that the mine would not incur compliance costs.

of mines that will likely require additional controls as well as the cost of such controls based on how prior citations have been abated.

Utilizing historical data and institutional knowledge, MSHA estimates that approximately 50 percent of mines were previously able to terminate respirable crystalline silica dust citations through the uptake of maintenance, repair, and/or other basic administrative controls to existing infrastructure. Table 4-6 depicts the number of mines, by size, that will require additional controls and the types of controls that will need to be adopted.

**Table 4-7. Affected Mines by Employment Size and Control Category Incurring Additional Engineering, 2019**

Control Category	Mine Employment Size [a]			Total Mines
	Small Mines (< 20 miners)	Medium Mines (19 < miners < 100)	Large Mines (> 100 miners)	
Engineering control -- Minimal capital expenditure	399	50	9	458
Engineering control -- Moderate capital expenditure	50	25	9	84
Engineering control -- Larger capital expenditure	20	8	9	38
<b>Total</b>	<b>469</b>	<b>83</b>	<b>28</b>	<b>580</b>

Numbers may not sum to total due to rounding.

[a] Miners and contract miners.

Table 4-8 presents a selection of the types of engineering controls mines might consider for use in meeting the proposed PEL. NIOSH has carefully evaluated most of the dust controls used in the mining industry and found that many of the controls may be used in combination with other control options, each supplementing the other. NIOSH (2019b, 2021a) has documented protective factors and exposure reductions of 30 to 90 percent or higher for many engineering and administrative controls. MSHA selected several of these that represent a wide range of options that mine operators could apply (in addition to dust control equipment maintenance) to an even wider range of situations in which baseline (existing) conditions include some control technologies, but miner exposures exceed the proposed PEL of 50 ug/m<sup>3</sup>.

Examples of versatile, effective controls that MSHA and NIOSH (2019b, 2021a) have observed missing from baseline (existing) dust controls at mines include sealed pressurized and filtered operator enclosures that exclude dust and provide equipment operators a clean place to work. NIOSH (2019b, 2021a) found operator enclosures (including mobile equipment cabs and stationary control booths, new or renovated) to reduce respirable dust levels by 90 percent or more on mobile equipment (e.g., haulage equipment, drilling rigs, tractor-mounted stone cutting equipment) or at stationary locations such as for longwall machine operators in underground coal mines or for crushing, screening and conveying equipment operators at

surface mines of all types.<sup>20</sup> In contrast, process enclosures perform the reverse function to reduce the amount of dust that gets out of an enclosure containing a dusty process that is controlled by a miner working outside it. One example is an enclosure around a primary dump hopper (into which dump trucks deposit mined material to be crushed).<sup>21</sup> NIOSH recommends adding plastic strip curtains and a concrete barricade to further enclose the opening for the dump truck on an existing enclosure because these components are not necessarily included in the original construction and provide an upgrade that will further enclose dust, calm the air inside, and reduce respirable dust concentrations where miners work outside the crushing equipment. Other examples of ventilated process enclosures include cowl-based dust extractors for small drills (e.g., rock or quarry drill) and at conveyor belt loading enclosures. Operator enclosures and process enclosures provide effective respirable crystalline silica control at both MNM mines and coal mines (NIOSH, 2019b, 2021a).

Mine facilities routinely contain numerous sources of dust emission such as conveyors, screening equipment, material transfer points into and out of process equipment (e.g., mills, kilns, concentrators) and, in some cases, packaging/bagging areas. Although capturing dust at its source is the most effective form of dust control, general exhaust (whole structure) ventilation is used by many mine facilities. NIOSH (2010b) recommends that facilities with whole structure ventilation maintain 10 “air changes per hour” (i.e., an hourly air flow rate that equals 10 times the cubic-foot volume of the structure), which, as an option can be increased to 20 or even 30 or more air changes per hour. MSHA assumes that mines have the recommended 10 air changes per hour in facilities as a baseline (existing) condition, but that where exposures are modestly elevated above the proposed PEL and additional controls are needed, an additional 10 air changes per hour will help flush airborne dust out of the structure. NIOSH found that a ventilation rate of 17 air changes per hour reduced average respirable dust levels by 47 percent (NIOSH, 2010b). MSHA started by assuming that 10 air changes per hour would provide at least an average of 50 percent reduction in respirable dust levels (the difference between the proposed and existing PELs for MNM mines), then considered how much airflow would be needed to achieve that level of reduction for a model mine structure of volume 60,000 cubic feet (e.g., a facility of 50 feet x 30 feet x 40 feet).<sup>22</sup> Based on this information, MSHA calculated that increasing the whole structure ventilation by 10 air changes per hour

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<sup>20</sup> These operator enclosures are best paired with administrative/work practice controls that promote consistent use of the enclosure. Operator enclosures only protect miners for the part of the shift that the miners work inside (e.g., 80 percent of the shift inside a control booth can reduce the miner exposure proportionally).

<sup>21</sup> The enclosure helps calm and contain the air inside so that dust released during dumping has a chance to settle, rather than billowing out of the hopper and engulfing (and thereby overexposing) the truck driver or crusher operator. Where primary dumps contribute to current overexposures, MSHA assumes that mine operators will bring these exposures down to a level below the existing PEL (MNM mines) or exposure limit (coal mines) by adjusting existing water sprays, and, if needed, installing an enclosure and/or added ventilation (NIOSH, 2019b, 2021a).

<sup>22</sup> For an MNM mine a 50 percent reduction in exposure level would reduce the average airborne level of respirable crystalline silica from 85  $\mu\text{g}/\text{m}^3$  (just below the existing PEL of 100) down to a level of 43  $\mu\text{g}/\text{m}^3$ . For a coal mine, a 50 percent reduction in exposure would bring a concentration of 75  $\mu\text{g}/\text{m}^3$  (just below the existing exposure level of 85.7  $\mu\text{g}/\text{m}^3$  ISO, assuming the shift was 8 hours) down to 38  $\mu\text{g}/\text{m}^3$ .



would require installing a ventilation system that draws an additional 10,000 cubic feet per minute of air flow from the structure.<sup>23</sup>

Bulk material loading (from conveyors to other conveyors, hoppers, bulk bags, trucks and railcars, or stockpiles) occurs throughout mines, typically releasing dust considerable respirable dust in the process. Spouts and chutes help minimize factors that allow dust to become airborne (such as the distance material falls, which is controlled by telescoping spouts that release dust within a foot or two of the destination surface). Dust suppression hoppers, which reduce air turbulence, decrease the concentration of respirable dust in the air by up to 88 percent (compared to a plain rigid spout) (NIOSH, 2019b). Alternatively, the materials can be made less dusty by slightly moistening them with water applied as a spray. Achieving and maintaining 1 to 4 percent moisture is optimal for reducing dust release. MSHA assumes that most mines are already applying water spray to dusty materials as a baseline condition; however, NIOSH found that rewetting (using additional spray equipment) is necessary to maintain the moisture level needed for effective dust control (NIOSH, 2019b, 2021a). Although preventing dust from becoming airborne is preferable, other types of water spray equipment use directional water spray, mists or fogs are needed to reduce miner exposure to dust that is already airborne. Consulting with a water spray professional, such as an equipment supplier's technical support representative can help mine operators achieve their goals.

When making changes to dust controls, NIOSH points out that it is helpful to be able to measure airborne dust, air and water pressure, and other dust control system functions using direct reading instruments and gauges (NIOSH, 2019b, 2021a). These tools are useful training aids that can help mine operators, mine maintenance personnel, and miners learn how modest adjustments to these critical parameters improve dust control system performance and reduce airborne respirable dust.

All the engineering controls mentioned here (various forms of operator or equipment enclosures, dust suppression hoppers/telescoping chutes, and water sprays) are compatible and can be installed individually, or in any combination where a mine operator identifies need for additional dust control. These example items were selected, not because they are the only option, but because represent wider groups of similar control measures, they are efficient (able to cut airborne respirable dust by at least half), and they are flexible options that can be added to existing dust controls – whatever those may be. In their series of best practices and handbooks on dust control for the mining industry NIOSH (2019b, 2021a) describes these methods and numerous other options that are also available for mine operators to substitute while selecting the combination appropriate to help each individual mine to achieve the proposed PEL of 50 ug/m<sup>3</sup>.

To support the cost analysis, the sample controls mentioned in Table 4-8 are organized by level of capital investment. For each level of investment, MSHA calculates a simple average

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<sup>23</sup> For a structure of volume 60,000 cubic feet, one air change per hour would be: 60,000 cubic feet per minute times 1 hour/ 60 minutes. Ten air changes per hour would be:  
(60,000 Ft<sup>3</sup>/ 1 air change) \* (10 air changes/hour) \* (1 hour/60 minutes) = 10,000 ft<sup>3</sup>/min air flow

across all controls under consideration in that category. This is because multiple engineering controls can make the necessary reductions in exposure to respirable crystalline silica dust. Mine operators will choose from alternatives based on specific conditions at their mine, mine layout, equipment in place, and other site-specific factors. Within each level of investment, MSHA believes any specific control technology is equally likely to be selected. Thus, without further information regarding mine operators' likely decisions, the expected value of purchased technologies should equal the simple average of the listed technologies in the category.

Where more precise information is unavailable, MSHA assumes operating and maintenance (O&M) costs to be 35 percent of initial capital expenditure and assumes that installation cost, when appropriate, will be equal to any initial capital expenditure. MSHA assumes most controls will have a ten-year service life, except for a 15-year service life for heavy haulage and excavating machinery, and a 30-year service life for new or substantially renovated structural ventilation systems. MSHA welcomes public comment concerning the engineering controls selected for this analysis and the assumptions used to estimate installation and O&M costs for these controls.

**Table 4-8. Selected Engineering Controls to Decrease Respirable Crystalline Silica Dust Exposure by Capital Expenditure Cost Range**

Engineering Control	2021 Capital Cost	2021 Installation Cost [a]	2021 O&M Cost [b]	Expected Service Life [c]
<b>Minimal capital expenditure</b>				
Dust extraction kit for rock drill	\$1,400	\$1,400	\$490	10
Upgrade water pump pressure to achieve fine mist	\$1,600	\$1,600	\$560	10
Mini-mister, boom mounted	\$1,800	\$1,800	\$630	10
Upgrade recirculating air filter in operator enclosure	\$0	\$0	\$420	10
Portable HEPA wet-dry vacuum, 9 gallon	\$595	\$0	\$600	2
Add cyclonic pre-cleaner upwind of air intake filter for operator enclosure	\$816	\$816	\$286	10
Vacuum pressure gauge (test suction on dust collector)	\$79	\$79	\$28	10
Water line pressure gauge (check pressure for water spray systems)	\$19	\$19	\$6	10
Differential pressure gauge (check ventilation system component function)	\$70	\$70	\$25	10
Hand-held real-time dust analyzer	\$60	\$0	\$21	1
Partially enclosed crusher/truck dump hopper with plastic strip curtains and dust/truck barricade	\$1,900	\$1,900	\$665	5
<i>Average</i>	<i>\$758</i>	<i>\$699</i>	<i>\$339</i>	<i>8.0</i>
<b>Moderate capital expenditure</b>				
Portable or fixed vacuum, HEPA, 15+ gallon	\$4,297	\$0	\$600	5

Engineering Control	2021 Capital Cost	2021 Installation Cost [a]	2021 O&M Cost [b]	Expected Service Life [c]
Repair and improve existing operator enclosure (door/ window fit/seal, fix HVAC)	\$2,650	\$2,650	\$530	10
Operator enclosure, haulage equipment	\$15,379	\$15,379	\$5,383	15
Replace or add cab to compact tractor	\$9,000	\$9,000	\$3,150	15
<b>Average</b>	<b>\$7,832</b>	<b>\$6,757</b>	<b>\$2,416</b>	<b>11.3</b>
<b>Larger capital expenditure</b>				
Add new whole building fan 10,000 CFM with baghouse/dust collector/ducts/ engineering, medium size structure	\$157,000	\$157,000	\$54,950	30
Add Conveyor belt loading enclosure and ventilation	\$28,000	\$28,000	\$9,800	30
Control room 10x10, with ventilation, heat/AC, HEPA filter	\$24,047	\$24,047	\$875	15
Enclose and ventilate screening equipment, 4 x 4 ft	\$25,184	\$25,184	\$8,814	10
Mist cannon, 25 gal/min (BossTek, 2022)	\$45,000	\$45,000	\$15,750	10
New compact track loader with cab/heat/AC	\$50,000	\$50,000	\$17,500	15
Truck loading, open-bed truck, telescoping spout, outer telescoping trunk with air suction, dust collector, ductwork	\$24,000	\$24,000	\$8,400	10
Truck loading, open bed, unventilated, hopper designed to minimized turbulence in delivered material	\$24,000	\$24,000	\$4,200	10
<b>Average</b>	<b>\$47,154</b>	<b>\$47,154</b>	<b>\$15,036</b>	<b>16.3</b>

[a] Unless otherwise specified, installation costs are assumed to be equal to capital cost.

[b] Unless otherwise specified, annual O&M costs are assumed to be equal to 35 percent of capital cost.

[c] Service life assumed to be 10 years if not otherwise specified.

The engineering control costs, annualized as a simple average by size of capital expenditure, are presented in Table 4-9 at varying discount rates. MSHA has modeled all the engineering control cost categories (inclusive of installation, maintenance, and capital cost), and presented them as a single range of values that may be incurred annually per affected mine. Because the service life of some components is expected to be 30 years, the costs of all engineering controls are annualized over 30 years (i.e., a HEPA vacuum with an expected five-year service life would be purchased six times during the same period in which the cost of enclosing and ventilating a conveyor belt would be incurred once). At a 3 percent real discount rate, annualized costs range from about \$560 per mine for the lowest cost tier of capital equipment to \$22,200 per mine for the highest cost tier. The annualized cost per mine is less than \$3,000.

**Table 4-9. Estimated Annualized Costs per Mine as a Simple Average of Engineering Controls by Capital Expenditure Category, 2021**

Control Category	Annualized Cost of Engineering Controls at Specified Real Discount Rate		
	0 Percent	3 Percent	7 Percent
Minimal capital expenditure	\$546	\$565	\$591
Moderate capital expenditure	\$3,576	\$3,786	\$4,088
Larger capital expenditure	\$20,767	\$22,195	\$24,350
<b>Average of All Mines [a]</b>	<b>\$2,298</b>	<b>\$2,437</b>	<b>\$2,641</b>

[a] Calculated as the sum of annualized engineering costs over all levels of capital expenditure and commodities divided by the total number of mines.

Table 4-10 totals estimated annualized engineering costs by control category and mine sector. Total annualized engineering costs are calculated at \$1.33 million to \$1.53 million over 30 years.

**Table 4-10. Estimated Total Annualized Engineering Costs (in thousands of dollars) by Control Category, 2021**

Control Category	Number of Mines	Annualized Engineering Cost (in thousands of dollars) at Specified Real Discount Rate			
		0 Percent	3 Percent	7 Percent	Percentage of Total Costs [a]
All Engineering Controls					
Total -- All	580	\$1,333	\$1,413	\$1,532	100.0%
Metal/Nonmetal	518	\$1,109	\$1,175	\$1,272	83.1%
Coal	62	\$224	\$238	\$260	16.9%
Minimal capital expenditure					
Subtotal -- Minimal	458	\$250.1	\$258.8	\$270.9	100.0%
Metal/Nonmetal	417	\$227.7	\$235.7	\$246.6	91.1%
Coal	41	\$22.4	\$23.1	\$24.2	8.9%
Moderate capital expenditure					
Subtotal -- Moderate	84	\$300.7	\$318.4	\$343.8	100.0%
Metal/Nonmetal	71	\$252.4	\$267.3	\$288.6	83.9%
Coal	14	\$48.3	\$51.1	\$55.2	16.1%
Larger capital expenditure					
Subtotal -- Larger	38	\$782.1	\$835.9	\$917.0	100.0%
Metal/Nonmetal	30	\$628.4	\$671.6	\$736.8	80.4%
Coal	7	\$153.7	\$164.2	\$180.2	19.6%

[a] Calculated as the average percent of total over all three discount rates.

### *Maintenance and Repair*

Beyond adopting more advanced engineering control infrastructure, an integral method of reducing respirable crystalline silica exposure is by increasing the frequency of maintenance

and repairs for dust control systems. MSHA believes that, when the appropriate dust control systems are utilized, that effective and regular maintenance and repair of such systems will result in silica concentration levels below the proposed PEL. MSHA's experience suggests that miner exposures between the proposed PEL and the existing PEL (or exposure level for coal) are largely due to deterioration of existing dust exposure controls. This deterioration may be intermittent due to delays in routine corrective maintenance, or persistent due to a deficiency that goes unnoticed. When respirable crystalline silica exposure levels approach the existing PEL, MSHA believes that the existing dust control equipment is not functioning as well as intended, usually because it has not been maintained in a fully functional condition and consequently is not providing the anticipated level of dust control. When these shortcomings are corrected, through regular maintenance or repair of the dust control equipment, respirable crystalline silica concentrations decrease below (and usually well below) the proposed PEL.

For example, underground coal mines use fluid bed scrubbers to clean ("scrub") dust and methane from air drawn from the vicinity of continuous mining machines. These scrubbers reduce dust levels by 80 to 90 percent in air downwind of continuous mining machine operations. However, NIOSH has shown that scrubber dust collection efficiency might decrease as much as 33 percent due to filter clogging by dust generated during just one pass of the continuous mining machine along the mine face. Routine maintenance is required to keep scrubbers functioning as intended.

Mines can avoid deteriorating dust controls by increasing the routine maintenance frequency on existing dust control equipment. Such activities are typically conducted at the beginning of each shift (or as frequently as necessary) and can be incorporated into existing safety and operational checks already performed on most equipment to maintain operational efficiency.

MSHA believes mine operators already routinely check equipment for safety and operational integrity. For example, drill rig operators and operators of large-powered haulage equipment typically have a pre-shift checklist (available from manufacturers, NIOSH, or industry trade associations) to follow that is designed to maintain functionality and reduce wear and tear on their equipment. If it takes 10 minutes to complete a 20 to 25 item pre-shift checklist, an experienced equipment operator might add another 2.0 to 2.5 minutes to check dust controls (e.g., cab ventilation dust filters are in place; fan/AC turns on when activated; window and door seals appear intact; drill deck shroud is intact and adjusted to minimize gaps; dust suppression spray system has sufficient level; water pump responds when activated; and dust discharge point spray nozzles spray as expected). If the checklist is used five times per week to verify equipment condition and it adds 2.5 minutes each time the checklist is used 5 times per week, it would add a total of 163 minutes ( $= 2.5 \text{ minutes per day} \times 5 \text{ days} \times 13 \text{ weeks}$ ) to pre-shift maintenance checks per quarter.

Based on its experience and observations of mine activities, MSHA estimates mine operators would spend an additional 16 hours of time per quarter on additional inspection and maintenance (64 hours per year). This is an average estimate; small mines with less equipment

to check would require less than 16 hours per quarter while large mines would require more time. Furthermore, small mines are predominant in the industry as a whole and are likely to have a minimal amount of equipment (1 to 3 pieces of equipment). The example of an additional 163 inspection and maintenance minutes per quarter for a drill rig suggests that, with 16 hours per quarter, a mine could perform additional inspection and maintenance on 6 pieces of equipment of similar complexity (16 hours × 60 minutes per hour)/163 minutes per piece of equipment).

To account for additional maintenance and repair costs that might result from expanding inspection and maintenance checklists to cover dust suppression and control equipment, MSHA added 25 percent to the additional time spent checking equipment to cover additional maintenance and parts. Thus, for every \$1,000 mine operators spend on labor for checking equipment and additional maintenance, they will spend an additional \$250 on parts for maintenance and repairs. In general, the most common items identified for maintenance only require immediate adjustment or small, low-cost replacement items (e.g., refill the water tank; adjust or replace a noisy fan belt; or replace a spray nozzle).

In addition, mine operators may receive other benefits from more frequent maintenance and repairs. For example, dull drilling bits not only create more dust, but also cut less efficiently. More frequent equipment checks to ensure bits are sharp would reduce generated dust and result in more efficient operations. Similarly, more frequent, albeit small, repairs, may prevent more significant breakdowns that result in delays due to inoperable equipment. These are not quantified in the present analysis.

MSHA believes that increased maintenance and repair will be performed by employees in the following BLS Standard Occupational Classification (SOC) codes: Construction Equipment Operators (SOC 47-2070); Pipelayers, Plumbers, Pipefitters, and Steamfitters (SOC 47-2150); Helpers – Extraction Workers (SOC 47-5080); Miscellaneous Extraction Workers (SOC 47-5090); First-line Supervisors of Mechanics, Installers, and Repairers (SOC 49-1010); Bus and Truck Mechanics and Diesel Engine Specialists (SOC 49-3030); Heating, Air Conditioning, and Refrigeration Mechanics and Installers (SOC 49-9020); and Industrial Machinery Installation, Repair, and Maintenance Workers (SOC 49-9040). The value of the additional 64 hours per mine per year is calculated as an average of the loaded hourly wage rate of the specified occupations weighted by the relative employment of each occupation in the mining NAICS codes. For the purposes of cost annualization, these costs will be incurred every year over the 10-year analytic period for these costs.

