Published in final edited form as:
Am J Ind Med. 2020 March ; 63(3): 232–239. doi:10.1002/ajim.23074.

Respirable coal mine dust at surface mines, United States, 1982–2017

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Abstract

Background: Exposure to respirable coal mine dust can cause pneumoconiosis, an irreversible lung disease that can be debilitating. The mass concentration and quartz mass percent of respirable coal mine dust samples (annually, by occupation, by geographic region) from surface coal mines and surface facilities at U.S. underground mines during 1982–2017 were summarized.

Methods: Mine Safety and Health Administration (MSHA) collected and analyzed data for respirable dust and a subset of the samples were analyzed for quartz content. We calculated the respirable dust and quartz concentration geometric mean, arithmetic mean, and percent of samples exceeding the respirable dust permissible exposure limit (PEL) of 2.0 mg/m3, and the average percent of quartz content in samples.

Results: The geometric mean for 288 705 respirable dust samples was 0.17 mg/m^3 with 1.6% of the samples exceeding the 2.0 mg/m^3 PEL. Occupation-specific geometric means for respirable dust in active mining areas were highest among drillers. The geometric mean for respirable dust was higher in central Appalachia compared to the rest of the U.S. The geometric mean for respirable quartz including 54 040 samples was 0.02 mg/m^3 with 15.3% of these samples exceeding the applicable standard (PEL or reduced PEL). Occupation-specific geometric means for respirable quartz were highest among drillers.

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AUTHOR CONTRIBUTIONS

BCD, DB, JMH, CH, LK, and ASL participated in the conception or design of the work; participated in the acquisition, analysis, or interpretation of data for the work; drafted the work and revised it critically for important intellectual content. All authors provided the final approval of this article to be published and agreement to be accountable for all aspects of the work.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

ETHICS APPROVAL AND INFORMED CONSENT

Data was collected for compliance purposes and is di-identified and publicly available. No reviews and approvals needed.

Conclusion: Higher concentrations of respirable dust or quartz in specific coal mining occupations, notably drilling occupations, and in certain U.S. regions, underscores the need for continued surveillance to identify workers at higher risk for pneumoconiosis.

Keywords

Coal mine dust; MSHA; occupational groups; quartz

1 | INTRODUCTION

The prevalence and severity of pneumoconiosis in U.S. coal miners have steadily increased in the last two decades.[1] Prevalence of the most severe and debilitating form, progressive massive fibrosis (PMF), has reached unprecedented levels,[2–4] as have the associated consequences including increased lung transplantation[1,5] and a higher percentage of federal Black Lung benefits claims awarded.[6] A recent study identified a cluster of 416 cases of PMF, primarily among former miners from Virginia or Kentucky, and 10% of these cases were in surface miners.[4] Although the prevalence varies by region and by state, pneumoconiosis has been observed among contemporary coal miners in each state where coal is mined, including miners who work at underground and surface operations.[7–9]

To better inform our understanding of the pneumoconiosis trends in the U.S., we recently summarized the annual mass concentration and quartz mass concentration of respirable dust samples collected during 1982–2017 for compliance purposes in underground coal mines by Mine Safety and Health Administration (MSHA) inspectors.[10] The primary findings demonstrated that the mean percent quartz content in Appalachian underground coal mines consistently exceeded 5% and nearly one-third of U.S. coal mines had a least one section placed on a reduced standard. Our initial focus was to summarize the exposures of underground miners because the majority of coal mine dust-related respiratory health research has focused on underground miners. However, pneumoconiosis and other occupational respiratory diseases also occur in surface coal miners, which is noteworthy given current differences between the surface and underground coal mining industries in the United States. In 2017, surface operations produced 500 million short tons of coal, compared with 271 million from underground mines; there were twice as many surface mines than underground mines, and surface operations employed 17 800 more miners than underground operations (29 000 underground miners).[11]

Investigations in the 1980s[12–14] identified pneumoconiosis with radiographic characteristics of silicosis among drillers at surface coal mines and analysis of inspector dust samples collected at surface coal mines identified drilling occupations as having the highest quartz exposures.[15,16] More than two decades later, severe pneumoconiosis continued to be identified among surface coal miners, with evidence suggesting drillers continued to be at highest risk.[4,7,8]

We are unaware of any recent scientific study summarizing the results of air samples collected during inspections at U.S. surface coal mines. In light of the long-recognized hazard of silica and other hazardous dust exposures in surface coal miners, we analyzed 36 years of MSHA inspector-collected respirable dust and quartz (crystalline silica) surface coal mine data to describe trends over time, by occupation, and by region. These data can be used to inform public health decision-making.