Table 4-11 presents the average loaded hourly wage for the occupations specified above by commodity. Differences in average hourly wages by sector account for the difference in average cost per affected mine.

**Table 4-11. Estimated Increased Maintenance and Repair Costs per Mine, 2021**

Cost Components	Mine Sector	Average Loaded Hourly Wage Rate [a] (2021 dollars)	Average Cost Per Affected Mine [a] (2021 dollars)
Incremental costs incurred each year: <ul style="list-style-type: none"> <li>64 hours per year</li> <li>Hours spent by a mix of occupations (e.g., equipment operators, extraction workers, etc.)</li> <li>Hours valued at weighted average of loaded wage</li> <li>Value of labor hours multiplied by 1.25 to account for cost of increased maintenance and repairs</li> </ul>	Coal	\$55.68	\$4,455
	Metal/ Nonmetal	\$40.01	\$3,201

[a] Calculations based on estimated incremental hours for performing additional inspections; BLS Occupational Employment and Wage Statistics (OEWS). National industry-specific and by ownership, May 2021; BLS Employer Costs for Employee Compensation – December 2021; and Overhead multiplier from Department of Labor (DOL). Defining and Delimiting the Exemptions for Executive, Administrative, Professional, Outside Sales and Computer Employees. Final Rule. 84 Federal Register 51230.

Multiplying the average cost per mine by the estimated number of affected mines results in total annual and annualized cost by commodity.<sup>24</sup> Table 4-12 shows the estimated 1,226 affected mines that are expected to incur total annual and annualized costs of \$4.09 million for increased maintenance and repair.

**Table 4-12. Annual and Annualized Increased Maintenance and Repair Control Costs (in thousands of dollars) by Commodity, 2021**

Mine Category	Mines Needing Control	Total Annual Cost (thousands of 2021 dollars)	Percent by Commodity
<b>Total</b>	<b>1,226</b>	<b>\$4,087</b>	<b>100.0%</b>
Metal/Nonmetal	1,096	\$3,508	85.8%
Coal	130	\$579	14.2%

### *Administrative Controls*

#### *General Controls*

Administrative controls comprise a variety of methods to reduce exposure to respirable crystalline silica dust. In general, the shared characteristic of these methods is that mine operators evaluate situations in which exposure can be reduced through changes in policies

<sup>24</sup> If estimated annual costs are identical for each year over a given analytic period, then by definition, annual costs are equal to annualized costs. Annualized costs are a stream of equal periodic costs having the same PV as the original stream of costs. In this case, the stream of annualized costs is identical to the original stream of annual costs and will therefore have the same PV.

and work practices, and implements those changes by informing miners through training, published announcements, procedures, instructions, and signage.

Examples of administrative controls that can substantially lower miners' exposure to respirable crystalline silica are often relatively straightforward policies that might include:

- Requiring operators of equipment with enclosed cabs to work with doors and windows shut. This not only inhibits entry of dust into the cab, but also improves effectiveness of installed ventilation and filter systems. For example, NIOSH cites a study that showed operating equipment with open cab doors and windows reduced dust exposure by less than 40 percent, but when operating the same equipment with closed doors and windows, dust exposure might be reduced more than 90 percent.
- Prohibiting meetings, other gatherings, and activities of miners near or downwind of dust-producing equipment (e.g., drilling rigs, crushing equipment), removes workers from high dust areas, thus reducing exposure in proportion to meeting time as a percentage of shift time. Similarly, creating "safe meeting places" for miners to meet, take breaks, and eat lunch reduces exposure by removing workers from high dust areas and dusty equipment.
- Setting speed limits and minimum distances for equipment operated on dusty haul roads. NIOSH showed that reducing equipment travel speed from 25 miles per hour (mph) to 10 mph reduced dust by 58 percent. Similarly, requiring a 20 second distance between vehicles reduced exposure to the driver in the following vehicle up to 52 percent. Furthermore, these reductions benefit not just equipment drivers, but also miners who work near the road.
- Moving the location of dust-generating activities, such as stone cutting to more remote, less frequented, areas of the work site, or scheduling such operations when fewer miners will be in the vicinity.

While many of these examples are relatively simple applications of common-sense policies, they can be circumvented either accidentally or deliberately. Thus, administrative controls are not always effective, or as effective as they could be, because they depend on miners following the revised policies and work practices. Therefore, administrative/work practice controls rank lower than engineering controls in the hierarchy of effectiveness. NIOSH finds that training and evaluation by mine operators can help ensure the administrative/work practice controls are observed and successful (NIOSH, 2022).

MSHA developed a structure for estimating the additional costs attributable to further developing administrative controls. The cost of administrative controls is primarily composed of labor hours. MSHA believes that mines will spend, on average, an additional 16 labor hours on administrative controls in the first year of the 10-year analytic period, and an additional 2 labor hours per year in the subsequent years of the 10-year analytic period.



In addition to the time spent identifying opportunities for administrative controls, mine staff need to prepare and publish training and instructional materials, and post signage and/or other informational materials to implement such controls. Thus, MSHA increases the value of labor hours by a factor of 2.0 in year 1, and a factor of 1.1 in years 2 through 10 to account for these additional costs. That is, for every \$1,000 a mine operator spends on identifying opportunities to reduce exposure to respirable crystalline silica through administrative means in year 1, an additional \$1,000 will be spent formulating new – or revising existing – policies and procedures, documenting changes in manuals and guidance, preparing instructional and training materials, and posting signage to remind miners of the changes. In the following years, years 2 through 10, for every \$1,000 a mine spends on employing administrative means to reduce exposure, it will spend an additional \$100 revising policies and procedures, preparing manuals, guidance, and training materials, and posting signage. MSHA estimates 50 percent of affected mines would incur additional costs in any given year.

MSHA expects that the additional labor hours will be performed by employees in the following occupation codes: Occupational Health and Safety Specialists and Technicians (SOC 19-5010); First-Line Supervisors of Construction Trades and Extraction Workers (SOC 47-1010); Construction Equipment Operators (SOC 47-2070); Surface Mining Machine Operators and Earth Drillers (SOC 47-5020); Helpers – Extraction Workers (SOC 47-5080); Miscellaneous Extraction Workers (SOC 47-5090). The value of the additional 16 hours per mine per year is calculated as an average of the loaded hourly wage rate weighted by the relative employment of these occupations in the mining industry.

Table 4-13 presents the estimated average cost per affected mine for each commodity based on the specifications for additional administrative controls outlined above. The table also presents the average loaded hourly wage for the occupations specified above; differences in average hourly wages by commodity account for the difference in average cost per mine by commodity.

**Table 4-13. Estimated Administrative Control Costs per Mine, 2021**

Cost Components	Mine Sector	Annual Cost Per Affected Mine
<b>Incremental costs incurred in year 1 of 10:</b>		
<ul style="list-style-type: none"> <li>16 hours per year</li> <li>Hours spent by a mix of occupations (e.g., OHS technicians, 1st line supervisors, equipment operators, extraction workers, etc.)</li> <li>Hours valued at weighted average of loaded wage</li> <li>Value of labor hours multiplied by 2.0 to account for publishing new/revised procedures, training, signage, etc.</li> </ul>	Metal/ Nonmetal	\$1,327
	Coal	\$2,076
<b>Incremental costs incurred in years 2 - 10:</b>		
<ul style="list-style-type: none"> <li>2 hours per year</li> <li>Same occupations</li> <li>Hours valued at weighted average of loaded wage</li> <li>50 percent of affected mines incur additional costs in any given year</li> <li>Value of labor hours multiplied by 1.1 to account for publishing revised procedures, training, signage, etc.</li> </ul>	Metal/ Nonmetal	\$46
	Coal	\$71

Table 4-14 shows the estimated number of affected mines and annual costs expected to be incurred in year 1 and years 2 through 10 for administrative controls. Additionally, the table shows that total annualized costs range from \$226,000 (0 percent real discount rate) to \$281,000 (7 percent real discount rate).

**Table 4-14. Annual and Annualized Administrative Control Costs (in thousands of dollars), 2021**

Mine Sector	Mines Needing Control	Total Annual Cost (thousands of dollars)	Total Annualized Cost (in thousands of dollars) at Specified Discount Rate			Percent by Commodity
			0 Percent	3 Percent	7 Percent	
Incremental costs incurred in year 1						
Total	1,226	\$1,725	\$226	\$249	\$281	100.0%
Metal/Nonmetal	1,096	\$1,455	\$190	\$210	\$237	84.4%
Coal	130	\$270	\$35	\$39	\$44	15.6%
Incremental costs incurred in years 2 - 10						
Total	1,226	\$59.3				
Metal/Nonmetal	1,096	\$50				
Coal	130	\$9				

### *Respiratory Protection*

The proposed PEL of 50 µg/m<sup>3</sup> may result in increased uptake of respirators by miners when compared with current usage under the existing PEL of 100 µg/m<sup>3</sup>. While MSHA believes that additional respirator use is likely to occur only in the short term, until mines are able to consistently control sources of respirable crystalline silica dust exposure at the proposed PEL using more engineering controls, estimated incremental use is modeled as if it remains constant over the 10-year analytic period. MSHA believes that miners who are most likely to need incremental respirator use work in the following occupations:

- Kiln, Mill, and Concentrator Workers (MNM mines)
- Mobile Workers & Jackhammer Operators (MNM mines)
- Miners in Other Occupations (MNM mines)
- Underground Miners (Coal mines)
- Surface Miners (Coal mines)

MSHA assumes that 20 percent of miners in these occupations who have respirable crystalline silica exposures in the 50 µg/m<sup>3</sup> to 100 µg/m<sup>3</sup> range for MNM and 50 µg/m<sup>3</sup> to 85.7 µg/m<sup>3</sup> for Coal will increase their use of respiratory protection. Table 4-15 presents the estimated number of miners, including contract workers, who meet the criteria listed above. Approximately 2,109 miners and contract workers are expected to increase their respirator use. About 94 percent of these workers are in the MNM mining sector.

**Table 4-15. Estimated Number of Miners Requiring Respiratory Protection, 2019**

Mine Sector	Miners (including Contractors) with 50 < Exposure ≤ 100 µg/m <sup>3</sup>	Miners (including Contractors) Requiring Additional Respiratory Protection	Percent of Miners
<b>Total</b>	<b>10,544</b>	<b>2,109</b>	<b>100.0%</b>
Metal/Nonmetal	9,918	1,984	94.1%
Coal	626	125	5.9%

In the following subsections, MSHA first estimates the subset of these mine operators who will have to be issued new respirators because of the rule, then the incremental cost of additional respirator use.

### *New Respirator Purchases*

MSHA believes that given the existing respiratory protection standards, the majority of miners in all sectors have already been issued respirators where exposures exceed the existing PEL. However, some mine operators with miners currently at low risk of exceeding the existing PEL may now need to purchase respirators to account for possible exposures in the range from 50 µg/m<sup>3</sup> to 100 µg/m<sup>3</sup> for MNM and from 50 µg/m<sup>3</sup> to 85.7 µg/m<sup>3</sup> for Coal. It is likely that

some, but not all, miners newly at risk for exposure in this range as a result of the proposed PEL will not have respirators. In addition, because respirators will be used more under the proposed PEL, respirators will deteriorate more quickly and need replacement. Thus, in addition to miners who do not need to wear a respirator under the existing exposure level and PEL, but will need to under the proposed PEL, some miners who already wear respirators will need to replace them more frequently due to increased utilization.

MSHA estimates that in Year 1, mine operators will incur costs for new respirators for 50 percent of the 2,109 miners that will require a respirator (a total of 1,054). In years 2 through 10, mine operators will incur costs for 50 percent of the total number of respirators purchased in Year 1 annually (a total of 527). Furthermore, MSHA assumes that all new respirator purchases in any year throughout the analytic period will require fit testing and training.

To estimate the cost of new respirators, MSHA assumes that mine operators will purchase tight-fitting, re-useable half-mask elastomeric respirators at a cost of \$39.57 each plus \$17.29 for filters.<sup>25</sup> In addition, MSHA assumes respirators are assigned to individuals, not shared equipment. Furthermore, miners issued new respirators will also require an additional 2 hours for fit testing and training.<sup>26, 27</sup> MSHA estimates the cost of new respirators below in Table 4-16, utilizing the weighted average loaded wage of all mine workers in each commodity when estimating fit testing and training costs.

**Table 4-16. Estimated Cost of New Respirators, Fit Testing and Training per Miner, 2021**

Cost Components	Mine Sector	New Respirator Cost Per Miner	Fit Testing and Training	Annual Cost Per Entity-Standard Respirator Usage
-- Respirators cost \$40	Metal/Nonmetal	\$56.86	\$82.32	\$139.18
-- Respirator filters cost \$17				
-- 2 hours per miner for fit testing and training	Coal	\$56.86	\$93.36	\$150.22

Table 4-17 presents the estimated annual costs of purchasing new respirators for incremental respiratory protection under the proposed PEL for miners who do not currently

<sup>25</sup> Based on online (non-discount) prices: Websites for Northern Safety, 2022: \$29.14/each 3M Series 6500 half mask respirator, \$10.25/pair for P100 pancake filters; and Grainger, 2022: \$50.00 for MSA 420 series half mask respirator, \$24.32 for P100 filter cartridges (package of 2). Prices are higher end of potential range, supplier bulk discounts available from numerous other sources.

<sup>26</sup> OSHA APF rulemaking (update to 29 CFR 1910.134) Unit Costs: 1 hour employee training, 1 hour employee qualitative fit testing. Alternatively, 2 hours for quantitative fit testing (from costs estimated in 2001-2006; may be reduced due to efficiency of more modern quantitative fit testing equipment currently available and widely used). MSHA assumes that worker fit testing is conducted in small groups; two to four miners are fit tested during the hour, but all remain part of the group for the full hour.

<sup>27</sup> MSHA assumes there will be no additional labor costs for personnel conducting fit testing or training because current respiratory protection programs already require these steps.

require respiratory protection under the existing PEL. In year 1, a total of 1,054 miners (including contractors) who occasionally perform tasks where they would likely be exposed to respirable crystalline silica in the range of 50 µg/m<sup>3</sup> to 100 µg/m<sup>3</sup> for MNM (and 85.7 µg/m<sup>3</sup> for Coal) are expected to be provided with new respirators by mine operators. Estimated year 1 costs over all commodities are expected to total about \$147,000. In years 2 through 10, annual costs are expected to be half of this total.

**Table 4-17. Estimated Annual Cost of New Respirator Purchases, 2021**

Mine Sector	Miners Including Contractors	Total Annual Cost	Percent of Total Annual Cost
Year 1			
<b>Total</b>	<b>1,054</b>	<b>\$147,453</b>	<b>100.0%</b>
Metal/Nonmetal	992	\$138,044	93.6%
Coal	63	\$9,409	6.4%
Years 2-10			
<b>Total</b>	<b>527</b>	<b>\$73,726</b>	<b>100.0%</b>
Metal/Nonmetal	496	\$69,022	93.6%
Coal	31	\$4,704	6.4%

Table 4-18 summarizes the total annualized cost of new respirator purchases by commodity. Overall, the proposed PEL is expected to lead mine operators to purchase new respirators costing an average of \$81,100 to \$83,500 per year over ten years.

**Table 4-18. Estimated Annualized Cost of New Respirator Purchases, 2021**

Mine Sector	Total Annualized Cost at Specified Real Discount Rate			Percent of Total Annualized Cost
	0 Percent	3 Percent	7 Percent	
<b>Total</b>	<b>\$81,099</b>	<b>\$82,118</b>	<b>\$83,537</b>	<b>100.0%</b>
Metal/Nonmetal	\$75,924	\$76,878	\$78,206	93.6%
Coal	\$5,175	\$5,240	\$5,330	6.4%

### *Additional Respirator Use*

Here, MSHA estimates the cost of additional respirator use under the proposed PEL to miners who do not need it under the existing PEL. Starting with the estimated number of miners and contract workers expected to increase their use of respirators (Table 4-19), MSHA estimated the cost of this additional use, assuming that the hours of additional respirator use in year 1 will remain constant over the 10-year analytic period; there will be no reduction in use following year 1. On average, MSHA believes additional respirator use will be necessary an average of four hours per week or an additional 208 hours per year. Thus, if the elastomeric respirator for costing uses two filters at a time, and the filters last eight hours before requiring replacement, then these miners will need an additional 26 pairs of filters per year; at an average price of \$17.29 per pair for filters, mine operators will spend an additional \$450 per miner (= \$17.29 × 26) for respirator filters.

Table 4-19 presents the estimated total annual and annualized cost of additional respirator usage by commodity. The cost of additional respirator use is expected to average about \$948,000 per year over the 10-year analytic period.

**Table 4-19. Estimated Annual and Annualized Cost of Additional Respirator Use, 2021**

Mine Sector	Miners Including Contractors	Total Annual and Annualized Cost	Percent of Total Annual Cost
<b>Total</b>	<b>2,109</b>	<b>\$948,023</b>	<b>100.0%</b>
Metal/Nonmetal	1,984	\$891,711	94.1%
Coal	125	\$56,312	5.9%

The estimate presented in Table 4-19 may be an overestimate of the cost of incremental respirator use. First, although MSHA assumed incremental utilization would remain constant over the 10-year period, it is likely that incremental use will decline as mines implement and perfect additional controls. However, with little data to support an assumption concerning how quickly incremental use might decrease, MSHA chose to model it as constant. Second, while most mines operate year-round, a number of mines may operate for as little as three months per year. This will also decrease incremental respirator use relative to MSHA's estimate.

### ***Medical Surveillance***

Under the proposed rule, MSHA would require each MNM mine operator to offer mandatory medical examinations to miners who are new to the mining industry, and voluntary periodic examinations to all other miners. The medical examinations would be provided at no cost to the miner.

The medical examinations would be provided by a physician or other licensed health care professional (PLHCP) or specialist. A medical examination would include: a miner's medical and work history; a physical examination; a chest X-ray, and a pulmonary function test.

The proposed rule would require mine operators to provide an initial medical exam for all miners who begin work in the mining industry for the first time. The exam must take place within 30 days after beginning employment, at no cost to the miner. The proposed medical surveillance standards extend to MNM miners the opportunity for medical surveillance that is available to coal miners under existing rules. Following the initial exam, mine operators must also offer periodic medical exams to MNM miners at least every five years at no cost to the miner.

To estimate the costs of the medical surveillance requirement, MSHA first estimated the "unit cost" of a single medical examination. MSHA then estimated how many examinations would occur in each year over a 20-year period,<sup>28</sup> and then multiplied those numbers of

<sup>28</sup> MSHA chose a 20-year analytic period for estimating the number of examinations using the average length of employment; see ***Number of Examinations Per Year*** for more detailed explanation.

examinations by the unit cost, to determine total costs in each year. MSHA summed the costs in each year to arrive at a total cost estimate over the 20-year period.

Under the proposed standards, miners must first be identified as being new to the mining industry. If they are new, then they must first receive an immediate examination. If, instead, they are not new to mining, then they are categorized as belonging to a group of workers who are eligible for an examination every five years. Workers who are new to mining, after they have their initial examination, are expected to have another follow-up examination within three years. If the three-year follow-up examination indicates any medical concerns associated with lung disease, then these miners are eligible to have another follow-up exam in two years. After this additional two-year follow-up exam, or if the three-year follow-up examination indicates no medical concerns associated with lung disease, then these miners will enter the category of miners eligible for five-year exams at no cost to the miner.

In the current analysis, MSHA does not have information to accurately measure the percentage of miners who would be offered another exam two years after the three-year exam. However, MSHA expects that it will be a small fraction of miners and, as such, MSHA assumes it to be 5 percent. MSHA is seeking public comment and input to refine this figure in the economic analysis in the final rule stage. The remaining 95 percent of those new miners who take the three-year follow-up exam enter directly into the category of workers eligible for five-year exams.

### **Unit Costs**

MSHA assumes that all examinations entail the same cost elements, which are as follows (in decreasing order of cost): the physical examination, chest X-ray, spirometry test, lost work time while being examined, lost travel time, symptom assessment and occupational history, transportation cost, and recordkeeping of the mine operator. Table 4-20 displays these estimated components in 2021 dollars, which sum to a unit cost of \$586 per examination. MSHA's unit cost is based on OSHA's calculation of the same components in its Regulatory Economic Analysis of medical surveillance associated with the OSHA Silica Rule, with which MSHA concurs (OSHA, 2016b). In its regulatory economic analysis (REA) of its silica rule, OSHA initially acquired cost estimates in 2009 dollars, which it then converted to 2012 dollars using the consumer price index (CPI) for medical care (U.S. BLS, 2022). MSHA applied the same index to inflate those 2012 costs to 2021 dollars, which are listed below in Table 4-21.<sup>29</sup>

**Table 4-20. Estimated Cost Per Medical Examination, 2021**

<b>Cost Components</b>	<b>Cost</b>
Physical Examination	\$147.93

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<sup>29</sup> The original costs in 2012 dollars were multiplied by the ratio of the index in June 2021 to the index in June 2012 to convert them to 2021 dollars. This ratio was 1.259.

Cost Components	Cost
Chest X-Ray	\$111.11
Spirometry Test	\$76.33
Lost Work Time While Being Examined	\$81.54
Lost Travel Time	\$81.54
Symptom Assessment and Occupational History	\$46.52
Transportation Cost	\$25.00
Recordkeeping of Mine Operator	\$16.39
<b>Total</b>	<b>\$586.35</b>

**Physical Examination.** MSHA applied the cost component that OSHA described as “physical examination by knowledgeable HCP, evaluation and office consultation including detailed examination” with “special emphasis on the respiratory system,” which was originally \$110.83 in 2012 dollars. MSHA added an additional component which OSHA listed as “other necessary tests” (e.g., a tuberculosis test) costing \$66.50 in 2012, but “required by 10 percent of workers,” implying an average additional cost of \$6.65 per miner in 2012 dollars (OSHA, 2016a).

**Chest X-ray.** MSHA applied the cost component that OSHA described as “chest X-ray, radiologic examination, chest; stereo, frontal. Costs include consultation and written report” which was originally \$88.24 in 2012 dollars.

**Spirometry Test.** MSHA applied the cost component that OSHA described as “Pulmonary function test, Spirometry, including measurement of forced vital capacity (FVC), forced expiratory volume at 1 second (FEV<sub>1</sub>), and FEV<sub>1</sub>/FVC ratio,” which was originally \$60.62 in 2012 dollars.

**Lost Work Time While Being Examined.** MSHA assumes a miner’s lost work time while being examined would be 2 hours, consistent with OSHA’s estimated lost work time. To estimate the cost, MSHA multiplied the two hours by the loaded wage rate of \$36.72 for an MNM miner.<sup>30</sup>

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<sup>30</sup> This hourly rate was derived from the OEWS May 2021 survey. NAICS 212200 and 212300 were combined for Metal and Non-Metal Mining wages. MSHA multiplied the mean wage rate by a benefit factor of 1.493 to obtain the fully loaded wage, and 17 percent of the mean wage was also added to account for overhead cost. The occupation codes used for each occupation are as follows: 47-5022, 47-5041, 47-5043, 47-5044, 47-5049, 47-5051, 47-5081, 57-5099, 49-9071, 51-9021, 51-9192, 53-7011.

Bureau of Labor Statistics: Occupational Employment and Wage Statistics (OEWS). National industry-specific and by ownership. May 2021. Downloaded from <https://www.bls.gov/oes/tables.htm> on April 29, 2022. OEWS wage rates are already expressed in 2021 dollars and do not need to be adjusted for inflation.



***Lost Work Time While Travelling.*** MSHA estimated the lost work time while travelling to and from the examination to be 2 hours (one hour each way). MSHA then multiplied the two hours by the same loaded wage rate, which explains why lost travel time was estimated to have the same cost as lost work time while being examined.

***Symptom Assessment and Occupational History.*** MSHA applied the cost component that OSHA described as “Complete occupational and health history survey, assumed one third of physical exam cost,” which was originally \$36.94 in 2012 dollars.

***Transportation Cost.*** MSHA estimated the transportation cost of \$25 based on the assumptions of: (a) 100 miles round trip by car, (b) a mileage rate of 20 miles per gallon (implying 5 gallons of gas would be needed), (c) a price of gasoline of \$4.00 per gallon, and (d) depreciation of the car (“wear and tear”) of \$5.00 for each 100-mile trip.

***Recordkeeping of Mine Operator.*** OSHA assumed 15 minutes of labor needed for the employer’s recordkeeping of the examination. MSHA assumed the labor involved would be that of an occupational health and safety specialist in MNM mining, whose loaded hourly rate (including overhead) was estimated at \$59.06. Thus, MSHA obtained the cost estimate of one-fourth of this hourly rate.<sup>31</sup>

***Number of Examinations Per Year.*** MSHA used the same estimated number of full-time equivalent (FTE) employees in MNM mining that it is using in its preliminary benefits analysis of the silica rule, which is 184,615 FTE workers.<sup>32</sup> MSHA assumed FTE employment would remain constant over the 20 years following promulgation of the medical surveillance requirement.<sup>33</sup> MSHA estimates that the average length of employment as an MNM miner (before leaving the mining occupation) is 22 years, which is derived from a NIOSH survey that found the average

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BLS: Employer Costs for Employee Compensation – December 2021. Downloaded from: <https://www.bls.gov/news.release/pdf/ecec.pdf> on April 29, 2022.

Department of Labor (DOL). Defining and Delimiting the Exemptions for Executive, Administrative, Professional, Outside Sales and Computer Employees. Final Rule. 84 Federal Register 51230.

<sup>31</sup> The hourly wage rate was derived from the OEWS May 2021 survey. NAICS 212200 and 212300 were combined for Metal and Non-Metal Mining wages. MSHA multiplied the mean wage rate by a benefit factor of 1.488 to obtain the fully loaded wage, and 1 percent of the mean wage was also added to account for overhead cost. The occupation codes used was for Occupational Health & Safety Specialist (19-5011).

<sup>32</sup> In 2019, 211,203 miners and contractors worked 369.2 million hours, which is equivalent to 184,615 FTE workers (= 369,230,521 hours worked ÷ 2,000 FTE hours per year). Thus, there are 1.14 employees for every 1 FTE employee (= 211,203 ÷ 184,615).

<sup>33</sup> MSHA chose to express mine employment in FTEs for the benefits analysis because health impacts would differ between part-time miners, who would experience less exposure to respirable crystalline silica dust and thus would be less likely to experience the same negative health effects in the same amount of time as miners who worked full-time or more. A similar logic applies to miners deciding whether to accept medical exams, thus medical surveillance costs are also estimated based on FTE miners.

mining experience of MNM miners is approximately 11 years.<sup>34</sup> Based on this estimate, MSHA assumed that each year 8,392 miners (about 1/22, or 4.55 percent, of 184,615 FTE MNM miners) would leave the industry, and be replaced by the same number of new workers entering.

**Estimated Costs Under the Proposed Requirements.** MSHA estimates total costs over the 20-year analytic period under two different scenarios due to uncertainty concerning miner participation in the medical surveillance program. Assuming a participation rate of 25 percent (Scenario 1), total estimated costs over 20 years range from \$137.8 million (7 percent discount rate) to \$267.8 million (0 percent discount rate). Annualized costs range from \$13.0 million (with a 7 percent discount) to \$13.4 million (0 percent discount rate). The annualized cost per MNM miner (the annualized cost divided by the estimated 184,615 FTE MNM miners per year) ranges from \$70.33 (7 percent discount rate) to \$72.53 (0 percent discount rate) per miner.

Scenario 2 assumes the participation rate is 75 percent. Total costs over the 20-year analytic period range from \$226.8 million (7 percent discount rate) to \$431.9 million (0 percent discount rate). Annualized costs range from \$21.4 million (7 percent discount rate) to \$21.6 million (0 percent discount rate). The annualized cost per MNM miner range from \$115.96 (7 percent discount rate) to \$116.97 (0 percent discount rate). A summary of estimated medical surveillance costs under the two scenarios is presented in Table 4-21.

**Table 4-21. Summary of Estimated Medical Surveillance Costs for MNM Miners by Participation Rate and Discount Rate, 2021**

Cost Type	0 percent Real Discount Rate	3 percent Real Discount Rate	7 percent Real Discount Rate
Annual Costs (millions of dollars)			
25 percent participation rate	\$267.8	\$196.7	\$137.6
75 percent participation rate	\$431.9	\$320.1	\$226.8
Annualized Cost (millions of dollars)			
25 percent participation rate	\$13.4	\$13.2	\$13.0
75 percent participation rate	\$21.6	\$21.5	\$21.4
Annualized Cost per MNM miner			
25 percent participation rate	\$72.53	\$71.62	\$70.33
75 percent participation rate	\$116.97	\$116.55	\$115.96

<sup>34</sup> The 2012 report by NIOSH, entitled, "National Survey of the Mining Population: Part 1: Employees," (<https://www.cdc.gov/niosh/mining/works/coversheet776.html>) includes the findings of its 2008 survey on mine operators and miners in the U.S. (Details on the survey methodology and results are available in the link.) The NIOSH survey found the following mine experiences for different types of MNM mines, which average to about 11 years (11.375 to be precise): metal mines, 10.7 years; nonmetal, 12.0 years; stone, 12.5 years, and sand and gravel 10.3 years. For comparison, the same survey found the average mining experience for coal miners was 16.0 years. These averages reflected the average number of years that respondent miners had worked at mines at the time the survey was conducted. MSHA considered these average mine experiences to represent approximately one half of the mining tenure these miners would have (the years in mining when they leave). Conversely, MSHA estimated miners' total expected tenure to be twice these average mining experiences.

### *Summary: Estimated Annualized Costs Attributable to Proposed Changes to 30 CFR Part 60*

In this section, MSHA totals the annualized costs of meeting the compliance requirements of the proposed change to the PEL under the new 30 CFR Part 60. This includes the estimated costs associated with exposure monitoring; additional engineering controls; increased maintenance and repair measures; administrative controls; additional respiratory protection; and medical surveillance attributable to the rule.

As shown in Table 4-22, MSHA projects that Part 60 annualized compliance costs will total \$56.2 million over ten years at a 3 percent real discount rate. Exposure monitoring accounts for more than \$32.0 million (57 percent) of this total; medical surveillance \$17.4 million (31 percent); exposure controls account for another \$5.8 million (10 percent), and respiratory protection \$1.03 million (2 percent).

**Table 4-22. Summary of Part 60 Compliance Costs by Sector and Requirement, 2021**

Mine Sector	0 Percent Real Discount Rate		3 Percent Real Discount Rate		7 Percent Real Discount Rate	
	Annualized Cost (millions of dollars)	Percent Subtotal	Annualized Cost (millions of dollars)	Percent Subtotal	Annualized Cost (millions of dollars)	Percent Subtotal
<b>All Mines</b>						
Exposure Monitoring	\$30.60	55.9%	\$32.02	57.0%	\$34.30	58.7%
Exposure Controls	\$5.65	10.3%	\$5.75	10.2%	\$5.90	10.1%
Respiratory Protection	\$1.03	1.9%	\$1.03	1.8%	\$1.03	1.8%
Medical Surveillance	\$17.49	31.9%	\$17.37	30.9%	\$17.20	29.4%
<b>Total, Part 60 Costs</b>	<b>\$54.76</b>	<b>100.0%</b>	<b>\$56.17</b>	<b>100.0%</b>	<b>\$58.43</b>	<b>100.0%</b>
<b>As Percent of All Mines</b>	<b>100.0%</b>		<b>100.0%</b>		<b>100.0%</b>	
<b>Metal/Nonmetal</b>						
Exposure Monitoring	\$27.29	54.0%	\$28.65	55.2%	\$30.85	57.1%
Exposure Controls	\$4.81	9.5%	\$4.89	9.4%	\$5.02	9.3%
Respiratory Protection	\$0.97	1.9%	\$0.97	1.9%	\$0.97	1.8%
Medical Surveillance**	\$17.49	34.6%	\$17.37	33.5%	\$17.20	31.8%
<b>Total, Part 60 Costs</b>	<b>\$50.55</b>	<b>100.0%</b>	<b>\$51.89</b>	<b>100.0%</b>	<b>\$54.03</b>	<b>100.0%</b>
<b>As Percent of All Mines</b>	<b>92.3%</b>		<b>92.4%</b>		<b>92.5%</b>	
<b>Coal</b>						
Exposure Monitoring	\$3.31	78.6%	\$3.36	78.6%	\$3.45	78.5%
Exposure Controls	\$0.84	19.9%	\$0.86	20.0%	\$0.88	20.1%
Respiratory Protection	\$0.06	1.5%	\$0.06	1.4%	\$0.06	1.4%
Medical Surveillance*	NA	NA	NA	NA	NA	NA
<b>Total, Part 60 Costs</b>	<b>\$4.21</b>	<b>100.0%</b>	<b>\$4.28</b>	<b>100.0%</b>	<b>\$4.40</b>	<b>100.0%</b>
<b>As Percent of All Mines</b>	<b>7.7%</b>		<b>7.6%</b>		<b>7.5%</b>	

\* No Medical Surveillance costs assigned to Coal because that sector is already required to have equivalent medical surveillance program.

\*\* Medical surveillance cost is presented as the average of the assumed participation rates of 75 percent and 25 percent. Medical Surveillance costs calculated at MNM level then attributed to commodity level based on percentage of FTE Miners and contractors working in that commodity.

### 4.3 Incremental Costs of Updating Respiratory Protection Standard

MSHA is also proposing to replace the Agency's existing standards for respiratory protection that reference the American National Standards Institute (ANSI) Z88.2-1969, Practices for Respiratory Protection (1969 ANSI), published by ANSI in 1969. (§§ 56.5005, 57.5005, and 72.710) and incorporate by reference the 2019 ASTM standard to improve respiratory protection for miners from all airborne contaminants.

In this section, MSHA discusses the cost to all mines attributable to the update from the 1969 ANSI standard to the 2019 ASTM standard. These costs are evaluated provision by provision, based on respirator use, either on a per miner or a per mine basis, as appropriate. However, when analyzing the cost of updating their respiratory protection practices, the costs incurred by mine operators will vary. This occurs for several reasons.

First, MSHA estimated the number of mines likely to update respiratory protection practices. MSHA assumes that all coal mines would be affected by the update to the 2019 ASTM standard because 30 CFR 72.700(a) requires coal mine operators to make respirators available to their miners. MSHA believes that in any given year respirators will be used at about 20 percent of MNM mines. Because mines without respirator-using miners are not required to have a respiratory protection "program," MSHA believes only 20 percent of MNM mines will incur costs to meet the 2019 ASTM standard in any given year.

Second, under § 57.5005, "approved respirators shall be selected, fitted, cleaned, used, and maintained in accordance with the requirements, as applicable, of ASTM F3387-19." MSHA would require minimally acceptable program elements: program administration; standard operating procedures; medical evaluations; respirator selection; training; fit testing; and maintenance, inspection, and storage. Beyond the minimum, MSHA proposes to provide mine operators with flexibility to select the provisions in ASTM F3387-19 that are applicable to the conditions of their mines and respirator use by their miners. Thus, mine operators' costs may vary. Conversely, among provisions that would be required, several are required under other standards and thus mine operators will not incur additional compliance costs because those costs are already incurred. For example, mines are already required to select NIOSH-approved respirators under §§ 56.5005, 57.5005, and 72.701. Similarly, miner respirator training is already performed as part of annual health and safety training under 30 CFR parts 46 and 48. More detailed information concerning incremental costs of particular ASTM provisions will be described in Section 4.3.1 below.

Third, only a relatively small subset of miners use respirators in any given year. Based on Greskevitch *et al.* (2007), about 10 percent of miners at MNM mines are expected to use

respirators in any given year. At coal mines, Greskevitch *et al.* found about 7.4 percent of coal miners use respirators in any given year. However, MSHA assumes that half of the 7.4 percent of coal miners do and will use respirators on an annual basis, because the Agency believes that dust control has improved significantly at coal mines, especially since MSHA's 2014 final rule on RCMD.

Table 4-23 presents the total number of mines compared to the total number of mines expected to incur compliance costs to update their respiratory protection program and practices. Of the 12,631 total mines, 3,411 (all 1,106 coal mines plus 2,305 MNM mines (20 percent of 11,525 MNM mines)) are expected to incur costs to update their respiratory protection program and practices to the 2019 ASTM standard. In addition, MSHA estimates about 6,900 miners and contractors wear respirators in any given year; that comprises less than 2.5 percent of all miners (including contractors ( $0.024 = 6,946 \div 284,778$ )). This is because not only are respirators worn for the purpose of airborne hazard control (including respirable crystalline silica and coal dust) at a small percentage of mines in any given year, but also because only a small fraction of the miners at those mines wear respirators.

**Table 4-23. Mines Incurring Incremental Costs of ASTM Update, 2019**

Mine Sector	Total Mines	Affected Mines	Miners Including Contractors in Affected Mines		Average per Affected Mine	
			Total Miners	Miners Wearing Respirators	Miners	Miners Wearing Respirators
All Mines	<b>12,631</b>	<b>3,411</b>	<b>115,816</b>	<b>6,946</b>	<b>34.0</b>	<b>2.0</b>
Metal/Nonmetal	11,525	2,305	42,240	4,224	18.3	1.8
Coal	1,106	1,106	73,576	2,722	66.5	2.5

\* Numbers may not sum to totals due to rounding.

### 4.3.1 Additional Costs Due to ASTM Update

Under the proposed rule, MSHA would require that a mine operator's respiratory protection program be in writing and that it include several minimally acceptable program elements: program administration; standard operating procedures; medical evaluations; respirator selection; training; fit testing; and maintenance, inspection, and storage. To comply with the proposed rule, mine operators would consult the 2019 ASTM standard. Beyond the minimally acceptable program elements, mine operators would select those respiratory protection practices that are applicable to the conditions of their mines and respirator use by their miners. Mine operators would compare the ASTM F3387-19 to their existing respiratory program or practices and identify the elements of their respiratory program or practices that need to be revised.

A comparison of the 1969 ANSI standard (which is incorporated by reference in 30 CFR 56.5005, 57.5005 and 72.710) and the 2019 ASTM standard showed that the two standards are

similar in several areas, which is not surprising as the more recent ASTM standard has historical roots in the earlier 1969 ANSI standard.

Those portions of the two standards that are the same do not require mine operators to incur additional costs when updating to the 2019 ASTM standard (e.g., maintaining written standard operating procedures for mines where respirators are used, although the program may need to be updated to reflect increased detail included in the 2019 ASTM standard).

In addition, a few established respiratory protection industry standards, although not required by current regulations, are already widely implemented in the mining industry (e.g., conducting respirator fit testing following recognized methods and protocols).

Here, MSHA evaluates the components of the 2019 ASTM standard that have the potential to impose additional costs on mine operators, and the basis for estimating those costs.

### *Approved Respirators*

Mine operators are familiar with MSHA's current requirements for using NIOSH-approved respirators and this analysis assumes that mine operators will not incur additional costs.

### *Written Standard Operating Procedures*

This analysis assumes that many mines where miners are required to wear respirators already have established written Standard Operating Procedures (SOPs) that comply with the ASTM. Therefore, MSHA assumes that 50 percent of affected mine operators, about 1,706 (see Table 4-23), will prepare new or updated SOPs. MSHA estimates large mines will require 8 hours, medium sized mines will require 6 hours, and small mines will require 4 hours of a supervisor's time to prepare SOPs.

MSHA assumes the 50 percent of mines that already have SOPs will update them at this time. This is expected to take three hours at a large mine, two hours at a medium sized mine, and one hour at small mines at the loaded hourly rates listed above. The time will be split between a health and safety technician (two-thirds of the hours) and a supervisor (one-third of the hours). The loaded hourly rate for a health and safety technician ranges from \$64.70 per hour in MNM mining to \$65.19 per hour in Coal mining. For First-Line Supervisors of Construction Trades and Extraction Workers, the loaded hourly wage ranges from \$60.09 per hour in MNM mining to \$77.36 per hour in Coal mines.

MSHA assumes that half of those mine operators updating written SOPs will provide miners with a copy of updated SOPs. MSHA assumes it will require about two hours of a supervisor's time at a large mine, one hour at a medium sized mine, and a quarter of an hour at small mines at the loaded hourly rates listed above to provide miners with written SOPs.

Finally, MSHA assumes that the costs described above will be incurred in the first year following promulgation by current mine operators. In year 2 and following years, these costs will be incurred by new mines which are estimated to enter the market at a rate of about 2 percent per year. When a new mine develops and completes written SOPs, there is no recurring cost because the SOPs would be maintained by the mine operator. Overall, the incremental cost to mine operators for this provision is estimated as \$200 per mine.

### *Medical Evaluations*

Under this provision, mine operators would update the information provided to the physician or other licensed healthcare professional (PLHCP) concerning each miner's work area; type and weight of respirator; duration and frequency of respirator use; work activities and environmental conditions; hazards; and other PPE worn. This information is assumed to be part of the miners' job description and personnel records (e.g., fit-test results) and is likely available electronically at most mines. From one hour (at a large mine) to a half-hour (at medium and small mines) of labor for a health and safety technician are assumed necessary to document this information in the miner's records and to transmit it to the PLHCP. MSHA estimates the incremental cost to mine operators for this provision to total \$33 per mine per year.

### *Fit Testing Frequency*

The 2019 ASTM standard provides for annual respirator fit testing to ensure the issued make, model, and size of respirator still fits the miner properly and the miner is still able to achieve a good face seal. MSHA assumes that, on average, miners already receive annual fit testing because mine operators often bundle fit testing as part of the respirator wearer's annual training. Although the current ANSI standard does not address specific fit testing methods and equipment, MSHA assumes mine operators who currently use respirators are already following recognized and published fit testing methods and protocols (e.g., OSHA, ASTM).