2 | METHODS

2.1 | Permissible exposure limits

In 1972, the MSHA permissible exposure limit (PEL) for respirable dust was reduced to 2.0 mg/m^3.[17] However, when the quartz content of the respirable dust sample exceeds 5% in an average of multiple samples, the PEL for respirable dust is reduced for that area of the mine based on the following formula[17]:

$$\text{MSHA PEL } = \frac{\frac{10mg}{m^3}}{\%\text{ Quartz}}$$

The PELs were based on time-weighted average concentrations sampled over an 8-hour work shift. Sampling devices must be worn by a specified mining occupation and remain operational throughout the entire shift or for 8 hours, whichever time was less. Each sample was compared to the historic PEL of 2.0 mg/m^3 for the respirable dust analysis (MSHA reduced the PEL to 1.5 mg/m^3 on August 1, 2016 and required sampling for the full duration of the miner's shift, even if longer than 8 hours).

2.2 | Respirable dust and respirable quartz data

Data consist of respirable dust air samples collected by MSHA inspectors at surface mines during 1982–2017 to assess for compliance with dust regulations and included a subset of samples analyzed for quartz content. NIOSH received 1982–1999 respirable dust data from MSHA's Laboratory Information Management System database and 2000–2017 data were publicly available.[18] Respirable quartz data for 1982–2017 were received from MSHA's Pittsburgh Quartz Database. Respirable dust data include the date the sample was taken, the concentration of respirable dust, the sample type (eg, designated work position), the occupation code, and the MSHA mine ID. For respirable dust samples analyzed for quartz, the concentration of airborne respirable quartz, and the percentage of quartz (by weight) in the sample were also calculated.

The respirable dust and respirable quartz samples were included in the analysis if they met the following criteria: (a) sample was taken at a surface coal mine or at surface facilities of an underground coal mine; (b) designated by MSHA as valid; (c) occupational "full-shift" (ie, at least 8-hours) sample; and (d) sample was collected by an MSHA inspector. Additionally, respirable quartz samples were included in the analysis if the quartz content was greater than or equal to zero. Concentrations were imputed for respirable dust and respirable quartz samples with a value of less than the minimum quantifiable concentration (MQC) based upon the distribution of quantifiable samples MQC/√2.[19]

2.2.1 | Occupations—MSHA collected samples from a variety of surface miner occupations with most from previously-established higher risk occupations (eg, highwall drill operator, bulldozer operator, and blaster/shooter/shotfirer). The occupation-specific geometric mean, arithmetic mean, and percent of samples exceeding the MSHA PEL for respirable dust and respirable quartz were calculated. Not all results exceeding the MSHA PEL led to an MSHA citation; for example, there was no upward adjustment for sampling uncertainty. Surface miner occupations with fewer than 400 respirable dust samples were combined. Occupations were also combined to summarize results for samples collected in specific areas of work including the strip mine (active mining area), shop/maintenance (includes work in the shop and maintenance work throughout the facility), and coal prep facility. Within the strip mine area, we created a combined drillers occupation group that consisted of highwall drill operator and helper, rock driller, blaster/shooter/shotfirer, and coal drill operator and helper.

2.2.2 | Geographical areas—MSHA coal mining districts are comprised of counties where a mine is located. Although MSHA districts changed during the study period, we assigned all samples to the current MSHA district as of the preparation of this manuscript. A map of the MSHA districts can be found at https://www.msha.gov/about/program-areas/coal-mine-safety-and-health. Data from MSHA Districts 4, 5, and 12 were combined (central Appalachia) and compared with MSHA Districts 2 to 3 and 7 to 10 combined (rest of the United States). Detailed methods and maps are available in a recent publication.[10]

2.3 | Data analysis

Data were analyzed by the calendar year, occupation, and MSHA district. For respirable dust and quartz, the number of samples, the geometric mean, arithmetic mean, 95th percentile, and percent of samples over the PEL were calculated. The mean percentage of quartz was also reported for respirable quartz samples. All analyses were conducted using SAS (version 9.4, SAS Institute, Cary, NC). Data from central Appalachia were compared to the rest of the United States using Proc TTEST Cochran in SAS and a statistically significant difference was determined at $P < .05$. Figures were created using SigmaPlot (version 12.5, Systat Software, San Jose, CA).

3 | RESULTS

Summaries of the respirable dust samples and respirable dust samples containing quartz collected by MSHA inspectors during 1982–2017 are presented. The driller occupations had the highest respirable quartz concentrations. Central Appalachia had statistically higher respirable dust, respirable quartz, and percent quartz in samples compared to the rest of the United States.