However, a new provision under the 2019 ASTM standard is that the fit testing would be overseen by a trained technician or supervisor. Thus, the time of the trained supervisor is an additional cost under this provision. MSHA assumes fit testing will be performed in small groups of four, which takes about one hour. Thus, the incremental cost of the supervisor's time is calculated as 0.25 hours multiplied by the number of miners who wear respirators at the mine. MSHA estimates the incremental cost to mine operators for this provision will range from \$329 for large mines (on average, from 15 to 56 miners requiring fit testing; see Table 4-23) to \$9 for small mines with perhaps only one miner needing fit testing. The overall average is estimated to total \$32 per mine per year.

### *Respirator Selection*

The provisions for respirator selection in the 2019 ASTM standard are the current standard of care for respirator users in the U.S. This analysis assumes that mine operators are



already using these criteria for selecting respiratory protection. This analysis assumes that mine operators will not incur additional costs for this provision.

### *Mine Operator Responsibilities*

In addition to mine operators' responsibilities related to respirator selection, the 2019 ASTM standard provides that mine operators allow miners wearing respirators to leave a hazardous atmosphere for any reason related to the respirator, including, but not limited to respirator malfunction and in response to a respirator problem such as contaminant leakage or increased breathing resistance. For this analysis, MSHA estimated a labor cost of 16 hours per 100 miners per year (approximately an average of 10 minutes per miner per year) across the mining industry, which is calculated and valued at the average miner loaded hourly wage rate (\$40.93 for MNM mining and \$46.68 for Coal mining).

The mine operator would also investigate the cause of respirator failures and communicate with the respirator manufacturer and government agencies about defects. Both respirator failure and defects are considered very rare events. To account for the potential time involved should defective respirators be encountered, this analysis adds a minimal amount of labor (a respiratory protection administrator spends 0.25 hours per 100 respirator users per year for each of the 10 years of the analysis).

MSHA estimates that both provisions combined will cost a mine operator \$14 per year.

### *Training the "Respirator Trainer"*

Under the 2019 ASTM standard, the respirator trainer will provide training to others with responsibilities for implementing the mine operator's respirator program, and therefore, this person would have an elevated level of training. The length of the train-the-trainer programs offered by numerous organizations varies (from half-day to multi-day, for a wide range of costs, or at no cost).<sup>35, 36</sup> For this analysis, a 4.5-hour labor charge (health and safety professional or technician level) and an average course plus materials cost of \$200 is estimated to be incurred by each mine in the first year. At an average cost of about \$479 per mine, this is the single most expensive provision MSHA expects mine operators to incur. For existing mines, this cost is unlikely to recur except when a respirator trainer leaves the mine operator's employment. It is likely to be incurred by the 2 percent of new mines entering the market in any given year.

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<sup>35</sup> Nebraska Safety Council offers a 6 hour course for \$799 (including a "Trainer kit" of materials designed to help the new trainer) <https://nesafetycouncil.org/index.php/worker-education-and-events/training-courses/16-workplace-safety/nebraska-training-courses/92-respiratory-protection-and-fit-testing-train-the-trainer>

<sup>36</sup> The American Association of Occupational Health Nurses offers 4-to-5-hour multi-module free online course entitled "Role of the Respiratory Protection Program Administrator," developed in conjunction with NIOSH, OSHA, and Baylor University. A course completion certificate is available at a nominal charge: <http://aaohn.org/page/respiratory-protection-1278>



## *Training for the Mine Operator/Supervisor and the Person Issuing Respirators*

The mine operator or supervisor of any miner who must wear a respirator would receive training on the elements of the respiratory protection practice in the SOPs and related topics. For large and medium mines, MSHA believes the training will take about two hours, thus utilizing two hours of a health and safety technician's time plus two hours for the supervisor being trained (valued at their respective average loaded hourly rates, see discussion in *Written Standard Operating Procedures*, above). At small mines, the training is expected to require one hour for the health and safety technician and the supervisor being trained. The overall average cost in the first year is estimated to be about \$152 per mine and will also be incurred in years two through ten by – at a minimum – new mines entering the market.

### *Miner Training*

All miners receive training each year under the 1969 ANSI standard. Most mines incorporate this into their existing annual health and training program, and therefore MSHA estimates that there are no incremental costs attributable to this provision.

This provision would result in an additional 1 hour of special supplemental training time for miners who use self-contained breathing apparatus (SCBA) respirators. However, training on these types of respirators is specified in 30 CFR part 49. Therefore, no costs for SCBA training are attributed to this proposal.

### *Maintenance, Inspection, and Storage*

The provisions for respirator selection in the 2019 ASTM standard are the current standard of care for respirator users in the U.S. This analysis assumes that mine operators are already using these criteria for maintaining, inspecting, and storing respirators. This analysis assumes that mine operators will not incur additional costs for this provision.

## *Program Administration*

### *a. Recordkeeping*

MSHA assumes recordkeeping primarily results in labor costs ranging from 4 hours in small mines, 16 hours in medium sized mines, to 24 hours in large mines in the first year; the time spent in the second and subsequent years will be half that of the first year. Recordkeeping tasks might be performed by a Human Resources Assistant (Office Clerk) with a loaded hourly rate of \$35.74 in Coal mining, and \$32.78 in MNM mining. Thus, recordkeeping at a large coal mine is estimated to cost \$858 (= 24 hours × \$35.74) in the first year, and \$429 in subsequent years (= 12 hours × \$35.74). At medium sized mines MSHA estimates that recordkeeping will take 16 hours in year 1 for an estimated average cost of \$551 (= 16 hours × \$34.44), and eight hours in years 2 and following for an estimated average cost of \$275. Among small mines,

recordkeeping costs an average of \$133 per mine in year 1 (four hours), and \$67 per mine (two hours) in subsequent years.

### ***b. Program Audit***

Program costs for an annual review and written report by the program administrator are included with the annual labor time ranging from 8 hours for a large mine, 4 hours for a medium sized mine, and 1 hour for a small mine. (Smaller mines are assumed to have shorter, less complex programs.) The program administrator who performs the review and prepares the report is assumed to be a “first-line supervisor of construction trades and extraction workers” (SOC 47-1010) with an average loaded hourly rate of \$77.26 in Coal mining and \$60.09 for MNM mining. A second review in the form of an outside audit is to be conducted by a person not involved in the respirator program. This could be an internal manager or supervisor from a different department (e.g., accounting, or a “first line supervisor of maintenance and repairs” (SOC 49-1010); supervisor average loaded hourly rate of \$86.81 in Coal mining and \$71.20 for MNM mining, for which half of the original report preparation time (0.5 to 4 hours) is allotted. The audit is to be repeated at a frequency determined by the complexity of the program. MSHA assumes 50 percent of affected mines perform the entire audit protocol in any given year, for which MSHA estimates program audit costs average about \$189 per mine per year.

Table 4-24 summarizes the specific components (described in detail above) of each minimally acceptable provision under the 2019 ASTM Standard Practice for Respiratory Protection that mines would adopt, and under which MSHA expects costs will be incurred. The table also reports the expected average annual cost per mine in the first year and subsequent years following promulgation. The costs by provision presented here are weighted averages of costs over all mines calculated by commodity and mine size.

**Table 4-24. Summary of ASTM (Standard Practice for Respiratory Protection) Requirements and Estimated Incremental Cost per Affected Mine, 2021**

Summary of Minimally Acceptable Components	Average Cost per Mine	
	Year 1	Years 2-10
<b>2. Written Standard Operating Procedures (SOPs)</b>		
Detailed SOPs	\$400	\$400
Provide each miner with copy of SOPs		
<b>3. Medical Evaluations</b>		
Send each miner’s respiratory protection records to PLHCP	\$33	\$33
<b>4. Fit Testing</b>		
Trained technician or supervisor’s time to supervise fit testing	\$32	\$32
<b>6. Mine Operator Responsibilities</b>		
Time lost due to respirator problem	\$14	\$14
Time to investigate defective respirators		
<b>8. Training the Respirator Trainer</b>		

Summary of Minimally Acceptable Components	Average Cost per Mine	
	Year 1	Years 2-10
Training for respiratory protection trainer	\$479	\$479
<b>9. Training for the Mine Operator/Supervisor and the Person Issuing Respirators</b> Training for respiratory protection program manager and person issuing respirators	\$152	\$152
<b>12. Recordkeeping</b> Labor time to create and maintain records	\$229	\$115
<b>13. Program Audit</b> Time for program administrator to prepare written audit and review by third party	\$189	\$189

### 4.3.2 Estimated Incremental Costs Related to ASTM Update

Table 4-25 presents average compliance cost per mine by commodity. In year 1, compliance costs average about \$1,100 per MNM mine to \$1,500 for Coal mines; the overall average is estimated to be \$1,200 per mine. In years 2 – 10, average costs per mine are smaller, ranging from \$240 for MNM mines to \$430 for Coal mines, with an overall average of \$300 per mine.

The average number of mines incurring costs under the ASTM revision is fewer than the number of affected mines because not all affected mines are expected to incur costs under every provision. In the first year following promulgation, only 50 percent of affected mines are expected to incur costs under provision 2 (SOPs) because many mines already have SOPs that comply with the ASTM.

In years 2 through 10, the number of affected mines that would incur costs is smaller than year 1 because new mines entering the industry are primarily expected to pay additional compliance costs. For example, provisions 2 (SOPs), 8 (Training for the Respirator Trainer), 9 (Training for the Mine Operator and Person Responsible for Issuing Respirators) are principally initial costs incurred in the first year of operation. In subsequent years, those costs would generally be incurred by the 2 percent of new mines entering the industry.

**Table 4-25. Respiratory Protection Practices Additional Costs per Mine, 2021**

Mine Sector	Year 1		Years 2 - 10	
	Mines Incurring Costs	Cost per Mine	Mines Incurring Costs	Cost per Mine
<b>Total</b>	<b>3,411</b>	<b>\$1,234</b>	<b>3,411</b>	<b>\$305</b>
Metal/Nonmetal	2,305	\$1,090	2,305	\$243
Coal	1,106	\$1,534	1,106	\$433

As shown in Table 4-26, the cost of revising respiratory protection practices to the 2019 ASTM standard are at a maximum in the first year following promulgation, but thereafter drop to about one-quarter of the first-year amount. On an annualized basis at a 3 percent real

discount rate, compliance costs total \$1.40 million, with 56 percent of those costs attributable to MNM mines, and 44 percent attributable to Coal mines.

**Table 4-26. Respiratory Protection Practices Total Costs by Year and Annualized Costs (in thousands of dollars) per Year, 2021**

Component	Total Cost per Year (thousands of dollars)		Total Annualized Costs (thousands of dollars) per Year at Specified Real Discount Rate			
	Year 1	Years 2 - 10	0 Percent	3 Percent	7 Percent	Percentage of Total Costs*
<b>Total</b>	<b>\$4,209</b>	<b>\$1,040</b>	<b>\$1,357</b>	<b>\$1,400</b>	<b>\$1,461</b>	<b>100.0%</b>
Metal/Nonmetal	\$2,512	\$560	\$755	\$782	\$820	55.9%
Coal	\$1,697	\$479	\$601	\$618	\$641	44.1%

\* Calculated at the 3 percent real discount rate.

#### 4.4 Summary of Annualized Costs of the Proposed Rule

Here, MSHA totals the annualized costs of each of the estimated cost controls examined above: administrative controls, inspection and maintenance controls, additional engineering controls, and incremental respiratory protection attributable to the rule.

Annualized total compliance costs are summarized in Table 4-27 by the detailed components of each provision of the proposed rule, and by mine sector and provision in Table 4-28. MSHA projects that, at a 3 percent real discount rate, annualized compliance costs will total \$57.6 million over ten years. Almost 92 percent of these costs will be incurred by the MNM mine sector. By provision, exposure monitoring accounts for over \$32.0 million per year (56 percent of total annualized costs); conversely, additional respiratory protection comprises about 1.8 percent of total costs (\$1.03 million). The cost of modifying respiratory protection practices to the 2019 ASTM standard adds another \$1.40 million (2 percent) to the total.

**Table 4-27. Summary of Annualized Compliance Costs of Proposed Rule by Detailed Components (in thousands of 2021 dollars)**

Detailed Component	0 Percent	3 Percent	7 Percent
Exposure Monitoring			
Baseline sampling	\$1,259	\$1,884	\$2,954
Periodic sampling	\$20,867	\$21,742	\$23,093
Corrective action & Process change sampling	\$5,531	\$5,480	\$5,392
Semiannual Evaluation	\$2,939	\$2,911	\$2,865
Controls			
Engineering Control			
Capital expenditure [a]	\$1,333	\$1,413	\$1,532
Increase Maintenance and Repair	\$4,087	\$4,087	\$4,087
Administrative Control	\$226	\$249	\$281
Respiratory Protection			

Detailed Component	0 Percent	3 Percent	7 Percent
New Respirator Purchases	\$81	\$82	\$84
Additional Respirator Use	\$948	\$948	\$948
Medical Surveillance [b]	\$17,492	\$17,370	\$17,196
<b>Subtotal, Part 60 Costs</b>	<b>\$54,763</b>	<b>\$56,166</b>	<b>\$58,430</b>
ASTM Update			
Written Standard Operating Procedures	\$80	\$90	\$103
Medical Evaluations	\$111	\$111	\$111
Fit Testing	\$110	\$110	\$110
Mine Operator Responsibilities	\$49	\$49	\$49
Training the Respirator Trainer	\$193	\$215	\$246
Training for the Mine Operator/Supervisor and the Person Issuing Respirators	\$61	\$68	\$78
Recordkeeping	\$430	\$436	\$443
Program Audit	\$322	\$322	\$322
<b>Subtotal, ASTM Update</b>	<b>\$1,357</b>	<b>\$1,400</b>	<b>\$1,461</b>
<b>Total, All Mines</b>	<b>\$56,119</b>	<b>\$57,566</b>	<b>\$59,892</b>

[a] Includes annualized installation costs and O&M.

[b] Medical surveillance cost is the average cost under the assumed participation rate of 75 percent and 25 percent.

**Table 4-28. Summary of Estimated Annualized Compliance Costs (millions of 2021 dollars) by Rule Provision and Mine Sector, 2021**

	0 Percent Real Discount Rate		3 Percent Real Discount Rate		7 Percent Real Discount Rate	
	Annualized Cost (millions of dollars)	Percent Subtotal	Annualized Cost (millions of dollars)	Percent Subtotal	Annualized Cost (millions of dollars)	Percent Subtotal
<b>Mine Sector</b>						
All Mines						
Exposure Monitoring	\$30.60	54.5%	\$32.02	55.6%	\$34.30	57.3%
Exposure Controls	\$5.65	10.1%	\$5.75	10.0%	\$5.90	9.9%
Respiratory Protection	\$1.03	1.8%	\$1.03	1.8%	\$1.03	1.7%
Medical Surveillance [a]	\$17.49	31.2%	\$17.37	30.2%	\$17.20	28.7%
<b>Subtotal, Part 60 Costs</b>	<b>\$54.76</b>	<b>97.6%</b>	<b>\$56.17</b>	<b>97.6%</b>	<b>\$58.43</b>	<b>97.6%</b>
ASTM 2019	\$1.36	2.4%	\$1.40	2.4%	\$1.46	2.4%
<b>Total, All Mines</b>	<b>\$56.12</b>	<b>100.0%</b>	<b>\$57.57</b>	<b>100.0%</b>	<b>\$59.89</b>	<b>100.0%</b>
<b>As Percent of All Mines</b>	<b>100.0%</b>		<b>100.0%</b>		<b>100.0%</b>	
Metal/Nonmetal						
Exposure Monitoring	\$27.29	53.2%	\$28.65	49.8%	\$30.85	51.5%
Exposure Controls	\$4.81	9.4%	\$4.89	8.5%	\$5.02	8.4%

Mine Sector	0 Percent Real Discount Rate		3 Percent Real Discount Rate		7 Percent Real Discount Rate	
	Annualized Cost (millions of dollars)	Percent Subtotal	Annualized Cost (millions of dollars)	Percent Subtotal	Annualized Cost (millions of dollars)	Percent Subtotal
Respiratory Protection	\$0.97	1.9%	\$0.97	1.7%	\$0.97	1.6%
Medical Surveillance [a]	\$17.49	34.1%	\$17.37	30.2%	\$17.20	28.7%
<i>Subtotal, Part 60 Costs</i>	<i>\$50.55</i>	<i>98.5%</i>	<i>\$51.89</i>	<i>90.1%</i>	<i>\$54.03</i>	<i>90.2%</i>
ASTM 2019	\$0.76	1.5%	\$0.78	1.4%	\$0.82	1.4%
<b>Total, All Mines</b>	<b>\$51.31</b>	<b>100.0%</b>	<b>\$52.67</b>	<b>91.5%</b>	<b>\$54.85</b>	<b>91.6%</b>
<b>As Percent of All Mines</b>	<b>91.4%</b>		<b>91.5%</b>		<b>91.6%</b>	
Coal						
Exposure Monitoring	\$3.31	68.8%	\$3.36	68.6%	\$3.45	68.5%
Exposure Controls	\$0.84	17.4%	\$0.86	17.5%	\$0.88	17.5%
Respiratory Protection	\$0.06	1.3%	\$0.06	1.3%	\$0.06	1.2%
Medical Surveillance [b]	--	--	--	--	--	--
<i>Subtotal, Part 60 Costs</i>	<i>\$4.21</i>	<i>87.5%</i>	<i>\$4.28</i>	<i>87.4%</i>	<i>\$4.40</i>	<i>87.3%</i>
ASTM 2019	\$0.60	12.5%	\$0.62	12.6%	\$0.64	12.7%
<b>Total, All Mines</b>	<b>\$4.81</b>	<b>100.0%</b>	<b>\$4.90</b>	<b>100.0%</b>	<b>\$5.04</b>	<b>100.0%</b>
<b>As Percent of All Mines</b>	<b>8.6%</b>		<b>8.5%</b>		<b>8.4%</b>	

[a] Medical surveillance cost is presented as the average of the assumed participation rates of 75 percent and 25 percent. Medical Surveillance costs calculated at MNM level then attributed to commodity level based on percentage of FTE Miners and contractors working in that commodity.

[b] No Medical Surveillance costs assigned to Coal because that sector is already required to have equivalent medical surveillance program.

## 5 NET BENEFITS

The net benefits of the proposed rule are the differences between the estimated benefits and costs. Table 5-1 shows estimated net benefits using alternative discount rates of 0, 3, and 7 percent for costs. While the net benefits of the proposed rule vary considerably depending on the choice of the discount rate used to annualize costs and benefits, total benefits exceed total costs under each discount rate considered. MSHA's estimate of the net annualized benefits of the proposed rule, using a uniform discount rate for both costs and benefits of 3 percent, is \$118.2 million a year with the largest share (\$108.8 million; 92.0 percent) attributable to the MNM sector.

**Table 5-1. Annualized Costs, Benefits, and Net Benefits of MSHA's Proposed Respirable Crystalline Silica Rule (in Millions 2021 \$)**

Impact Category	MNM			Coal			Total		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
<b>Benefits</b>									
Mortality	\$160.0	\$99.4	\$49.4	\$13.8	\$8.6	\$4.3	\$73.8	\$108.0	\$53.8
Morbidity Preceding Mortality	\$19.6	\$13.3	\$7.5	\$1.7	\$1.2	\$0.7	\$21.3	\$14.5	\$8.2
Morbidity Not Preceding Mortality	\$67.5	\$48.7	\$31.3	\$6.3	\$4.6	\$2.9	\$73.8	\$53.2	\$34.2
<b>Total</b>	<b>\$247.1</b>	<b>\$161.4</b>	<b>\$88.2</b>	<b>\$21.8</b>	<b>\$14.3</b>	<b>\$7.9</b>	<b>\$268.9</b>	<b>\$175.7</b>	<b>\$96.2</b>
<b>Costs</b>									
Exposure Monitoring	\$27.3	\$28.7	\$30.9	\$3.3	\$3.4	\$3.5	\$30.6	\$32.0	\$34.3
Exposure Controls	\$4.8	\$4.9	\$5.0	\$0.8	\$0.9	\$0.9	\$5.6	\$5.7	\$5.9
Respiratory Protection	\$1.0	\$1.0	\$1.0	\$0.1	\$0.1	\$0.1	\$1.0	\$1.0	\$1.0
Medical Surveillance	\$17.5	\$17.4	\$17.2	--	--	--	\$17.5	\$17.4	\$17.2
ASTM Update	\$0.8	\$0.8	\$0.8	\$0.6	\$0.6	\$0.6	\$1.4	\$1.4	\$1.4
<b>Total</b>	<b>\$51.3</b>	<b>\$52.6</b>	<b>\$54.8</b>	<b>\$4.8</b>	<b>\$4.9</b>	<b>\$5.0</b>	<b>\$56.1</b>	<b>\$57.5</b>	<b>\$59.9</b>
<b>Net Benefits</b>	<b>\$195.8</b>	<b>\$108.8</b>	<b>\$33.4</b>	<b>\$17.0</b>	<b>\$9.4</b>	<b>\$2.9</b>	<b>\$212.8</b>	<b>\$118.2</b>	<b>\$36.3</b>

Note: Medical surveillance cost is the average cost under the assumed participation rate of 75 percent and 25 percent.

[a] For the purpose of simplifying the estimation of the monetized benefits of avoided illness and death, MSHA simply added the monetized benefits of morbidity preceding mortality to the monetized benefits of mortality at the time of death, and both would be discounted at that point. In theory, however, the monetized benefits of morbidity should be recognized (and discounted) at the onset of morbidity, as this is what a worker's willingness to pay is presumed to measure—that is, the risk of immediate death or an immediate period of illness that a worker is willing to pay to avoid—a practice that would increase the present value of discounted morbidity benefits. A parallel tendency toward underestimation occurs with regard to morbidity not preceding mortality, since it implicitly assumes that the benefits occur at retirement, as per the Buchanan model, but many, if not most, of the 2/0 or higher silicosis cases will have begun years before (with those classifications, in turn, preceded by a 1/0 classification). As a practical matter, however, the Agency lacks sufficient data at this time to refine the analysis in this way.



## 6 ECONOMIC FEASIBILITY

MSHA considers economic feasibility in terms of industry-wide revenue and overall cost of a rule in mining industry, including MNM and coal. To establish economic feasibility, MSHA uses a revenue screening test—whether the yearly costs of a rule are less than 1 percent of revenues, or are negative (i.e., provide net cost savings)—to presumptively establish that compliance with the regulation is economically feasible for the mining industry. The resulting ratio of annualized compliance costs to revenues from the screener analysis should be interpreted with care. If annualized compliance costs comprise less than 1 percent of revenue, MSHA presumes that the affected entities can incur the compliance costs without significant economic impacts.<sup>37</sup>

For the MNM and coal mining sectors, MSHA estimates the projected impacts of the rule by calculating the average annualized compliance costs for each sector as a percentage of total revenues. To be consistent with costs that are calculated in 2021 dollars, MSHA first inflated mine revenues expressed in 2019 to their 2021 equivalent using the GDP Implicit Price Deflator. Due to inflation, the nominal value of a dollar in 2021 is estimated to be about 5.4 percent higher than in 2019.

**Table 6-1. Total Mines, Revenues and Employment by Sector, 2019**

Mine Sector	Mines	2019 Revenues (millions of dollars), Inflated to 2021 Dollars	Miners Including Contractors
<b>Total</b>	<b>12,631</b>	<b>\$115,348</b>	<b>284,778</b>
Metal/Nonmetal	11,525	\$88,316	211,202
Coal	1,106	\$27,032	73,576

Table 6-2 presents the projected impacts of the proposed rule. The table compares aggregate annualized compliance costs for MNM and coal sectors at a 0 percent, 3 percent, and 7 percent real discount rate to total annual revenues. At a 3 percent real discount rate, total aggregate annualized compliance costs are projected to be \$57.6 million (including both 30 CFR Part 60 and 2019 ASTM Update Costs), while aggregate revenues are estimated to be \$115.3 billion in 2021 dollars. Thus, the mining industry is expected to incur compliance costs that comprise 0.05 percent of total revenues.

For the MNM sector, MSHA estimates that the annualized costs of the proposed rule (including ASTM update costs) would be \$52.7 million at 3 percent discount rate, which is approximately 0.06 percent of total annual revenue of \$88.3 billion (\$52.7 million/\$88.3 billion) for MNM mine operators. For the coal sector, MSHA estimates that the annualized cost of the proposed rule would also be \$4.9 million at 3 percent, which is approximately 0.02 percent of total annual revenue of \$27.0 billion (\$4.90 million/\$27.0 billion) for coal mine operators.

<sup>37</sup> MSHA is not required to produce hard and precise estimates of cost to establish economic feasibility. Rather, MSHA must provide a reasonable assessment of the likely range of costs of its standard, and the likely effects of those costs on the industry. See *United Steelworkers of America v. Sec'y of Labor*, 647 F.2d at 1264; see also *Nat'l Min. Ass'n v. Sec'y, U.S. Dep't of Lab.*, 812 F.3d 843, 865 (11th Cir. 2016).

The ratios of screening analysis are well below the 1.0 percent of threshold, and therefore, MSHA has concluded that the requirements of the proposed rule are economically feasible, and no sector will likely incur a significant cost.

**Table 6-2. Estimated Annualized Compliance Costs as Percent of Mine Revenues by Sector, 2021**

Mine Sector	2019 Revenues (millions 2021 dollars)	Annualized Costs (millions of 2021 dollars) 0 Percent Real Discount Rate		Annualized Costs (millions of 2021 dollars) 3 Percent Real Discount Rate		Annualized Costs (millions of 2021 dollars) 7 Percent Real Discount Rate	
		Compliance Costs	Cost as % of Revenues	Compliance Costs	Cost as % of Revenues	Compliance Costs	Cost as % of Revenues
30 CFR Part 60 Costs							
Total	\$115,348	\$54.76	0.05%	\$56.17	0.05%	\$58.43	0.05%
Metal/Nonmetal	\$88,316	\$50.55	0.06%	\$51.89	0.06%	\$54.03	0.06%
Coal	\$27,032	\$4.21	0.02%	\$4.28	0.02%	\$4.40	0.02%
30 CFR Part 60 + 2019 ASTM Upgrade Costs							
Total	\$115,348	\$56.12	0.05%	\$57.57	0.05%	\$59.89	0.05%
Metal/Nonmetal	\$88,316	\$51.31	0.06%	\$52.67	0.06%	\$54.85	0.06%
Coal	\$27,032	\$4.81	0.02%	\$4.90	0.02%	\$5.04	0.02%

## 7 REGULATORY ALTERNATIVES

The proposed rule presents a comprehensive approach for lowering miners' exposure to respirable crystalline silica. The proposal includes the following regulatory provisions: lowering miners' respirable crystalline silica exposure to a PEL of 50  $\mu\text{g}/\text{m}^3$  for a full-shift exposure, calculated as an 8-hour TWA; initial baseline sampling for miners who are reasonably expected to be exposed to respirable crystalline silica; periodic sampling for miners who are at or above the proposed action level of 25  $\mu\text{g}/\text{m}^3$  but at or below the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ ; and semi-annual evaluation of changing mining processes that would reasonably be expected to result in new or increased exposures

In developing the proposed rule, MSHA considered two regulatory alternatives. Both alternatives include less stringent monitoring provisions than the proposed monitoring provisions. One of the alternatives also combines less stringent monitoring with a more stringent PEL. MSHA discusses the regulatory options in the sections below, from least expensive to most expensive.

### 7.1 Regulatory Alternative #1: Changes in Sampling and Evaluation Requirements

Under this alternative, the proposed PEL would remain unchanged at 50  $\mu\text{g}/\text{m}^3$  and the proposed action level would remain unchanged at 25  $\mu\text{g}/\text{m}^3$ . Further, mine operators would conduct: (1) baseline sampling for miners who may be exposed to respirable crystalline silica at or above the proposed action level of 25  $\mu\text{g}/\text{m}^3$ , (2) periodic sampling twice per year for miners who are at or above the proposed action level of 25  $\mu\text{g}/\text{m}^3$  but at or below the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ , and (3) annual evaluation of changing mining processes or conditions that would reasonably be expected to result in new or increased exposures.

Mine operators would be required to undertake sampling under this regulatory alternative and would thus incur compliance costs. However, monitoring requirements under this alternative are less stringent than the requirements under the proposed rule because the number of miners to be sampled for baseline sampling would be smaller than in the proposed rule and the frequency of periodic sampling and evaluations of changing mining processes or conditions are set at half the frequency of the proposed monitoring requirements. Therefore, the cost of compliance will be lower under this alternative. MSHA estimates that annualized monitoring costs will total \$17.3 million for this alternative (at a 3 percent discount rate), compared to \$32.0 million for the proposed monitoring requirements, resulting in an estimated \$14.7 million in lower costs per year (Table 7-1).

Although this alternative does not eliminate exposure monitoring, the requirements are minimal relative to the monitoring requirements under the proposed rule. However, MSHA believes it is necessary for mine operators to establish a solid baseline for any miner who is reasonably expected to be exposed to respirable crystalline silica. In addition, periodic monitoring helps mine operators correlate mine conditions to miner exposure levels and see exposure trends more rapidly than would result from semi-annual or annual sampling. This

would enable mine operators to take measures necessary to ensure continued compliance with the PEL. Further, more frequent monitoring would enable mine operators to ensure the adequacy of controls at their mines and better protect miners' health. These benefits cannot be quantified, but they are nevertheless material benefits that increase the likelihood of compliance.

**Table 7-1. Summary of Part 60 Annualized Compliance Costs (in Millions of 2021 \$), Regulatory Alternative 1 and Proposed Requirements: All Mines, 2021**

Mine Sector	0 Percent Real Discount Rate		3 Percent Real Discount Rate		7 Percent Real Discount Rate	
	Annualized Cost (millions of dollars)	Percent of Proposed	Annualized Cost (millions of dollars)	Percent of Proposed	Annualized Cost (millions of dollars)	Percent of Proposed
<b>Regulatory Alternative #1: Changes in Sampling and Evaluation Requirements</b>						
Exposure Monitoring	\$16.29		\$17.33		\$19.02	
Exposure Controls	\$5.65		\$5.75		\$5.90	
Respiratory Protection	\$1.03		\$1.03		\$1.03	
Medical Surveillance	\$17.49		\$17.37		\$17.20	
<b>Total, Part 60 Costs</b>	<b>\$40.46</b>	<b>73.9%</b>	<b>\$41.48</b>	<b>73.8%</b>	<b>\$43.15</b>	<b>73.8%</b>
<b>Proposed Requirements</b>						
Exposure Monitoring	\$30.60		\$32.02		\$34.30	
Exposure Controls	\$5.65		\$5.75		\$5.90	
Respiratory Protection	\$1.03		\$1.03		\$1.03	
Medical Surveillance	\$17.49		\$17.37		\$17.20	
<b>Total, Part 60 Costs</b>	<b>\$54.76</b>	<b>100.0%</b>	<b>\$56.17</b>	<b>100.0%</b>	<b>\$58.43</b>	<b>100.0%</b>

MSHA also believes that requiring more frequent periodic sampling would provide mine operators with greater confidence that they are in compliance with the proposed rule. Because of the variable nature of miner exposures to airborne concentrations of respirable crystalline silica, maintaining exposures below the proposed action level provides mine operators with reasonable assurance that miners would not be exposed to respirable crystalline silica at levels above the PEL on days when sampling is not conducted. MSHA believes that the benefits of the proposed sampling requirements justify the additional costs relative to Regulatory Alternative 1.

## **7.2 Regulatory Alternative #2: Changes in Sampling and Evaluation Requirements and the Proposed PEL**

Under this regulatory alternative, the proposed PEL would be set at 25 µg/m<sup>3</sup>; mine operators would install whatever controls are necessary to meet this PEL; and no action level would be proposed. Further, mine operators would: (1) not be required to conduct baseline sampling or periodic sampling, (2) conduct semi-annual evaluations of changing conditions, and (3) sample as frequently as necessary to determine the adequacy of controls.

Mine operators would not be required to undertake baseline or periodic sampling. However, mine operators would be required to perform semi-annual evaluations of changing mining processes or conditions. Further, mine operators would be required to perform post-evaluation sampling when the operators determine as a result of the semi-annual evaluation that miners may be exposed to respirable crystalline silica at or above proposed PEL at 25  $\mu\text{g}/\text{m}^3$ . When estimating the cost of the proposed monitoring requirements, MSHA assumes that the number of samples for corrective action and semi-annual evaluation are relatively small (2.5 percent of miners) because samples from sampling to determine the adequacy of controls and from MSHA can both be used to meet the requirements. Since this alternative does not require periodic sampling, MSHA increases samples after each evaluation to 10 percent of miners to ensure the monitoring requirements can be met.

This alternative also sets the proposed PEL at 25  $\mu\text{g}/\text{m}^3$ . In addition to the estimated cost of compliance with a PEL of 50  $\mu\text{g}/\text{m}^3$ , mine operators would incur additional engineering control costs to meet a PEL of 25  $\mu\text{g}/\text{m}^3$ . To estimate these additional engineering control costs, MSHA largely uses the same methodology as for mines affected at the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ .

### **7.2.1 Number of Mines Affected Under Regulatory Alternative 2**

MSHA first estimated the number of mines expected to incur the cost of implementing engineering controls to reach the more stringent PEL. After excluding mines that are affected at the proposed PEL of 50  $\mu\text{g}/\text{m}^3$  (to avoid double-counting), MSHA finds that 3,477 mines (2,991 MNM mines and 486 coal mines) operating in 2019 had at least one sample at or above 25  $\mu\text{g}/\text{m}^3$  but below 50  $\mu\text{g}/\text{m}^3$ .<sup>38</sup>

To this number, MSHA adds the 1,226 affected mines expected to incur costs to reach the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ . Based on its experience and knowledge, MSHA does not expect the mines that installed engineering controls to meet the PEL of 50  $\mu\text{g}/\text{m}^3$  will also be able to comply with a PEL of 25  $\mu\text{g}/\text{m}^3$ . For example, to comply with the proposed PEL of 50  $\mu\text{g}/\text{m}^3$ , a mine might need to add the engineering controls necessary to achieve an additional 10 air changes per hour over that achieved by existing controls, which are costed in Section 7.2.2. However, such a mine facility would then need to add an additional 10 air changes per hour to meet the more stringent PEL of 25  $\mu\text{g}/\text{m}^3$ , which is not costed in Section 7.2.2. Thus, MSHA expects that the 1,226 affected mines will incur additional costs to meet the PEL of 25  $\mu\text{g}/\text{m}^3$  specified under this alternative.

MSHA estimates a total of 4,703 mines will incur costs to purchase, install, and operate engineering controls to meet the PEL of 25  $\mu\text{g}/\text{m}^3$  under this alternative. MNM mines account for 4,087 (87 percent) and coal mines 616 (13 percent). Further, of the estimated 4,087 MNM

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<sup>38</sup> About 8,053 of mines active in 2019 either did not have a sample > 25  $\mu\text{g}/\text{m}^3$  or did not have a sample in the last 5 years.

mines and 616 coal mines, 1,096 MNM mines (27 percent) and 130 coal mines (21 percent) are also estimated to incur compliance costs to reach the proposed PEL of 50 µg/m<sup>3</sup>.

## 7.2.2 Estimated Engineering Control Costs Under Regulatory Alternative 2

MSHA identified potential engineering controls that would enable mines with respirable crystalline silica dust exposures at or above 25 µg/m<sup>3</sup> but below 50 µg/m<sup>3</sup> categories to meet the PEL of 25 µg/m<sup>3</sup> under consideration for this alternative. While MSHA assumes that mine operators will base such decisions on site-specific conditions such as mine layout and existing infrastructure, MSHA cannot make further assumptions about the specific controls that might be adopted and instead assumes the expected value of purchased technologies should equal the simple average of the technologies listed in each control category.

Where more precise information is unavailable, MSHA assumes operating and maintenance (O&M) costs to be 35 percent of initial capital expenditure, infrastructure service life to be 10 years, and that any installation cost will be equal to any initial capital expenditure (Table 7-2). MSHA also assumes the larger capital expenditure controls will have a 30-year service life. MSHA welcomes public comment concerning the engineering controls selected for this analysis and the assumptions used to estimate installation and O&M costs for these controls.

**Table 7-2. Selected Engineering Controls to Decrease Respirable Crystalline Silica Dust Exposure by Capital Expenditure Cost Range Under Regulatory Alternative 2**

Engineering Control	2021 Capital Cost	2021 Installation Cost [a]	2021 O&M Cost [b]	Expected Service Life [c]
<b>Minimal capital expenditure</b>				
Stone saw enclosure	\$0	\$0	\$1,378	1
<b>Larger capital expenditure</b>				
Increase facility ventilation from 20 to 30 air changes per hour	\$157,000	\$157,000	\$9,153	30
Full length of conveyor enclosed and ventilated	\$896,373	\$896,373	\$51,988	30
Crusher/grinder: appropriate size ventilation for air flow	\$184,640	\$184,640	\$10,709	30
Plumbing for hose installations, floor re-sloping and troughs	\$43,076	\$43,076	\$3,951	30
<b>Average</b>	<b>\$256,218</b>	<b>\$256,218</b>	<b>\$15,436</b>	<b>24.2</b>

[a] Unless otherwise specified, installation costs are assumed to be equal to capital cost.

[b] Unless otherwise specified, annual O&M costs are assumed to be equal to 35 percent of capital cost.

[c] Service life assumed to be 10 years if not otherwise specified.

However, the difficulty of meeting a PEL of 25 µg/m<sup>3</sup> is such that MSHA's experience suggests a single control from Table 7-2 will not be sufficient. For example, respirable crystalline silica dust exposure at such a stringent limit as 25 µg/m<sup>3</sup> is likely to occur at more than one area of the mine; in addition to increasing ventilation to a crusher/grinder, enclosing and ventilating

the mine conveyor belt would be necessary to reduce concentrations below the limit. Similarly, increasing facility ventilation from 20 to 30 air changes per hour may not be adequate to meet the limit; 40 air changes per hour might be necessary. Therefore, MSHA assumes mine operators will purchase and install at least two of the engineering controls listed in Table 7-2. This may be a conservative assumption.

Table 7-3 presents the average annualized engineering control costs per mine and total annualized engineering control costs by mine sector. Because the service life of nearly all components is expected to be 30 years, the costs of all engineering controls are annualized over 30 years. At a 3 percent real discount rate, the average annualized engineering control costs are about \$94,300 per mine, resulting in an additional cost of \$443.6 million if the PEL is set at 25  $\mu\text{g}/\text{m}^3$  instead of 50  $\mu\text{g}/\text{m}^3$ .

**Table 7-3. Estimated Annualized Costs as a Simple Average per Mine and Total Engineering Controls per Mine Under Regulatory Alternative 2, by Category, 2021**

	Annualized Cost of Engineering Controls at		
	Specified Real Discount Rate		
	0 Percent	3 Percent	7 Percent
Annualized Engineering Control Costs per Mine, Over All Controls	\$73,574	\$94,328	\$127,356
Total Annualized Engineering Control Costs by Mine Sector (millions) [a]			
<b>Total</b>	<b>\$346.0</b>	<b>\$443.6</b>	<b>\$599.0</b>
MNM	\$300.7	\$385.5	\$520.5
Coal	\$45.3	\$58.1	\$78.5

[a] Based on an estimated 616 Coal and 4,087 MNM mines, for 4,703 total affected mines.

Table 7-4 summarizes the estimated annualized cost of this alternative under consideration. At a 3 percent real discount rate, exposure monitoring costs less than the proposed rule; however, this lower cost is more than offset by the increased control costs necessitated by the requirement that mines maintain respirable crystalline silica exposure levels below 25  $\mu\text{g}/\text{m}^3$ . At an estimated annualized cost of \$491.2 million, this alternative would cost nearly eight times more than the proposed requirements.

**Table 7-4. Summary of Part 60 Annualized Compliance Costs (in Millions of 2021 \$) Under Regulatory Alternative 2 and Proposed Requirements: All Mines, 2021**

	0 Percent Real Discount Rate		3 Percent Real Discount Rate		7 Percent Real Discount Rate	
	Annualized Cost (millions of dollars)	Percent of Proposed	Annualized Cost (millions of dollars)	Percent of Proposed	Annualized Cost (millions of dollars)	Percent of Proposed
<b>Mine Sector</b>						
<b>Regulatory Alternative #2: Changes in PEL Sampling and Evaluation Requirements</b>						
Exposure Monitoring	\$25.06		\$24.83		\$24.43	
Exposure Controls	\$350.30		\$447.93		\$603.29	
Respiratory Protection	\$1.03		\$1.03		\$1.03	

Mine Sector	0 Percent Real Discount Rate		3 Percent Real Discount Rate		7 Percent Real Discount Rate	
	Annualized Cost (millions of dollars)	Percent of Proposed	Annualized Cost (millions of dollars)	Percent of Proposed	Annualized Cost (millions of dollars)	Percent of Proposed
Medical Surveillance	\$17.49		\$17.37		\$17.20	
<b>Total, Part 60 Costs</b>	<b>\$393.88</b>	<b>719.3%</b>	<b>\$491.16</b>	<b>874.4%</b>	<b>\$645.95</b>	<b>1105.3%</b>
<b>Proposed Requirements</b>						
Exposure Monitoring	\$30.60		\$32.02		\$34.30	
Exposure Controls	\$5.65		\$5.75		\$5.90	
Respiratory Protection	\$1.03		\$1.03		\$1.03	
Medical Surveillance	\$17.49		\$17.37		\$17.20	
<b>Total, Part 60 Costs</b>	<b>\$54.76</b>	<b>100.0%</b>	<b>\$56.17</b>	<b>100.0%</b>	<b>\$58.43</b>	<b>100.0%</b>

This alternative requires exposure monitoring that is more stringent than Regulatory Alternative 1, but less stringent than the proposed requirements. In addition, Regulatory Alternative 2 increases miner protection by proposing to set the PEL at 25 µg/m<sup>3</sup>, resulting in measurable avoided mortality and other health benefits. Table 7-5 presents the avoided morbidity and mortality cases over the 60-year regulatory analysis time horizon under this alternative. Under this alternative, the avoided 60-year mortality is expected to be 981, which is 2.4 times higher than the expected avoided mortality of 410 under a proposed PEL of 50 µg/m<sup>3</sup>. The avoided 60-year morbidity under the regulatory alternative of 25 µg/m<sup>3</sup> is expected to be 1,948, which is 1.4 times higher than the expected avoided 60-year morbidity of 1,420 under the proposed PEL of 50 µg/m<sup>3</sup>.