3.1 | Respirable coal mine dust

The percentage of respirable dust samples exceeding the PEL, by year, is shown in Table 1. There were 288 705 respirable dust samples collected during 1982–2017 included in this analysis; 6479 samples (2.2%) were less than the MQC and were imputed, and 4520 (1.6%) of the respirable dust samples exceeded the MSHA PEL.

The overall geometric mean and arithmetic mean for respirable dust exposure were 0.17; 0.35 mg/m^3, respectively. The annual respirable dust geometric mean and arithmetic mean are shown in Figure 1. Although the mean exposures declined over time, the 95th percentile averaged 1.13 mg/m^3 during the time period analyzed (Table 1).

Aside from drilling occupations, occupations[20] in the strip mine with the highest geometric mean and arithmetic mean respirable dust exposures, respectively, included groundman (0.20; 0.32 mg/m^3), auger helper (0.19; 0.31 mg/m^3), scraper operator (0.19; 0.33 mg/m^3), refuse truck driver/backfill truck driver (0.16; 0.30 mg/m^3), auger operator (0.16; 0.27 mg/m^3), bulldozer operator (0.15; 0.29 mg/m^3), and coal truck driver (0.14; 0.26 mg/m^3) (Table 2). For the combined drilling occupations (highwall drill operator and helper, rock driller, blaster/shooter/shotfirer, coal drill operator, and helper) the respirable dust geometric mean, arithmetic mean, and 95th percentile, respectively, (0.26; 0.61; 2.10 mg/m^3) were all higher than the overall means for each of those metrics (Table 2). The coal drill helper is not individually presented in Table 2 but is combined into drilling occupations. Occupations were also combined by areas of work where the samples were collected such as strip mine, shop/maintenance, and prep facility (Table 2). The concentrations of respirable dust for the strip mine were lower than the other areas of work.

Overall, the geometric mean and arithmetic mean for respirable dust, respectively, were significantly higher in central Appalachia (0.19; 0.38 mg/m^3) than the rest of U.S. (0.15; 0.33 mg/m^3), $P < .05$.

3.2 | Respirable quartz dust

The annual percentages of respirable dust samples containing quartz that exceed the PEL or the reduced PEL are shown in Table 1. Of the 54 040, respirable quartz samples collected during 1982–2017 included in the analysis; 10 245 samples (19.0%) were less than the MQC and were imputed, and 15.3% of the samples exceeded the applicable dust standard (PEL or reduced PEL). The overall respirable quartz geometric mean and arithmetic mean were 0.02 and 0.06 mg/m^3, respectively. In general, there was a decline over time in respirable quartz concentrations, but the mean percent quartz in the samples was similar over time and remained above 5% in all but 1 year (2010) (Table 1). The annual respirable quartz concentration geometric mean and arithmetic mean are presented in Figure 2. Although the mean exposures were declining over time, the 95th percentile averaged 0.20 mg/m^3 indicating there was substantial exposure to respirable quartz during the time period analyzed (Table 1).

The occupations with the highest geometric mean and arithmetic mean respirable quartz exposures included highwall drill helper (0.09; 0.24 mg/m^3), rock driller (0.07; 0.17 mg/m^3), highwall drill operator (0.06; 0.16 mg/m^3), blaster/shooter/shotfirer (0.05; 0.07 mg/m^3), scraper operator (0.05; 0.10 mg/m^3), coal drill operator (0.05; 0.15 mg/m^3), and bulldozer operator (0.04; 0.08 mg/m^3) (Table 2).

Among the drilling occupations, more than 32% of quartz samples exceeded the PEL. The respirable quartz arithmetic mean for the drilling occupations was 0.15 mg/m^3, which was nearly three times higher than the average of all other occupational exposure (0.04 mg/m^3). The mean percent quartz in drilling occupations samples analyzed for quartz was nearly double the average (13.2% vs 7.2%). The results for respirable quartz for the strip mine were higher than the other areas. Occupations in the prep facility area including the scalper-screen operator, crusher attendant, car dropper, coal sampler, and fine coal plant operator had over 10% of the respirable dust samples containing quartz that exceeded the respirable dust PEL (or reduced PEL).

The mean percent quartz in samples was significantly higher in central Appalachia compared to the rest of U.S. (7.5% vs 7.0%; $P < .05$). The mean percent quartz was usually above 5% in all MSHA coal mine districts. The geometric mean for respirable quartz was slightly, but significantly higher in central Appalachia (0.021 vs 0.020 mg/m^3; $P < .05$).