**Table 7-5. Estimated Cases of Avoided Mortality and Morbidity over 60 Years (Regulatory Analysis Time Horizon) Following Rule Promulgation Under Regulatory Alternative 2**

Health Outcome	Total Avoided Cases over 60 Years [a]		
	MNM	Coal	Total
<b>Morbidity</b>			
Silicosis	1,736.9	211.5	1,948.4
<b>Morbidity Total (Net of Silicosis Fatalities)</b>	<b>1,736.9</b>	<b>211.5</b>	<b>1,948.4</b>
<b>Mortality</b>			
NMRD (net of silicosis mortality)	408.7	<b>57.8</b>	<b>466.4</b>
Silicosis	206.0	25.6	231.5
ESRD	193.4	27.3	220.8
Lung Cancer [b]	54.7	7.3	62.0
<b>Mortality Total</b>	<b>862.8</b>	<b>118.0</b>	<b>980.7</b>

[a] Cases include full-time-equivalent contract miners and assume compliance with the current limits.

[b] Lung cancer estimates assume a 15-year lag between exposure and health effect.

Table 7-6 presents the benefits associated with this avoided morbidity and mortality. The expected total benefits, discounted at 3 percent, are \$365.5 million, which is twice the expected total benefits of \$175.7 million under the proposed PEL of 50 µg/m<sup>3</sup>. Under this regulatory alternative, these benefits are made up of \$258.0 million due to avoided mortality,



\$34.5 million due to morbidity preceding mortality, and \$73.0 million due to morbidity not preceding mortality. However, when compared to the annualized costs, the net benefits of this alternative are negative at both a 3 percent and 7 percent real discount rate.

**Table 7-6. Annualized Monetized Benefits over 60 Years (Regulatory Analysis Time Horizon) Following Rule Promulgation (in Millions of 2021 \$) Under Regulatory Alternative 2, by Health Outcome and Discount Rate**

Health Outcome	MNM			Coal			Total		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
<b>Avoided Morbidity (Not Preceding Mortality)</b>									
Silicosis (Excluding Silicosis Deaths)	\$90.3	\$65.1	\$41.8	\$11.0	\$7.9	\$5.1	\$101.3	\$73.0	\$46.9
<b>Avoided Morbidity (Not Preceding Mortality) Total</b>	<b>\$90.3</b>	<b>\$65.1</b>	<b>\$41.8</b>	<b>\$11.0</b>	<b>\$7.9</b>	<b>\$5.1</b>	<b>\$101.3</b>	<b>\$73.0</b>	<b>\$46.9</b>
<b>Mortality</b>									
NMRD (Excluding Silicosis Deaths)	\$175.7	\$106.3	\$49.6	\$24.9	\$15.0	\$7.0	\$200.6	\$121.2	\$56.6
Silicosis	\$84.3	\$56.1	\$32.1	\$10.3	\$7.0	\$4.1	\$94.4	\$63.1	\$36.2
ESRD	\$82.7	\$50.6	\$24.8	\$11.6	\$7.2	\$3.6	\$94.3	\$57.8	\$28.3
Lung Cancer	\$24.0	\$13.9	\$5.9	\$3.2	\$1.9	\$0.8	\$27.3	\$15.8	\$6.7
<b>Avoided Mortality Total</b>	<b>\$366.6</b>	<b>\$226.9</b>	<b>\$112.4</b>	<b>\$50.1</b>	<b>\$31.1</b>	<b>\$15.4</b>	<b>\$416.7</b>	<b>\$258.0</b>	<b>\$127.8</b>
<b>Avoided Morbidity (Preceding Mortality)</b>									
NMRD (Excluding Silicosis Deaths)	\$21.2	\$13.9	\$7.3	\$3.0	\$2.0	\$1.0	\$24.2	\$15.8	\$8.3
Silicosis	\$10.7	\$8.0	\$5.3	\$1.3	\$1.0	\$0.7	\$12.0	\$9.0	\$6.0
ESRD	\$10.1	\$6.7	\$3.8	\$1.4	\$1.0	\$0.5	\$11.5	\$7.7	\$4.3
Lung Cancer	\$2.8	\$1.8	\$0.8	\$0.4	\$0.2	\$0.1	\$3.2	\$2.0	\$0.9
<b>Avoided Morbidity (Preceding Mortality) Total</b>	<b>\$44.8</b>	<b>\$30.3</b>	<b>\$17.1</b>	<b>\$6.1</b>	<b>\$4.2</b>	<b>\$2.3</b>	<b>\$51.0</b>	<b>\$34.5</b>	<b>\$19.5</b>
<b>Grand Total</b>	<b>\$501.7</b>	<b>\$322.4</b>	<b>\$171.3</b>	<b>\$67.2</b>	<b>\$43.1</b>	<b>\$22.8</b>	<b>\$568.9</b>	<b>\$365.5</b>	<b>\$194.1</b>

MSHA solicits further comment on the extent to which these regulatory alternatives may improve or reduce the effectiveness of the proposed rule.

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## TECHNICAL APPENDIX A – ABBREVIATED HYPOTHETICAL EXAMPLE WITH SAMPLE LIFE TABLES

For illustrative purposes, a hypothetical example is provided below using abbreviated life tables to demonstrate the manner in which the number of cases avoided in a single year is estimated. In this example, MSHA considers silicosis mortality among MNM miners. Specifically, MSHA models the risks in a given year  $t$  for the subset of 11,769 MNM total miners who are in the exposure group over  $100 \mu\text{g}/\text{m}^3$ . Due to the proposed PEL, this group would experience a drop in exposure from  $100 \mu\text{g}/\text{m}^3$  (assuming full compliance with the existing limit) to  $50 \mu\text{g}/\text{m}^3$  (assuming full compliance with the proposed PEL).

Assuming the proposed PEL goes into effect in 2024, the life table below (Table A - 1) represents the oldest cohort of coal miners (cohort 1, born in 1944) still accruing risks during that year. This group is assumed to have begun working in 1965 at age 21 and to have retired in 2010 at age 66. For this cohort, the new PEL would go into effect only during the final year of life, 14 years after retirement<sup>41</sup>:

**Table A - 1. Example Life Table for Cohort 1's Silicosis Mortality Risk Under Proposed PEL, for MNM Miners Currently Exposed to a Concentration of  $100 \mu\text{g}/\text{m}^3$  of Respirable Crystalline Silica**

Calendar Year	Age, $t$	Cumulative Exposure, $E$	Silicosis Mortality Hazard, $h_t$ (per 100,000)	All-Cause Death Hazard, $d_t$ (per 100,000)	Survival Rate, $S_t$	Silicosis Death Risk, $r_t$
1964 <sup>[a]</sup>	20	0.000	4.7	135.3	1	0.00000
1965	21	0.087	4.7	135.3	0.9986	0.00005
⋮	⋮	⋮	⋮	⋮	⋮	⋮
2009	65	3.934	44.2	1893.0	0.8003	0.00035
2010	66	3.934	44.2	1893.0	0.7852	0.00035
⋮	⋮	⋮	⋮	⋮	⋮	⋮
2023	79	3.934	44.2	4193.4	0.5347	0.00024
2024 <sup>[b]</sup>	80	3.934	44.2	6808.3	0.5123	0.00023

[a] Red text represents years of exposure at  $100 \mu\text{g}/\text{m}^3$  under the existing PEL.

[b] Black text represents years during retirement.

[c] The final column shows that silicosis death risk is lower at age 79 than at age 66 for this particular cohort. This indicates that a smaller proportion of the cohort's starting population is expected to die from silicosis at the age of 79 than is expected to die from silicosis at the age of 66. This is partly attributable to the fact that fewer members of the cohort are alive at the age of 79 than at the age of 66.

The new PEL does not confer benefits to this cohort because they were already retired. Thus, in the calendar year 2024, the risk reduction for this  $i = 1^{\text{st}}$  cohort is  $\Delta r_t^{(1)} = \tilde{r}_t^{(1)} - r_t^{(1)} = 0$ . Similarly, for cohorts 2 through 15, implementation of the proposed PEL would yield no benefits, as the proposed PEL would have gone into effect after these cohorts retired.

<sup>41</sup> In this hypothetical example, MSHA assumes the same exposure level before and after 1973 TLV. That is, the calculation of cumulative exposure for all age cohorts follows the same approach.



However, we can instead inspect cohorts 38 through 42 (Table A - 2), all of whom would still be working when the proposed PEL goes into effect in 2024. Just as the cohort  $i = 1$  is the oldest group of miners (born in 1944) that accumulate risk during the 60-year period, the cohort  $i = 38$  is the 38<sup>th</sup> oldest group of miners (born in 1981) that accumulate risk during the 60-year period.

Abbreviated life tables (with interior columns removed) are shown below for these cohorts  $i = \{38, 39, 40, 41, 42\}$ . The tables are staggered to show synchronization of exposures by calendar year. Blue and red cells display exposures under the proposed and existing PELs, respectively. Black cells show years of retirement. The blue highlighted row when cumulative exposure did not continue to increase shows the first year of implementation of the proposed PEL.

**Table A - 2. Example Abbreviated Life Tables Showing Silicosis Mortality Risk Under Proposed PEL for Cohorts 38 – 42 Among MNM Miners Currently Exposed to a Concentration of 100  $\mu\text{g}/\text{m}^3$  of Respirable Crystalline Silica, Staggered to Show Synchronization**

Calendar Year	Cohort 38		Cohort 39		Cohort 40		Cohort 41		Cohort 42	
	Age	$r_t^{(38)}$	Age	$r_t^{(39)}$	Age	$r_t^{(40)}$	Age	$r_t^{(41)}$	Age	$r_t^{(42)}$
2001	20	0.00000								
2002	21	0.00005	20	0.00000						
2003	22	0.00005	21	0.00005	20	0.00000				
2004	23	0.00005	22	0.00005	21	0.00005	20	0.00000		
2005	24	0.00005	23	0.00005	22	0.00005	21	0.00005	20	0.00000
2006	25	0.00005	24	0.00005	23	0.00005	22	0.00005	21	0.00005
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2022	41	0.00015	40	0.00015	39	0.00015	38	0.00015	37	0.00015
2023	42	0.00015	41	0.00015	40	0.00015	39	0.00015	38	0.00015
2024	43	0.00015	42	0.00015	41	0.00015	40	0.00015	39	0.00015
2025	44	0.00015	43	0.00015	42	0.00015	41	0.00015	40	0.00015
2026	45	0.00015	44	0.00015	43	0.00015	42	0.00015	41	0.00015
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2045	64	0.00036	63	0.00024	62	0.00024	61	0.00025	60	0.00025
2046	65	0.00035	64	0.00024	63	0.00024	62	0.00024	61	0.00025
2047	66	0.00035	65	0.00035	64	0.00024	63	0.00024	62	0.00024
2048	67	0.00034	66	0.00035	65	0.00023	64	0.00024	63	0.00024
2049	68	0.00033	67	0.00034	66	0.00023	65	0.00023	64	0.00024
2050	69	0.00033	68	0.00033	67	0.00023	66	0.00023	65	0.00023
2051	70	0.00032	69	0.00033	68	0.00022	67	0.00023	66	0.00023
2052	71	0.00031	70	0.00032	69	0.00022	68	0.00022	67	0.00023
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2060	79	0.00024	78	0.00025	77	0.00017	76	0.00018	75	0.00019
2061	80	0.00023	79	0.00024	78	0.00016	77	0.00017	76	0.00018
2062			80	0.00023	79	0.00016	78	0.00016	77	0.00017
2063					80	0.00015	79	0.00016	78	0.00016
2064							80	0.00015	79	0.00016
2065									80	0.00015



In general, the blue-colored silicosis mortality risk  $\hat{r}_t^{(i)}$  are lower<sup>42</sup> due to reduced exposures of 50  $\mu\text{g}/\text{m}^3$  under the proposed PEL. For comparison, if the proposed PEL had not gone into effect in year 2024, then all blue cells would be replaced by higher exposures at 100  $\mu\text{g}/\text{m}^3$  (assuming full compliance with the existing MNM PEL). The silicosis mortality risks  $\hat{r}_t^{(i)}$  at year  $t$  among cohort  $i$  are shown in the Table A - 3 below assuming exposure to concentrations of 100  $\mu\text{g}/\text{m}^3$  under the existing PEL.

**Table A - 3. Abbreviated Life Tables Showing Silicosis Mortality Risk Under Existing PEL for Cohorts 38 – 42 Among MNM Miners Currently Exposed to a Concentration of 100  $\mu\text{g}/\text{m}^3$  of Respirable Crystalline Silica, Staggered to Show Synchronization**

Calendar Year	Cohort 38		Cohort 39		Cohort 40		Cohort 41		Cohort 42	
	Age	$\hat{r}_t^{(38)}$	Age	$\hat{r}_t^{(39)}$	Age	$\hat{r}_t^{(40)}$	Age	$\hat{r}_t^{(41)}$	Age	$\hat{r}_t^{(42)}$
2001	20	0.00000								
2002	21	0.00005	20	0.00000						
2003	22	0.00005	21	0.00005	20	0.00000				
2004	23	0.00005	22	0.00005	21	0.00005	20	0.00000		
2005	24	0.00005	23	0.00005	22	0.00005	21	0.00005	20	0.00000
2006	25	0.00005	24	0.00005	23	0.00005	22	0.00005	21	0.00005
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2022	41	0.00015	40	0.00015	39	0.00015	38	0.00015	37	0.00015
2023	42	0.00015	41	0.00015	40	0.00015	39	0.00015	38	0.00015
2024	43	0.00028	42	0.00015	41	0.00015	40	0.00015	39	0.00015
2025	44	0.00028	43	0.00028	42	0.00015	41	0.00015	40	0.00015
2026	45	0.00028	44	0.00028	43	0.00028	42	0.00015	41	0.00015
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2045	64	0.00036	63	0.00036	62	0.00037	61	0.00037	60	0.00038
2046	65	0.00035	64	0.00036	63	0.00036	62	0.00037	61	0.00037
2047	66	0.00035	65	0.00035	64	0.00036	63	0.00036	62	0.00037
2048	67	0.00034	66	0.00035	65	0.00035	64	0.00036	63	0.00036
2049	68	0.00033	67	0.00034	66	0.00035	65	0.00035	64	0.00036
2050	69	0.00033	68	0.00033	67	0.00034	66	0.00035	65	0.00035
2051	70	0.00032	69	0.00033	68	0.00033	67	0.00034	66	0.00035
2052	71	0.00031	70	0.00032	69	0.00033	68	0.00033	67	0.00034
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2060	79	0.00024	78	0.00025	77	0.00026	76	0.00027	75	0.00028
2061	80	0.00023	79	0.00024	78	0.00025	77	0.00026	76	0.00027
2062			80	0.00023	79	0.00024	78	0.00025	77	0.00026
2063					80	0.00023	79	0.00024	78	0.00025
2064							80	0.00023	79	0.00024
2065									80	0.00023

From Table A - 3, the five silicosis mortality risk columns  $\hat{r}_t^{(38)}$  are identical for the five cohorts because under the existing PEL each cohort would possess the same exposure history.

<sup>42</sup> In some cases, risk reductions are not seen until exposure reductions are accumulated over several years.

Specifically, each cohort would encounter a constant exposure of 100 µg/m<sup>3</sup> during each year of work if the existing PEL remained in effect (assuming full compliance).

Taking the difference between these two tables' risk values (existing PEL and proposed PEL) yields a reduction in silicosis mortality risk of  $\Delta r_t^{(i)} = \tilde{r}_t^{(i)} - r_t^{(i)}$  for each of the five cohorts in a given year  $t$ . These risk reductions are shown in Table A - 4 below at each year of life for the five cohorts.

**Table A - 4. Risk Reductions (Existing PEL – Proposed PEL) by Year for Cohorts 38 – 42**

Calendar Year	Cohort 38		Cohort 39		Cohort 40		Cohort 41		Cohort 42	
	Age	$\Delta d_t^{(38)}$	Age	$\Delta d_t^{(39)}$	Age	$\Delta d_t^{(40)}$	Age	$\Delta d_t^{(41)}$	Age	$\Delta d_t^{(42)}$
2001	20	0.00000								
2002	21	0.00000	20	0.00000						
2003	22	0.00000	21	0.00000	20	0.00000				
2004	23	0.00000	22	0.00000	21	0.00000	20	0.00000		
2005	24	0.00000	23	0.00000	22	0.00000	21	0.00000	20	0.00000
2006	25	0.00000	24	0.00000	23	0.00000	22	0.00000	21	0.00000
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2022	41	0.00000	40	0.00000	39	0.00000	38	0.00000	37	0.00000
2023	42	0.00000	41	0.00000	40	0.00000	39	0.00000	38	0.00000
2024	43	0.00013	42	0.00000	41	0.00000	40	0.00000	39	0.00000
2025	44	0.00013	43	0.00013	42	0.00000	41	0.00000	40	0.00000
2026	45	0.00013	44	0.00013	43	0.00013	42	0.00000	41	0.00000
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2045	64	0.00000	63	0.00012	62	0.00013	61	0.00012	60	0.00013
2046	65	0.00000	64	0.00012	63	0.00012	62	0.00013	61	0.00012
2047	66	0.00000	65	0.00000	64	0.00012	63	0.00012	62	0.00013
2048	67	0.00000	66	0.00000	65	0.00012	64	0.00012	63	0.00012
2049	68	0.00000	67	0.00000	66	0.00012	65	0.00012	64	0.00012
2050	69	0.00000	68	0.00000	67	0.00011	66	0.00012	65	0.00012
2051	70	0.00000	69	0.00000	68	0.00011	67	0.00011	66	0.00012
2052	71	0.00000	70	0.00000	69	0.00011	68	0.00011	67	0.00011
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2060	79	0.00000	78	0.00000	77	0.00009	76	0.00009	75	0.00009
2061	80	0.00000	79	0.00000	78	0.00009	77	0.00009	76	0.00009
2062			80	0.00000	79	0.00008	78	0.00009	77	0.00009
2063					80	0.00008	79	0.00008	78	0.00009
2064							80	0.00008	79	0.00008
2065									80	0.00008

For a single calendar year (*e.g.*, 2045, or Year 22 of implementation), the total reduction in risk is the row sum across the  $\Delta r_t^{(i)}$  columns for the 60 “active” cohorts who are accruing risks in that calendar year. This row sum excludes any cohorts who are not accumulating risks during that year because (a) they already died or (b) they have not yet entered the work force. As we move down the table through successive calendar years, older miner cohorts reach their assumed end of life and cease to contribute to risk reductions, and newer miner cohorts enter the work force with no previous exposure. Assuming a uniform age distribution, 45-year-long

careers, and a constant labor force, older workers are replaced by new workers who are 20 years old.

An example, this row sum can be computed and interpreted just for the five cohorts shown above. Summing the  $\Delta r_t^{(i)}$  values across the row for the calendar year 2045 (in Table A - 4) yields a total reduction in silicosis mortality risk<sup>43</sup> among by summing the five cohorts in the year 2045 of:

$$\sum_{i=38}^{42} \left( \tilde{r}_{t=2045}^{(i)} - r_{t=2045}^{(i)} \right) = 0.00000 + 0.00012 + 0.00013 + 0.00012 + 0.00013 \quad (\text{A} - 1)$$

$$\sum_{i=38}^{42} \left( \tilde{r}_{t=2045}^{(i)} - r_{t=2045}^{(i)} \right) = 0.00050 \quad (\text{A} - 2)$$

This reduction in risk is attributable to the implementation of the proposed PEL but only encompasses five of the 60 cohorts with surviving members during the calendar year 2045. Accordingly, we can extend the summation to include all rows for the 60 active cohorts with surviving members in the year 2045:

$$\sum_{i=22}^{81} \left( \tilde{r}_{t=2045}^{(i)} - r_{t=2045}^{(i)} \right) = 0.0040 \quad (\text{A} - 3)$$

This is the total reduction in risk in the year 2045 across the 60 active cohorts with surviving members in that calendar year. This collection of cohorts corresponds to the 11,769 MNM miners whose exposure decreases from 100  $\mu\text{g}/\text{m}^3$  to 50  $\mu\text{g}/\text{m}^3$  because of the proposed PEL. Among this group, the total cases avoided during the year 2045 can be computed using Eq. A-1 through A-9:

$$c_t = \frac{N}{45} \sum_i \left( \tilde{r}_t^{(i)} - r_t^{(i)} \right) = \frac{11,769}{45} (0.0040) = 1.04 \quad (\text{A} - 4)$$

This results in 1.04 cases of silicosis mortality avoided in the year 2045 among the group of MNM miners experiencing exposure over 100  $\mu\text{g}/\text{m}^3$  but assumed under compliance with the current PEL to be exposed at 100  $\mu\text{g}/\text{m}^3$ . Repeating this calculation for the 21,805 MNM miners who experience exposures between 50-100  $\mu\text{g}/\text{m}^3$  yields an estimate of 0.66 cases avoided in the year 2045. Accordingly, 22 years after promulgation (in year 2045), the proposed PEL would avert  $1.04 + 0.66 = 1.70$  cases of silicosis mortality among all MNM miners, including working miners and retired miners. This estimate accounts for the 60 distinct miner cohorts with surviving members in the year 2045, which have different exposure histories and varying times

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<sup>43</sup> Here,  $t$  represents the implementation year (expressed as either “Year 1” or as a calendar year such as 2024). However,  $t = \text{Year 1}$  does not necessarily correspond to the 1<sup>st</sup> row of each life table. In calendar year  $t = 1$ , the corresponding row of the life table is  $i - t + 1$ , where  $i = 1$  represents the oldest “active” cohort.

under the existing vs. proposed PEL. However, the population of interest (for which benefits are being estimated) is non-retired miners, which make up three-quarters (45/60) of the total population of working and retired miners. Applying this fraction to the preceding estimate gives an average of  $1.70 \times 45/60 = 1.28$  avoided cases of silicosis mortality among working MNM miners 22 years after promulgation. Following this procedure, the number of avoided cases per year was calculated for each health outcome, both among MNM and coal miners.

As a practical matter, however, there is no overriding reason for stopping the benefits analysis at 60 years. MSHA expects that, both in terms of cases prevented, and even regarding monetized benefits, particularly when lower discount rates are used, the estimated benefits of the standard would be noticeably larger on an annualized basis if the analysis extends further into the future. The Agency welcomes comment on the merit of extending the benefits analysis beyond the 60 years analyzed in the PRIA.

To compare costs to benefits, MSHA assumes that economic conditions remain constant and that annualized costs—and the underlying costs—will repeat for the entire 60-year time horizon used for the benefits analysis. MSHA welcomes comments on the assumption for both the benefit and cost analysis that economic conditions remain constant for 60 years. MSHA is particularly interested in what assumptions and time horizons should be used instead and why.

**TECHNICAL APPENDIX B – LIFETIME AVOIDED CASES BY HEALTH  
ENDPOINT AND EXPOSURE INTERVAL ATTRIBUTABLE TO THE  
PROPOSED RESPIRABLE CRYSTALLINE SILICA RULE AMONG COAL  
AND MNM MINERS**

**Table B - 1. Estimates of Lifetime Avoided Cases of Lung Cancer Mortality Among Coal Miners, by Exposure Interval**

	≤ 25 μg/m <sup>3</sup>	> 25 to ≤ 50 μg/m <sup>3</sup>	> 50 to ≤ 85.7 μg/m <sup>3</sup>	> 85.7 to ≤ 100 μg/m <sup>3</sup>	> 100 to ≤ 250 μg/m <sup>3</sup>	> 250 to ≤ 500 μg/m <sup>3</sup>	> 500 μg/m <sup>3</sup>	Total
<b>At-Risk Miner FTEs (with contractors)</b>								
Number	58,951	9,783	2,644	362	906	106	17	<b>72,768</b>
Percent of Total	81.0%	13.4%	3.6%	0.5%	1.2%	0.1%	0.0%	<b>100.0%</b>
<b>Median Annual Cumulative Exposure [a]</b>								
Baseline Scenario [b]	0.0122	0.0329	0.0597	0.0848	0.0848	0.0848	0.0848	
Proposed PEL 50 μg/m <sup>3</sup> Scenario [c]	0.0122	0.0329	0.0495	0.0495	0.0495	0.0495	0.0495	
<b>Average Lifetime Excess Risk (per 1,000 Miners) [d]</b>								
Baseline Scenario	0.71	1.95	3.63	5.28	5.28	5.28	5.28	
Proposed PEL 50 μg/m <sup>3</sup> Scenario	0.71	1.95	2.98	2.98	2.98	2.98	2.98	
<b>Lifetime Excess Cases</b>								
Baseline Scenario	41.8	19.1	9.6	1.9	4.8	0.6	0.1	<b>77.9</b>
Proposed PEL 50 μg/m <sup>3</sup> Scenario	41.8	19.1	7.9	1.1	2.7	0.3	0.0	<b>73.0</b>
<b>Lifetime Excess Cases Avoided by Proposed PEL</b>								<b>4.9</b>

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by production employees and contract miners.

[b] The baseline scenario caps all exposures at 100 μg/m<sup>3</sup> for MNM miners and at 85.7 μg/m<sup>3</sup> for coal miners.

[c] The Proposed PEL 50 μg/m<sup>3</sup> Scenario caps all exposures at 50 μg/m<sup>3</sup> for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

**Table B - 2. Estimates of Lifetime Avoided Cases of Silicosis Mortality Among Coal Miners, by Exposure Interval**

	≤ 25 µg/m <sup>3</sup>	> 25 to ≤ 50 µg/m <sup>3</sup>	> 50 to ≤ 85.7 µg/m <sup>3</sup>	> 85.7 to ≤ 100 µg/m <sup>3</sup>	> 100 to ≤ 250 µg/m <sup>3</sup>	> 250 to ≤ 500 µg/m <sup>3</sup>	> 500 µg/m <sup>3</sup>	Total
<b>At-Risk Miner FTEs (with contractors)</b>								
Number	58,951	9,783	2,644	362	906	106	17	<b>72,768</b>
Percent of Total	81.0%	13.4%	3.6%	0.5%	1.2%	0.1%	0.0%	<b>100.0%</b>
<b>Median Annual Cumulative Exposure [a]</b>								
Baseline Scenario [b]	0.0122	0.0329	0.0597	0.0848	0.0848	0.0848	0.0848	
Proposed PEL 50 µg/m <sup>3</sup> Scenario [c]	0.0122	0.0329	0.04945	0.04945	0.04945	0.04945	0.04945	
<b>Average Lifetime Excess Risk (per 1,000 Miners) [d]</b>								
Baseline Scenario	2.46	5.05	9.35	14.03	14.03	14.03	14.03	
Proposed PEL 50 µg/m <sup>3</sup> Scenario	2.46	5.05	8.09	8.09	8.09	8.09	8.09	
<b>Lifetime Excess Cases</b>								
Baseline Scenario	144.9	49.4	24.7	5.1	12.7	1.5	0.2	<b>238.5</b>
Proposed PEL 50 µg/m <sup>3</sup> Scenario	144.9	49.4	21.4	2.9	7.3	0.9	0.1	<b>227.0</b>
<b>Lifetime Excess Cases Avoided by Proposed PEL</b>								<b>11.6</b>

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by production employees and contract miners.

[b] The baseline scenario caps all exposures at 100 µg/m<sup>3</sup> for MNM miners and at 85.7 µg/m<sup>3</sup> for coal miners.

[c] The Proposed PEL 50 µg/m<sup>3</sup> Scenario caps all exposures at 50 µg/m<sup>3</sup> for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

**Table B - 3. Estimates of Lifetime Avoided Cases of ESRD Mortality Among Coal Miners, by Exposure Interval**

	≤ 25 µg/m <sup>3</sup>	> 25 to ≤ 50 µg/m <sup>3</sup>	> 50 to ≤ 85.7 µg/m <sup>3</sup>	> 85.7 to ≤ 100 µg/m <sup>3</sup>	> 100 to ≤ 250 µg/m <sup>3</sup>	> 250 to ≤ 500 µg/m <sup>3</sup>	> 500 µg/m <sup>3</sup>	Total
<b>At-Risk Miner FTEs (with contractors)</b>								
Number	58,951	9,783	2,644	362	906	106	17	<b>72,768</b>
Percent of Total	81.0%	13.4%	3.6%	0.5%	1.2%	0.1%	0.0%	<b>100.0%</b>
<b>Median Annual Cumulative Exposure [a]</b>								
Baseline Scenario [b]	0.0122	0.0329	0.0597	0.0848	0.0848	0.0848	0.0848	
Proposed PEL 50 µg/m <sup>3</sup> Scenario [c]	0.0122	0.0329	0.0495	0.0495	0.0495	0.0495	0.0495	
<b>Average Lifetime Excess Risk (per 1,000 Miners) [d]</b>								
Baseline Scenario	16.80	23.74	28.84	32.23	32.23	32.23	32.23	
Proposed PEL 50 µg/m <sup>3</sup> Scenario	16.80	23.74	27.14	27.14	27.14	27.14	27.14	
<b>Lifetime Excess Cases</b>								
Baseline Scenario	990.2	232.2	76.3	11.7	29.2	3.4	0.5	<b>1,343.5</b>
Proposed PEL 50 µg/m <sup>3</sup> Scenario	990.2	232.2	71.8	9.8	24.6	2.9	0.4	<b>1,332.0</b>
<b>Lifetime Excess Cases Avoided by Proposed PEL</b>				<b>11.6</b>				

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by production employees and contract miners.

[b] The baseline scenario caps all exposures at 100 µg/m<sup>3</sup> for MNM miners and at 85.7 µg/m<sup>3</sup> for coal miners.

[c] The Proposed PEL 50 µg/m<sup>3</sup> Scenario caps all exposures at 50 µg/m<sup>3</sup> for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).



**Table B - 4. Estimates of Lifetime Avoided Cases of NMRD Mortality Among Coal Miners, by Exposure Interval**

	≤ 25 µg/m <sup>3</sup>	> 25 to ≤ 50 µg/m <sup>3</sup>	> 50 to ≤ 85.7 µg/m <sup>3</sup>	> 85.7 to ≤ 100 µg/m <sup>3</sup>	> 100 to ≤ 250 µg/m <sup>3</sup>	> 250 to ≤ 500 µg/m <sup>3</sup>	> 500 µg/m <sup>3</sup>	Total
<b>At-Risk Miner FTEs (with contractors)</b>								
Number	58,951	9,783	2,644	362	906	106	17	<b>72,768</b>
Percent of Total	81.0%	13.4%	3.6%	0.5%	1.2%	0.1%	0.0%	<b>100.0%</b>
<b>Median Annual Cumulative Exposure [a]</b>								
Baseline Scenario [b]	0.0122	0.0329	0.0597	0.0848	0.0848	0.0848	0.0848	
Proposed PEL 50 µg/m <sup>3</sup> Scenario [c]	0.0122	0.0329	0.0495	0.0495	0.0495	0.0495	0.0495	
<b>Average Lifetime Excess Risk (per 1,000 Miners) [d]</b>								
Baseline Scenario	7.87	21.07	37.81	53.10	53.10	53.10	53.10	
Proposed PEL 50 µg/m <sup>3</sup> Scenario	7.87	21.07	31.45	31.45	31.45	31.45	31.45	
<b>Lifetime Excess Cases</b>								
Baseline Scenario	464.0	206.1	100.0	19.2	48.1	5.6	0.9	<b>844.0</b>
Proposed PEL 50 µg/m <sup>3</sup> Scenario	464.0	206.1	83.2	11.4	28.5	3.3	0.5	<b>797.1</b>
<b>Lifetime Excess Cases Avoided by Proposed PEL</b>								<b>46.9</b>

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by production employees and contract miners.

[b] The baseline scenario caps all exposures at 100 µg/m<sup>3</sup> for MNM miners and at 85.7 µg/m<sup>3</sup> for coal miners.

[c] The Proposed PEL 50 µg/m<sup>3</sup> Scenario caps all exposures at 50 µg/m<sup>3</sup> for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

**Table B - 5 Estimates of Lifetime Avoided Cases of Silicosis Morbidity Among Coal Miners, by Exposure Interval**

	≤ 25 µg/m <sup>3</sup>	> 25 to ≤ 50 µg/m <sup>3</sup>	> 50 to ≤ 85.7 µg/m <sup>3</sup>	> 85.7 to ≤ 100 µg/m <sup>3</sup>	> 100 to ≤ 250 µg/m <sup>3</sup>	> 250 to ≤ 500 µg/m <sup>3</sup>	> 500 µg/m <sup>3</sup>	Total
<b>At-Risk Miner FTEs (with contractors)</b>								
Number	58,951	9,783	2,644	362	906	106	17	<b>72,768</b>
Percent of Total	81.0%	13.4%	3.6%	0.5%	1.2%	0.1%	0.0%	<b>100.0%</b>
<b>Median Annual Cumulative Exposure [a]</b>								
Baseline Scenario [b]	0.0122	0.0329	0.0597	0.0848	0.0848	0.0848	0.0848	
Proposed PEL 50 µg/m <sup>3</sup> Scenario [c]	0.0122	0.0329	0.0495	0.0495	0.0495	0.0495	0.0495	
<b>Average Lifetime Excess Risk (per 1,000 Miners) [d]</b>								
Baseline Scenario	12.82	28.79	79.46	189.90	189.90	189.90	189.90	
Proposed PEL 50 µg/m <sup>3</sup> Scenario	12.82	28.79	54.25	54.25	54.25	54.25	54.25	
<b>Lifetime Excess Cases</b>								
Baseline Scenario	755.5	281.7	210.1	68.8	172.1	20.1	3.1	<b>1,511.4</b>
Proposed PEL 50 µg/m <sup>3</sup> Scenario	755.5	281.7	143.4	19.7	49.2	5.7	0.9	<b>1,256.0</b>
<b>Lifetime Excess Cases Avoided by Proposed PEL</b>				<b>255.3</b>				

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by production employees and contract miners.

[b] The baseline scenario caps all exposures at 100 µg/m<sup>3</sup> for MNM miners and at 85.7 µg/m<sup>3</sup> for coal miners.

[c] The Proposed PEL 50 µg/m<sup>3</sup> Scenario caps all exposures at 50 µg/m<sup>3</sup> for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

**Table B - 6 Estimates of Lifetime Avoided Cases of Lung Cancer Mortality Among MNM Miners, by Exposure Interval**

	≤ 25 µg/m <sup>3</sup>	> 25 to ≤ 50 µg/m <sup>3</sup>	> 50 to ≤ 100 µg/m <sup>3</sup>	> 100 to ≤ 250 µg/m <sup>3</sup>	> 250 to ≤ 500 µg/m <sup>3</sup>	> 500 µg/m <sup>3</sup>	Total
<b>At-Risk Miner FTEs (with contractors)</b>							
Number	118,672	32,369	21,805	9,185	1,825	759	<b>184,615</b>
Percent of Total	64.3%	17.5%	11.8%	5.0%	1.0%	0.4%	<b>100.0%</b>
<b>Median Annual Cumulative Exposure [a]</b>							
Baseline Scenario [b]	0.0061	0.0306	0.0603	0.0874	0.0874	0.0874	
Proposed PEL 50 µg/m <sup>3</sup> Scenario [c]	0.0061	0.0306	0.0437	0.0437	0.0437	0.0437	
<b>Average Lifetime Excess Risk (per 1,000 Miners) [d]</b>							
Baseline Scenario	0.35	1.81	3.67	5.46	5.46	5.46	
Proposed PEL 50 µg/m <sup>3</sup> Scenario	0.35	1.81	2.62	2.62	2.62	2.62	
<b>Lifetime Excess Cases</b>							
Baseline Scenario	42.1	58.7	80.1	50.1	10.0	4.1	<b>245.1</b>
Proposed PEL 50 µg/m <sup>3</sup> Scenario	42.1	58.7	57.2	24.1	4.8	2.0	<b>188.8</b>
<b>Lifetime Excess Cases Avoided by Proposed PEL</b>							<b>56.3</b>

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by production employees and contract miners.

[b] The baseline scenario caps all exposures at 100 µg/m<sup>3</sup> for MNM miners and at 85.7 µg/m<sup>3</sup> for coal miners.

[c] The Proposed PEL 50 µg/m<sup>3</sup> Scenario caps all exposures at 50 µg/m<sup>3</sup> for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

**Table B - 7 Estimates of Lifetime Avoided Cases of Silicosis Mortality Among MNM Miners, by Exposure Interval**

	≤ 25 µg/m <sup>3</sup>	> 25 to ≤ 50 µg/m <sup>3</sup>	> 50 to ≤ 100 µg/m <sup>3</sup>	> 100 to ≤ 250 µg/m <sup>3</sup>	> 250 to ≤ 500 µg/m <sup>3</sup>	> 500 µg/m <sup>3</sup>	Total
<b>At-Risk Miner FTEs (with contractors)</b>							
Number	118,672	32,369	21,805	9,185	1,825	759	<b>184,615</b>
Percent of Total	64.3%	17.5%	11.8%	5.0%	1.0%	0.4%	<b>100.0%</b>
<b>Median Annual Cumulative Exposure [a]</b>							
Baseline Scenario [b]	0.0061	0.0306	0.0603	0.0874	0.0874	0.0874	
Proposed PEL 50 µg/m <sup>3</sup> Scenario [c]	0.0061	0.0306	0.0437	0.0437	0.0437	0.0437	
<b>Average Lifetime Excess Risk (per 1,000 Miners) [d]</b>							
Baseline Scenario	2.46	4.84	9.35	14.29	14.29	14.29	
Proposed PEL 50 µg/m <sup>3</sup> Scenario	2.46	4.84	5.89	5.89	5.89	5.89	
<b>Lifetime Excess Cases</b>							
Baseline Scenario	291.7	156.7	203.9	131.3	26.1	10.9	<b>820.6</b>
Proposed PEL 50 µg/m <sup>3</sup> Scenario	291.7	156.7	128.4	54.1	10.8	4.5	<b>646.2</b>
<b>Lifetime Excess Cases Avoided by Proposed PEL</b>							<b>174.4</b>

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by production employees and contract miners.

[b] The baseline scenario caps all exposures at 100 µg/m<sup>3</sup> for MNM miners and at 85.7 µg/m<sup>3</sup> for coal miners.

[c] The Proposed PEL 50 µg/m<sup>3</sup> Scenario caps all exposures at 50 µg/m<sup>3</sup> for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

**Table B - 8 Estimates of Lifetime Avoided Cases of NMRD Mortality Among MNM Miners, by Exposure Interval**

	≤ 25 µg/m <sup>3</sup>	> 25 to ≤ 50 µg/m <sup>3</sup>	> 50 to ≤ 100 µg/m <sup>3</sup>	> 100 to ≤ 250 µg/m <sup>3</sup>	> 250 to ≤ 500 µg/m <sup>3</sup>	> 500 µg/m <sup>3</sup>	Total
<b>At-Risk Miner FTEs (with contractors)</b>							
Number	118,672	32,369	21,805	9,185	1,825	759	<b>184,615</b>
Percent of Total	64.3%	17.5%	11.8%	5.0%	1.0%	0.4%	<b>100.0%</b>
<b>Median Annual Cumulative Exposure [a]</b>							
Baseline Scenario [b]	0.0061	0.0306	0.0603	0.0874	0.0874	0.0874	
Proposed PEL 50 µg/m <sup>3</sup> Scenario [c]	0.0061	0.0306	0.0437	0.0437	0.0437	0.0437	
<b>Average Lifetime Excess Risk (per 1,000 Miners) [d]</b>							
Baseline Scenario	3.96	19.62	38.18	54.70	54.70	54.70	
Proposed PEL 50 µg/m <sup>3</sup> Scenario	3.96	19.62	27.87	27.87	27.87	27.87	
<b>Lifetime Excess Cases</b>							
Baseline Scenario	470.0	634.9	832.6	502.4	99.9	41.5	<b>2,581.3</b>
Proposed PEL 50 µg/m <sup>3</sup> Scenario	470.0	634.9	607.6	255.9	50.9	21.2	<b>2,040.5</b>
<b>Lifetime Excess Cases Avoided by Proposed PEL</b>							<b>540.8</b>

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by production employees and contract miners.

[b] The baseline scenario caps all exposures at 100 µg/m<sup>3</sup> for MNM miners and at 85.7 µg/m<sup>3</sup> for coal miners.