4 | DISCUSSION

To the best of our knowledge, a comprehensive assessment of respirable dust and respirable quartz exposures at U.S. surface coal mines has not been conducted. During 1982–2017, greater than 15% of respirable coal mine dust samples analyzed for quartz content exceeded the MSHA respirable dust PEL or the reduced PEL. Furthermore, nearly one-third of samples from drilling occupations exceeded the respirable dust PEL or reduced PEL, consistent with the epidemiological data indicating this surface mining occupation is at a higher risk for pneumoconiosis. In addition, MSHA has a surface mine drill dust control standard (30 CFR 72.620) that is enforced by inspector observation and is independent of air monitoring. Since 2000, MSHA has issued nearly 2200 citations for inadequate drill dust controls. We found higher respirable coal dust and quartz concentrations in central Appalachian surface mines compared to those in the rest of the United States. Annually, the surface mine national mean percent quartz was 5% or greater for nearly the entire study period (1982–2017), with a peak of 9.9% in 1998. The mean percent quartz was significantly higher in central Appalachia (7.5%) than the rest of the United States (7.0%). Importantly, both were higher than the underground mine samples mean percent quartz (6.7%) for central Appalachia and the rest of the United States (3.9%).[10]

Excessive exposure to respirable quartz can lead to silicosis, an irreversible and often progressive occupational respiratory disease. Silicosis has been previously documented in surface miners and excessive exposure to quartz has been implicated in the resurgence of severe pneumoconiosis in underground miners.[21–23] Previous studies have investigated the quartz content of MSHA samples and found that even in samples with less than 5% quartz content, 26.3% of these samples exceeded 100 μg/m^3 of respirable quartz, which was the equivalent of the PEL for samples containing quartz.[24,25] Particle size may also be a factor and Mischler et al[26] found that smaller crystalline silica particle size with a geometric mean of 0.3 μm had increased mitochondrial reactive oxygen species generation compared to silica particles with a geometric mean of 4.1 μm. Johann-Essex et al[27] found that samples from mines in mid-central Appalachia (MSHA District 4) had a higher percentage of very small particles and quartz than mines in more northern Appalachia. The characteristics of occupations and areas of work are key to understanding the distributions of exposures. Occupations in the strip mine such as drilling occupations, scraper operator, and bulldozer occupations disturb overburden and have the highest mean respirable quartz concentrations, while occupations in preparation facilities and shop/maintenance had higher respirable dust concentrations than strip mine occupations.

The respirable dust and respirable quartz exposure findings presented in this study could inform our understanding of differences in the distribution of respiratory disease and help guide interventions to reduce exposure. The MSHA 2014 rulemaking and subsequent NIOSH medical surveillance standards made a number of enhancements to the prior regulatory requirements including reductions in the PEL and establishment of medical surveillance for surface miners. We anticipate this surveillance will help identify cases of pneumoconiosis and help prevent the progression of the disease.

It is important to characterize the exposures of surface coal miners and understand the occupations at greatest risk of developing dust-related respiratory illness so steps can be taken to reduce preventable occupational lung diseases associated with surface coal mining. Data presented in this report can support that effort. It is also important to adequately characterize respiratory morbidity among U.S. surface coal miners. To that end, in 2010, NIOSH launched an initiative to conduct respiratory disease surveillance among U.S. surface coal miners. Our next objective will focus on the respiratory disease burden of U.S. surface coal miners using data that is currently being collected.

5 | CONCLUSIONS

There was a decline over time in the number of respirable surface coal mine dust samples exceeding the 2.0 mg/m^3 PEL. Overall, the respirable dust geometric mean was higher in central Appalachia compared to the rest of the United States. Additionally, both the respirable quartz geometric mean and the mean percent quartz in central Appalachia were higher than the rest of the country. We found that 1.6% of surface mine respirable dust samples exceeded 2.0 mg/m^3 and 15.3% of respirable dust samples containing quartz exceeded the respirable dust standard or the reduced standard. Overexposures to respirable dust containing quartz continue to occur at U.S. surface coal mines, particularly among miners in drilling occupations. Enhanced efforts to control quartz exposures is warranted.

ACKNOWLEDGMENTS

The authors thank technical reviewers Gerald Joy and Emanuele Cauda of NIOSH for providing insightful comments during the manuscript development. The authors are government employees and the work performed in the course of their normal duties. The work was performed at Respiratory Health Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Morgantown, WV.