[c] The Proposed PEL 50 µg/m<sup>3</sup> Scenario caps all exposures at 50 µg/m<sup>3</sup> for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

**Table B - 9 Estimates of Lifetime Avoided Cases of ESRD Mortality Among MNM Miners, by Exposure Interval**

	≤ 25 µg/m <sup>3</sup>	> 25 to ≤ 50 µg/m <sup>3</sup>	> 50 to ≤ 100 µg/m <sup>3</sup>	> 100 to ≤ 250 µg/m <sup>3</sup>	> 250 to ≤ 500 µg/m <sup>3</sup>	> 500 µg/m <sup>3</sup>	Total
<b>At-Risk Miner FTEs (with contractors)</b>							
Number	118,672	32,369	21,805	9,185	1,825	759	<b>184,615</b>
Percent of Total	64.3%	17.5%	11.8%	5.0%	1.0%	0.4%	<b>100.0%</b>
<b>Median Annual Cumulative Exposure [a]</b>							
Baseline Scenario [b]	0.0061	0.0306	0.0603	0.0874	0.0874	0.0874	
Proposed PEL 50 µg/m <sup>3</sup> Scenario [c]	0.0061	0.0306	0.0437	0.0437	0.0437	0.0437	
<b>Average Lifetime Excess Risk (per 1,000 Miners) [d]</b>							
Baseline Scenario	12.94	23.17	28.94	32.54	32.54	32.54	
Proposed PEL 50 µg/m <sup>3</sup> Scenario	12.94	23.17	26.07	26.07	26.07	26.07	
<b>Lifetime Excess Cases</b>							
Baseline Scenario	1,535.3	749.9	631.0	298.9	59.4	24.7	<b>3,299.3</b>
Proposed PEL 50 µg/m <sup>3</sup> Scenario	1,535.3	749.9	568.6	239.5	47.6	19.8	<b>3,160.7</b>
<b>Lifetime Excess Cases Avoided by Proposed PEL</b>							<b>138.6</b>

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hrs worked by production employees and contract miners.

[b] The baseline scenario caps all exposures at 100 µg/m<sup>3</sup> for MNM miners and at 85.7 µg/m<sup>3</sup> for coal miners.

[c] The Proposed PEL 50 µg/m<sup>3</sup> Scenario caps all exposures at 50 µg/m<sup>3</sup> for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

**Table B - 10 Estimates of Lifetime Avoided Cases of Silicosis Morbidity Among MNM Miners, by Exposure Interval**

	≤ 25 µg/m <sup>3</sup>	> 25 to ≤ 50 µg/m <sup>3</sup>	> 50 to ≤ 100 µg/m <sup>3</sup>	> 100 to ≤ 250 µg/m <sup>3</sup>	> 250 to ≤ 500 µg/m <sup>3</sup>	> 500 µg/m <sup>3</sup>	Total
<b>At-Risk Miner FTEs (with contractors)</b>							
Number	118,672	32,369	21,805	9,185	1,825	759	<b>184,615</b>
Percent of Total	64.3%	17.5%	11.8%	5.0%	1.0%	0.4%	<b>100.0%</b>
<b>Median Annual Cumulative Exposure [a]</b>							
Baseline Scenario [b]	0.0061	0.0306	0.0603	0.0874	0.0874	0.0874	
Proposed PEL 50 µg/m <sup>3</sup> Scenario [c]	0.0061	0.0306	0.0437	0.0437	0.0437	0.0437	
<b>Average Lifetime Excess Risk (per 1,000 Miners) [d]</b>							
Baseline Scenario	10.09	26.33	81.26	206.70	206.70	206.70	
Proposed PEL 50 µg/m <sup>3</sup> Scenario	10.09	26.33	43.63	43.63	43.63	43.63	
<b>Lifetime Excess Cases</b>							
Baseline Scenario	1,197.4	852.4	1,772.0	1,898.5	377.3	157.0	<b>6,254.6</b>
Proposed PEL 50 µg/m <sup>3</sup> Scenario	1,197.4	852.4	951.3	400.7	79.6	33.1	<b>3,514.6</b>
<b>Lifetime Excess Cases Avoided by Proposed PEL</b>							<b>2,740.0</b>

Notes:

[a] Median annual cumulative exposure was calculated by multiplying the median exposure (for the given exposure interval) by the time duration of (1 year)x(FTE ratio), where the FTE ratio is 0.87 for MNM miners and 0.99 for coal miners. These FTE ratios account for the average fraction of 2,000 hours worked by production employees and contract miners.

[b] The baseline scenario caps all exposures at 100 µg/m<sup>3</sup> for MNM miners and at 85.7 µg/m<sup>3</sup> for coal miners.

[c] The Proposed PEL 50 µg/m<sup>3</sup> Scenario caps all exposures at 50 µg/m<sup>3</sup> for both MNM and coal miners.

[d] Lifetime values refer to the cumulative total over a maximum lifetime of 80 years, which includes 45 years spent mining and 15 years of retirement. Excess values refer to the difference when comparing miners (exposed to respirable crystalline silica) to non-miners (who are not exposed to respirable crystalline silica).

**TECHNICAL APPENDIX C – 60-YEAR PROJECTED VALUE OF AVOIDED  
MORBIDITY AND MORTALITY, COMPLIANCE COSTS, AND NET BENEFITS  
ATTRIBUTABLE TO THE PROPOSED RESPIRABLE CRYSTALLINE SILICA  
RULE AMONG COAL AND MNM MINERS**



**Table C-1. Stream of Benefits over 60 Years Post Rule Promulgation for a PEL of 50 µg/m3 Accounting for Income Growth**

Year After Rule Promulgation	Value of Avoided Cases by Year (MNM and Coal Combined) Undiscounted in Millions 2021 \$			
	Avoided Mortality	Avoided Morbidity (Preceding Mortality)	Avoided Morbidity	Total
1	\$0.94	\$0.24	\$2.40	\$3.58
2	\$2.01	\$0.50	\$4.78	\$7.29
3	\$3.51	\$0.86	\$7.07	\$11.44
4	\$4.17	\$1.01	\$9.59	\$14.76
5	\$5.73	\$1.37	\$11.88	\$18.97
6	\$7.19	\$1.68	\$14.25	\$23.12
7	\$9.00	\$2.07	\$16.67	\$27.74
8	\$11.10	\$2.51	\$19.18	\$32.79
9	\$13.45	\$2.99	\$21.47	\$37.91
10	\$16.05	\$3.51	\$23.86	\$43.41
11	\$19.02	\$4.08	\$26.29	\$49.39
12	\$22.36	\$4.72	\$28.79	\$55.87
13	\$26.07	\$5.41	\$31.08	\$62.56
14	\$30.16	\$6.14	\$33.48	\$69.78
15	\$34.63	\$6.93	\$35.90	\$77.45
16	\$40.09	\$7.89	\$38.28	\$86.26
17	\$45.74	\$8.85	\$40.60	\$95.18
18	\$51.57	\$9.80	\$43.09	\$104.46
19	\$57.58	\$10.76	\$45.53	\$113.87
20	\$63.80	\$11.71	\$47.89	\$123.40
21	\$70.21	\$12.67	\$50.22	\$133.09
22	\$76.82	\$13.62	\$52.73	\$143.17
23	\$83.64	\$14.58	\$55.18	\$153.40
24	\$90.68	\$15.53	\$57.62	\$163.83
25	\$97.94	\$16.49	\$60.06	\$174.48
26	\$105.41	\$17.44	\$62.57	\$185.42
27	\$113.11	\$18.39	\$64.89	\$196.38
28	\$121.03	\$19.34	\$67.40	\$207.78
29	\$129.19	\$20.29	\$69.84	\$219.32
30	\$137.59	\$21.24	\$72.35	\$231.18
31	\$146.22	\$22.18	\$74.66	\$243.06
32	\$155.09	\$23.12	\$77.19	\$255.39
33	\$164.19	\$24.06	\$79.64	\$267.89
34	\$173.54	\$24.99	\$82.04	\$280.57

Year After Rule Promulgation	Value of Avoided Cases by Year (MNM and Coal Combined) Undiscounted in Millions 2021 \$			
	Avoided Mortality	Avoided Morbidity (Preceding Mortality)	Avoided Morbidity	Total
35	\$183.15	\$25.92	\$84.48	<b>\$293.55</b>
36	\$192.96	\$26.84	\$87.01	<b>\$306.81</b>
37	\$202.99	\$27.75	\$89.47	<b>\$320.21</b>
38	\$213.24	\$28.65	\$91.88	<b>\$333.77</b>
39	\$223.72	\$29.54	\$94.35	<b>\$347.61</b>
40	\$234.43	\$30.42	\$96.89	<b>\$361.74</b>
41	\$245.29	\$31.28	\$99.42	<b>\$375.99</b>
42	\$256.30	\$32.13	\$101.88	<b>\$390.31</b>
43	\$267.47	\$32.95	\$104.41	<b>\$404.84</b>
44	\$278.81	\$33.75	\$107.01	<b>\$419.57</b>
45	\$290.30	\$34.54	\$109.42	<b>\$434.26</b>
46	\$301.84	\$35.30	\$111.83	<b>\$448.97</b>
47	\$313.44	\$36.02	\$114.24	<b>\$463.70</b>
48	\$325.08	\$36.72	\$116.66	<b>\$478.46</b>
49	\$336.77	\$37.39	\$119.08	<b>\$493.24</b>
50	\$348.51	\$38.02	\$121.51	<b>\$508.05</b>
51	\$360.10	\$38.61	\$123.94	<b>\$522.65</b>
52	\$371.53	\$39.15	\$126.37	<b>\$537.06</b>
53	\$382.80	\$39.65	\$128.81	<b>\$551.26</b>
54	\$393.91	\$40.10	\$131.26	<b>\$565.26</b>
55	\$404.86	\$40.50	\$133.70	<b>\$579.06</b>
56	\$415.35	\$40.84	\$136.16	<b>\$592.34</b>
57	\$425.39	\$41.10	\$138.62	<b>\$605.11</b>
58	\$434.99	\$41.31	\$141.08	<b>\$617.38</b>
59	\$444.14	\$41.45	\$143.55	<b>\$629.15</b>
60	\$452.86	\$41.54	\$146.03	<b>\$640.42</b>
<b>0% Discount Rate</b>				
PV	\$10,429.06	\$1,278.44	\$4,427.50	\$16,135.00
Annualized	<b>\$173.82</b>	<b>\$21.31</b>	<b>\$73.79</b>	<b>\$268.92</b>
<b>3% Discount Rate</b>				
PV	\$2,988.77	\$400.50	\$1,473.49	\$4,862.76
Annualized	<b>\$107.99</b>	<b>\$14.47</b>	<b>\$53.24</b>	<b>\$175.71</b>
<b>7% Discount Rate</b>				
PV	\$754.92	\$115.33	\$480.22	\$1,350.46
Annualized	<b>\$53.77</b>	<b>\$8.21</b>	<b>\$34.21</b>	<b>\$96.19</b>

**Table C-2. Projected Stream of Compliance Costs over 60 Years Post Rule Promulgation**

Years After Rule Promulgation	Total Compliance Costs by Year (MNM and Coal Combined) Undiscounted in Millions of 2021 \$					
	Exposure Monitoring	Exposure Controls	Respiratory Protection	Medical Surveillance	ASTM Update	Total
1	\$61.7	\$12.2	\$1.1	\$15.3	\$4.2	\$94.4
2	\$49.7	\$5.1	\$1.0	\$14.8	\$1.0	\$71.6
3	\$44.7	\$5.1	\$1.0	\$14.3	\$1.0	\$66.1
4	\$39.6	\$5.1	\$1.0	\$18.7	\$1.0	\$65.5
5	\$34.6	\$5.1	\$1.0	\$18.2	\$1.0	\$59.9
6	\$29.5	\$5.3	\$1.0	\$18.0	\$1.0	\$54.9
7	\$29.5	\$5.1	\$1.0	\$17.5	\$1.0	\$54.2
8	\$29.5	\$5.1	\$1.0	\$17.0	\$1.0	\$53.7
9	\$29.5	\$5.1	\$1.0	\$18.8	\$1.0	\$55.5
10	\$29.5	\$5.1	\$1.0	\$18.3	\$1.0	\$55.0
11	\$29.5	\$8.7	\$1.1	\$18.0	\$4.2	\$61.5
12	\$29.5	\$5.1	\$1.0	\$17.5	\$1.0	\$54.1
13	\$29.5	\$5.1	\$1.0	\$17.0	\$1.0	\$53.7
14	\$29.5	\$5.1	\$1.0	\$18.8	\$1.0	\$55.5
15	\$29.5	\$5.1	\$1.0	\$18.3	\$1.0	\$55.0
16	\$29.5	\$7.0	\$1.0	\$18.0	\$1.0	\$56.6
17	\$29.5	\$5.1	\$1.0	\$17.5	\$1.0	\$54.2
18	\$29.5	\$5.1	\$1.0	\$17.0	\$1.0	\$53.7
19	\$29.5	\$5.1	\$1.0	\$18.8	\$1.0	\$55.5
20	\$29.5	\$5.1	\$1.0	\$18.3	\$1.0	\$55.0
21	\$29.5	\$8.7	\$1.1	\$15.3	\$4.2	\$58.8
22	\$29.5	\$5.1	\$1.0	\$14.8	\$1.0	\$51.4
23	\$29.5	\$5.1	\$1.0	\$14.3	\$1.0	\$51.0
24	\$29.5	\$5.1	\$1.0	\$18.7	\$1.0	\$55.4
25	\$29.5	\$5.1	\$1.0	\$18.2	\$1.0	\$54.9
26	\$29.5	\$5.3	\$1.0	\$18.0	\$1.0	\$54.9
27	\$29.5	\$5.1	\$1.0	\$17.5	\$1.0	\$54.2
28	\$29.5	\$5.1	\$1.0	\$17.0	\$1.0	\$53.7
29	\$29.5	\$5.1	\$1.0	\$18.8	\$1.0	\$55.5
30	\$29.5	\$5.1	\$1.0	\$18.3	\$1.0	\$55.0
31	\$29.5	\$12.2	\$1.1	\$18.0	\$4.2	\$65.0
32	\$29.5	\$5.1	\$1.0	\$17.5	\$1.0	\$54.1
33	\$29.5	\$5.1	\$1.0	\$17.0	\$1.0	\$53.7
34	\$29.5	\$5.1	\$1.0	\$18.8	\$1.0	\$55.5
35	\$29.5	\$5.1	\$1.0	\$18.3	\$1.0	\$55.0
36	\$29.5	\$5.3	\$1.0	\$18.0	\$1.0	\$54.9
37	\$29.5	\$5.1	\$1.0	\$17.5	\$1.0	\$54.2
38	\$29.5	\$5.1	\$1.0	\$17.0	\$1.0	\$53.7
39	\$29.5	\$5.1	\$1.0	\$18.8	\$1.0	\$55.5
40	\$29.5	\$5.1	\$1.0	\$18.3	\$1.0	\$55.0
41	\$29.5	\$8.7	\$1.1	\$15.3	\$4.2	\$58.8
42	\$29.5	\$5.1	\$1.0	\$14.8	\$1.0	\$51.4
43	\$29.5	\$5.1	\$1.0	\$14.3	\$1.0	\$51.0
44	\$29.5	\$5.1	\$1.0	\$18.7	\$1.0	\$55.4
45	\$29.5	\$5.1	\$1.0	\$18.2	\$1.0	\$54.9

Years After Rule Promulgation	Total Compliance Costs by Year (MNM and Coal Combined) Undiscounted in Millions of 2021 \$					
	Exposure Monitoring	Exposure Controls	Respiratory Protection	Medical Surveillance	ASTM Update	Total
46	\$29.5	\$7.0	\$1.0	\$18.0	\$1.0	\$56.6
47	\$29.5	\$5.1	\$1.0	\$17.5	\$1.0	\$54.2
48	\$29.5	\$5.1	\$1.0	\$17.0	\$1.0	\$53.7
49	\$29.5	\$5.1	\$1.0	\$18.8	\$1.0	\$55.5
50	\$29.5	\$5.1	\$1.0	\$18.3	\$1.0	\$55.0
51	\$29.5	\$8.7	\$1.1	\$18.0	\$4.2	\$61.5
52	\$29.5	\$5.1	\$1.0	\$17.5	\$1.0	\$54.1
53	\$29.5	\$5.1	\$1.0	\$17.0	\$1.0	\$53.7
54	\$29.5	\$5.1	\$1.0	\$18.8	\$1.0	\$55.5
55	\$29.5	\$5.1	\$1.0	\$18.3	\$1.0	\$55.0
56	\$29.5	\$5.3	\$1.0	\$18.0	\$1.0	\$54.9
57	\$29.5	\$5.1	\$1.0	\$17.5	\$1.0	\$54.2
58	\$29.5	\$5.1	\$1.0	\$17.0	\$1.0	\$53.7
59	\$29.5	\$5.1	\$1.0	\$18.8	\$1.0	\$55.5
60	\$29.5	\$5.1	\$1.0	\$18.3	\$1.0	\$55.0
<b>0% Discount Rate</b>						
PV	\$1,855	\$339	\$62	\$1,050	\$81	\$3,387
Annualized	\$30.9	\$5.6	\$1.0	\$17.5	\$1.4	\$56.4
<b>3% Discount Rate</b>						
PV	\$895	\$159	\$29	\$481	\$39	\$1,602
Annualized	\$32.3	\$5.7	\$1.0	\$17.4	\$1.4	\$57.9
<b>7% Discount Rate</b>						
PV	\$486	\$83	\$14	\$241	\$21	\$845
Annualized	\$34.6	\$5.9	\$1.0	\$17.2	\$1.5	\$60.2

**Table C-3. Projected Stream of Net Benefits over 60 Years Post Rule Promulgation**

Years After Rule Promulgation	Value of Avoided Cases Net of Costs by Year MNM and Coal Combined Undiscounted in Millions of 2021 \$		
	Value of Total Cases Averted by Year	Total Compliance Costs by Year	Net Value of Total Cases Averted by Year
1	\$3.58	\$94.4	-\$90.83
2	\$7.29	\$71.6	-\$64.31
3	\$11.44	\$66.1	-\$54.65
4	\$14.76	\$65.5	-\$50.69
5	\$18.97	\$59.9	-\$40.98
6	\$23.12	\$54.9	-\$31.77
7	\$27.74	\$54.2	-\$26.43
8	\$32.79	\$53.7	-\$20.86
9	\$37.91	\$55.5	-\$17.62
10	\$43.41	\$55.0	-\$11.59
11	\$49.39	\$61.5	-\$12.13
12	\$55.87	\$54.1	\$1.72
13	\$62.56	\$53.7	\$8.88
14	\$69.78	\$55.5	\$14.28
15	\$77.45	\$55.0	\$22.42
16	\$86.26	\$56.6	\$29.65
17	\$95.18	\$54.2	\$41.01
18	\$104.46	\$53.7	\$50.80
19	\$113.87	\$55.5	\$58.34
20	\$123.40	\$55.0	\$68.39
21	\$133.09	\$58.8	\$74.27
22	\$143.17	\$51.4	\$91.73
23	\$153.40	\$51.0	\$102.42
24	\$163.83	\$55.4	\$108.45
25	\$174.48	\$54.9	\$119.57
26	\$185.42	\$54.9	\$130.53
27	\$196.38	\$54.2	\$142.21
28	\$207.78	\$53.7	\$154.12
29	\$219.32	\$55.5	\$163.80
30	\$231.18	\$55.0	\$176.17
31	\$243.06	\$65.0	\$178.07
32	\$255.39	\$54.1	\$201.25
33	\$267.89	\$53.7	\$214.21
34	\$280.57	\$55.5	\$225.07
35	\$293.55	\$55.0	\$238.51

Years After Rule Promulgation	Value of Avoided Cases Net of Costs by Year MNM and Coal Combined Undiscounted in Millions of 2021 \$		
	Value of Total Cases Averted by Year	Total Compliance Costs by Year	Net Value of Total Cases Averted by Year
36	\$306.81	\$54.9	\$251.92
37	\$320.21	\$54.2	\$266.04
38	\$333.77	\$53.7	\$280.12
39	\$347.61	\$55.5	\$292.09
40	\$361.74	\$55.0	\$306.73
41	\$375.99	\$58.8	\$317.17
42	\$390.31	\$51.4	\$338.87
43	\$404.84	\$51.0	\$353.86
44	\$419.57	\$55.4	\$364.19
45	\$434.26	\$54.9	\$379.35
46	\$448.97	\$56.6	\$392.36
47	\$463.70	\$54.2	\$409.53
48	\$478.46	\$53.7	\$424.81
49	\$493.24	\$55.5	\$437.72
50	\$508.05	\$55.0	\$453.04
51	\$522.65	\$61.5	\$461.13
52	\$537.06	\$54.1	\$482.91
53	\$551.26	\$53.7	\$497.58
54	\$565.26	\$55.5	\$509.76
55	\$579.06	\$55.0	\$524.03
56	\$592.34	\$54.9	\$537.45
57	\$605.11	\$54.2	\$550.94
58	\$617.38	\$53.7	\$563.72
59	\$629.15	\$55.5	\$573.62
60	\$640.42	\$55.0	\$585.41
<b>0% Discount Rate</b>			
PV	\$16,135	\$3,387	\$12,748
Annualized	<b>\$268.9</b>	<b>\$56.4</b>	<b>\$212.5</b>
<b>3% Discount Rate</b>			
PV	\$4,863	\$1,602	\$3,261
Annualized	<b>\$175.7</b>	<b>\$57.9</b>	<b>\$117.8</b>
<b>7% Discount Rate</b>			
PV	\$1,350	\$845	\$505
Annualized	<b>\$96.2</b>	<b>\$60.2</b>	<b>\$36.0</b>