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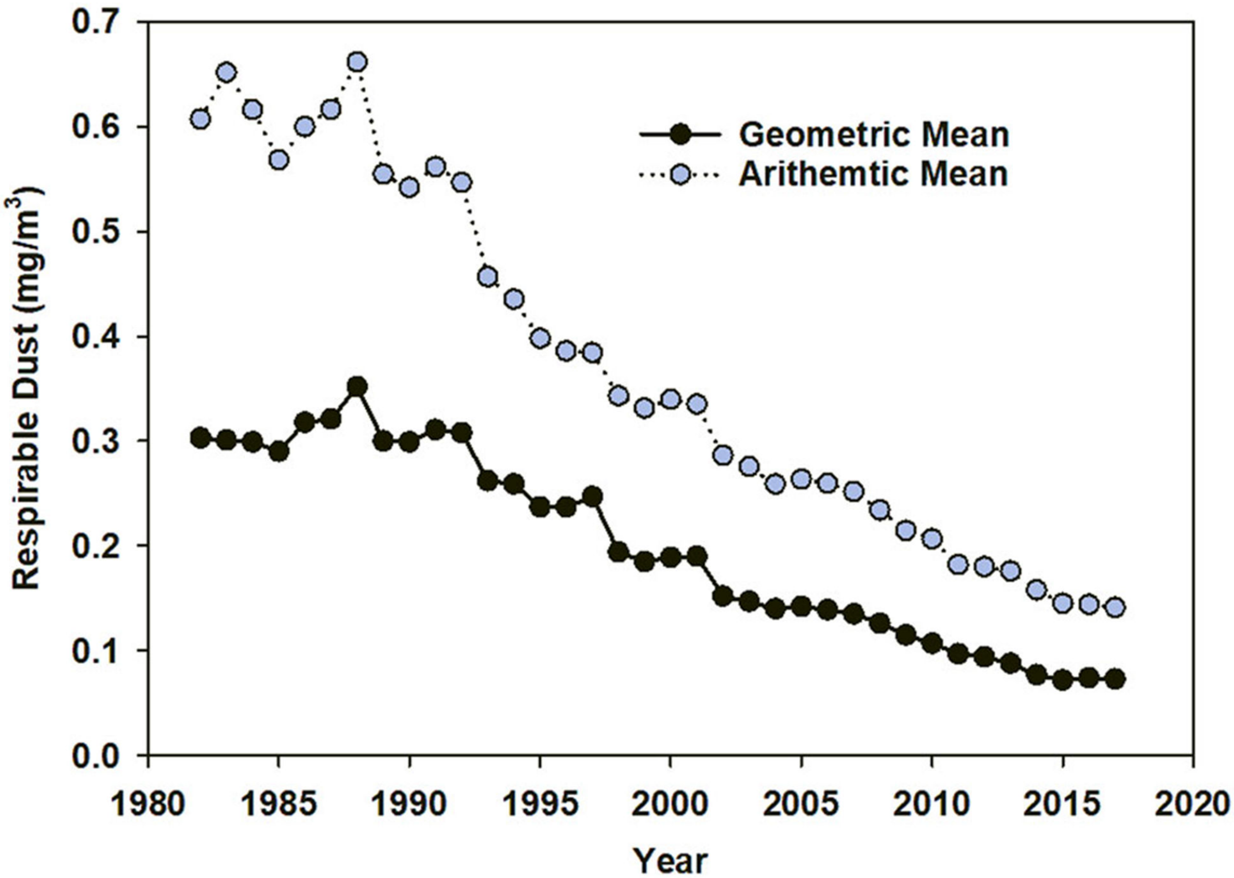

FIGURE 1.

Annual geometric and arithmetic mean respirable coal mine dust by year, 1982–2017

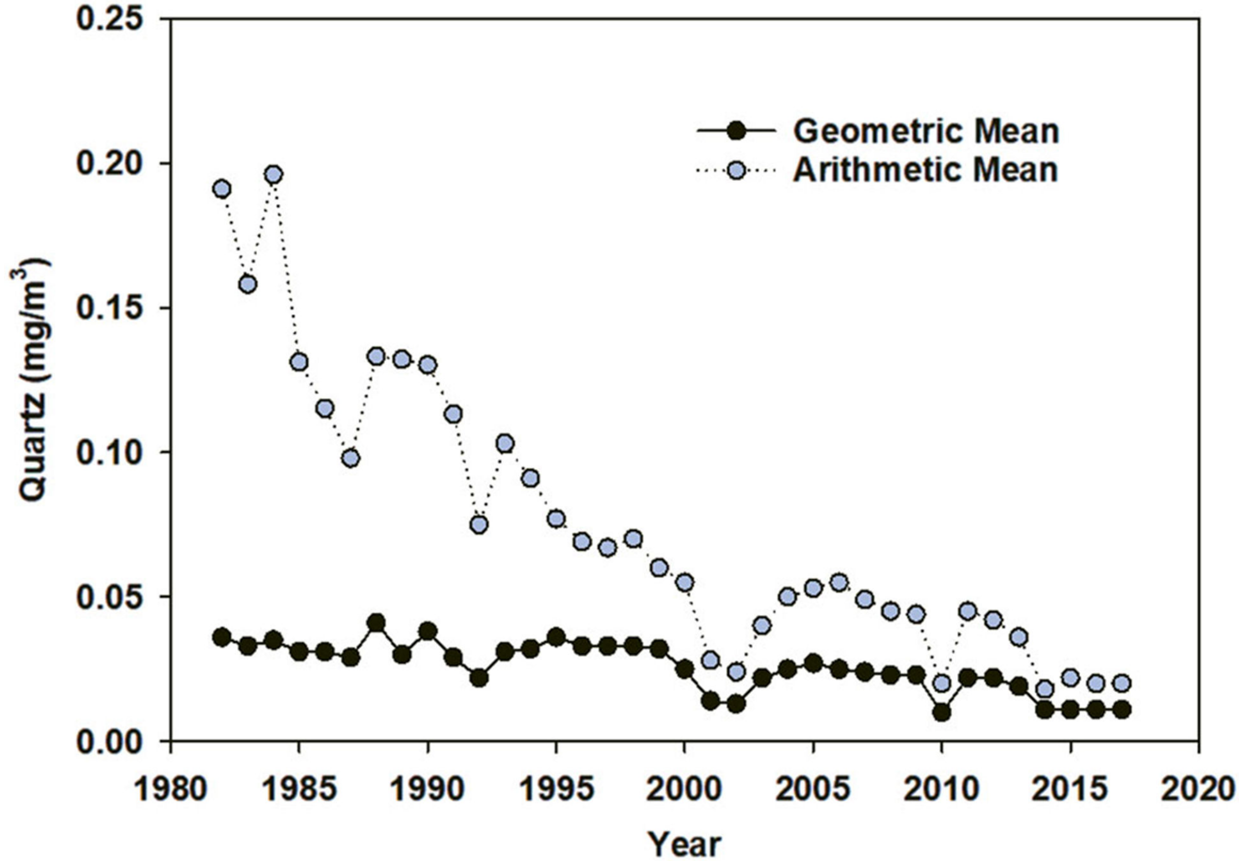

FIGURE 2.
Annual geometric and arithmetic mean respirable quartz by year, 1982–2017

TABLE 1

MSHA inspector samples respirable coal mine dust and respirable quartz by year, 1982–2017

		Respirable dust			Respirable quartz		
		All samples			All samples		
Year	n	95th	% >PEL	n	95th	% >PEL	% Quartz
1982	8857	1.80	3.7	535	0.79	44.1	8.7
1983	8052	2.00	4.5	1017	0.75	43.2	8.0
1984	8144	2.00	5.0	1009	0.75	42.4	8.1
1985	7919	1.70	3.4	771	0.60	39.7	6.6
1986	7199	1.90	4.2	887	0.56	37.3	6.1
1987	6765	1.80	4.0	717	0.40	33.5	5.8
1988	6910	2.00	4.8	961	0.57	36.3	6.9
1989	6571	1.70	3.7	686	0.64	35.1	7.3
1990	6614	1.70	3.4	682	0.47	37.4	7.6
1991	3869	1.50	3.1	407	0.42	26.0	6.4
1992	4163	1.80	3.5	1442	0.29	20.5	5.8
1993	5685	1.40	2.6	1303	0.40	28.6	6.5
1994	6264	1.40	2.2	1293	0.36	28.4	6.6
1995	5901	1.20	1.7	1436	0.27	25.1	9.3
1996	6515	1.14	1.2	1550	0.22	20.1	9.6
1997	7505	1.15	1.1	2021	0.22	19.7	9.4
1998	9233	1.04	1.0	1973	0.21	19.5	9.9
1999	10 184	1.07	1.0	2174	0.19	17.8	9.4
2000	9730	1.06	1.1	2044	0.16	15.2	8.2
2001	9967	1.04	0.9	5076	0.09	5.7	5.7
2002	9464	0.94	0.8	3952	0.08	5.2	5.5
2003	8231	0.91	0.7	1203	0.11	10.6	7.7
2004	8790	0.87	0.6	1146	0.16	14.5	8.8
2005	8690	0.88	0.7	1134	0.16	14.6	8.9
2006	7706	0.87	0.7	960	0.18	16.0	8.4
2007	8541	0.84	0.6	997	0.15	13.5	8.2
2008	10 435	0.78	0.5	1107	0.15	12.4	8.0

		Respirable dust			Respirable quartz		
		All samples			All samples		
Year	n	95th	% >PEL	n	95th	% >PEL	% Quartz
2009	11 401	0.75	0.3	1176	0.14	11.2	8.6
2010	9528	0.73	0.4	3202	0.06	3.3	4.9
2011	10 340	0.65	0.2	794	0.15	11.1	8.8
2012	10 101	0.64	0.2	773	0.13	11.6	8.8
2013	8619	0.64	0.4	622	0.11	11.3	7.6
2014	8283	0.59	0.1	2400	0.06	3.0	5.7
2015	8386	0.54	0.2	2377	0.07	2.9	6.4
2016	7227	0.51	0.2	2133	0.07	2.6	6.6
2017	6916	0.51	0.1	2080	0.07	3.0	6.7
Total	288 705	1.13	1.6	54 040	0.20	15.3	7.2

Abbreviations: PEL, permissible exposure limit; 95th, 95th percentile in mg/m^3.

TABLE 2

MSHA inspector samples respirable coal mine dust and respirable quartz by surface miner occupation 1982–2017

	Respirable dust					Respirable quartz					
	All samples					All samples					
Occupation	**n**	**GM**	**AM**	**95th**	**% >PEL**	**n**	**GM**	**AM**	**95th**	**% >PEL**	**% Quartz**
Highwall drill helper (D)	989	0.29	0.67	2.20	5.4	219	0.09	0.24	0.89	44.3	13.7
Rock driller (D)	400	0.27	0.60	2.05	5.0	107	0.07	0.17	0.64	39.3	10.9
Highwall drill operator (D)	22 907	0.26	0.65	2.34	6.0	7103	0.06	0.16	0.61	34.2	13.5
Blaster/shooter/shotfirer (D)	2826	0.24	0.36	1.00	1.1	829	0.05	0.07	0.17	14.5	11.1
Groundman	1139	0.20	0.32	0.88	0.5	240	0.02	0.03	0.07	2.9	4.4
Coal drill operator (D)	514	0.20	0.43	1.40	2.5	88	0.05	0.15	0.60	33.0	10.0
Auger helper	2814	0.19	0.31	0.90	0.4	367	0.02	0.03	0.07	3.8	3.6
Scraper operator	2986	0.19	0.33	1.00	1.5	293	0.05	0.10	0.34	31.1	8.3
Refuse truck driver/backfill truck driver	32 450	0.16	0.30	1.00	0.7	5188	0.02	0.04	0.13	8.9	5.1
Auger operator	3783	0.16	0.27	0.80	0.5	405	0.01	0.02	0.06	5.4	2.1
Bulldozer operator	58 526	0.15	0.29	1.00	0.8	12 331	0.04	0.08	0.29	21.6	13.9
Coal truck driver	5802	0.14	0.26	0.72	0.4	444	0.02	0.04	0.12	9.2	4.4
Water truck operator	1041	0.14	0.21	0.67	0.2	91	0.02	0.03	0.06	1.1	4.3
Coal Shovel Operator	1381	0.12	0.22	0.70	0.3	96	0.02	0.04	0.11	10.4	6.2
High lift operator/front end loader	55 905	0.12	0.22	0.70	0.3	6411	0.01	0.02	0.08	4.7	4.3
Stripping shovel operator	1895	0.12	0.20	0.69	0.2	161	0.02	0.06	0.18	18.6	9.6
Crane operator/dragline operator	4222	0.11	0.18	0.43	0.2	102	0.01	0.03	0.12	11.8	7.0
Road grader operator	3532	0.11	0.22	0.70	0.2	288	0.02	0.03	0.10	5.6	5.2
Rotary bucket excavator operator	1844	0.10	0.17	0.54	0.1	164	0.02	0.05	0.15	13.4	8.6
Backhoe operator	8154	0.09	0.16	0.55	0.2	681	0.02	0.05	0.17	14.8	8.6
Total strip mine	**213 908**	**0.15**	**0.31**	**1.00**	**1.2**	**35 689**	**0.03**	**0.08**	**0.27**	**18.2**	**10.0**
Total drillers (D) combined	27 670	0.26	0.61	2.10	5.4	8348	0.06	0.15	0.57	32.6	13.2
Welder (Shop)	1485	0.39	1.00	3.62	11.2	89	0.01	0.01	0.04	27.0	0.4
Welder (non-shop)	1030	0.35	0.74	2.40	7.3	342	0.01	0.01	0.03	21.1	1.0
Laborer/blacksmith	8786	0.30	0.59	2.00	4.6	2394	0.01	0.02	0.07	15.9	1.9
Electrician	3772	0.23	0.35	1.00	0.4	798	0.01	0.01	0.04	2.6	2.0
Oiler/greaser	2719	0.18	0.31	1.00	0.7	327	0.02	0.04	0.14	11.9	4.8

	Respirable dust					Respirable quartz					
	All samples					All samples					
Occupation	**n**	**GM**	**AM**	**95th**	**% >PEL**	**n**	**GM**	**AM**	**95th**	**% >PEL**	**% Quartz**
Mechanic	9123	0.18	0.36	1.20	1.4	2057	0.01	0.01	0.04	7.6	1.6
Total shop/maintenance	**27 999**	**0.23**	**0.47**	**1.53**	**2.9**	**6132**	**0.01**	**0.02**	**0.06**	**11.5**	**1.9**
Froth cell operator	479	0.74	0.97	2.36	7.1	272	0.01	0.01	0.03	7.4	1.2
Fine coal plant operator	3773	0.49	0.80	2.20	6.2	1592	0.01	0.02	0.05	10.7	1.4
Scalper-screen operator	1280	0.49	0.94	2.80	10.3	421	0.02	0.03	0.10	22.3	2.0
Dryer operator	834	0.39	0.69	1.80	3.4	258	0.01	0.01	0.04	8.9	1.2
Washer Operator	1365	0.31	0.49	1.42	1.3	408	0.01	0.02	0.04	3.9	1.8
Cleaning plant operator	7237	0.28	0.50	1.43	1.8	2154	0.01	0.01	0.04	5.8	1.4
Crusher attendant	1699	0.27	0.49	1.50	2.4	414	0.02	0.04	0.13	17.4	4.3
Coal sampler	1767	0.25	0.51	1.51	3.3	350	0.02	0.03	0.08	11.1	2.5
Utility man	6615	0.24	0.42	1.32	1.5	2332	0.01	0.02	0.05	5.5	2.1
Tipple operator	7301	0.23	0.46	1.49	2.6	1212	0.01	0.02	0.05	9.4	1.5
Car dropper	1370	0.18	0.30	0.92	0.9	90	0.01	0.02	0.05	12.2	1.5
Preparation plant foreman safety director	1092	0.18	0.30	0.91	0.3	168	0.01	0.02	0.04	1.8	2.1
Car trimmer/car loader	1152	0.16	0.25	0.72	0.6	84	0.01	0.01	0.03	6.0	2.4
Barge attendant	1007	0.12	0.20	0.60	0.1	62	0.01	0.01	0.03	3.2	1.5
Weighman	1677	0.10	0.17	0.51	0.1	65	0.01	0.01	0.03	4.6	1.3
Total prep facility	**39 699**	**0.26**	**0.49**	**1.50**	**2.6**	**10 225**	**0.01**	**0.02**	**0.05**	**8.3**	**1.8**
Cleanup man	2675	0.43	0.70	2.10	5.4	1048	0.01	0.02	0.05	11.1	1.7
Belt man/conveyor man	1202	0.27	0.44	1.31	1.7	403	0.01	0.02	0.06	8.2	2.4
Conveyor operator	585	0.25	0.46	1.50	2.2	98	0.02	0.04	0.11	12.2	3.6
Forklift operator	918	0.12	0.20	0.60	0.2	139	0.01	0.02	0.06	5.8	2.8
Outside foreman	840	0.11	0.20	0.68	0.1	77	0.01	0.02	0.07	3.9	2.9
Total misc	**7099**	**0.24**	**0.46**	**1.50**	**2.6**	**1994**	**0.01**	**0.02**	**0.06**	**9.1**	**2.2**
Jobs with <400 dust samples	3812	0.16	0.37	1.10	1.1	778	0.01	0.02	0.06	6.0	2.5
Total all areas and occupations	**288 705**	**0.17**	**0.35**	**1.13**	**1.6**	**54 040**	**0.02**	**0.06**	**0.20**	**15.3**	**7.2**

Abbreviations: AM, Arithmetic mean mg/m3; (D), drillers occupation; GM, Geometric mean mg/m^3; PEL, permissible exposure limit; 95th, 95th percentile mg/m3.

The bold values are summaries of number of samples, averages, etc, for each section including strip mine, shop/maintenance, prep facility and misc, and summary for all samples, and averages.