Mining, Metallurgy & Exploration (2022) 39:283–290
https://doi.org/10.1007/s42461-022-00563-7

Effectiveness of the CPDM in Reducing Overexposures to Coal Mine Dust

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Received: 22 September 2021 / Accepted: 4 February 2022 / Published online: 22 February 2022

Abstract
The Mine Safety and Health Administration (MSHA) promulgated a rule in 2014 that required numerous changes in compliance dust sampling requirements for coal mine operators. Two key parts of this rule were the lowering of the respirable coal mine dust standard from 2.0 mg/m^3 to 1.5 mg/m^3 and requiring operators of underground coal mines to use a continuous personal dust monitor (CPDM) for compliance sampling. The CPDM currently approved for compliance sampling is equipped with a display that provides miners with in-shift information on their respirable dust exposure. The goal is to provide an indication of a potential overexposure and empower the miner and mine operator to implement changes in controls and/or operating practices to prevent an overexposure from occurring. Compliance sampling data for four occupations that have historically had elevated dust exposures were downloaded from the MSHA website and analyzed to assess the impact of the CPDM on overexposures. These occupations include continuous miner operator, roof bolter operator, tailgate-side shearer operator, and jacksetter. MSHA inspector and mine operator sampling data from five years before the rule became effective was compared to sampling results for five years after the dust standard was lowered and CPDM use was required. The analysis indicates that use of the CPDM has resulted in substantially lower percentages of samples exceeding the applicable respirable dust standard for these four occupations. A discussion of key dust rule changes, the CPDM, and compliance sampling results are provided.

Keywords Personal dust monitor · Coal workers' pneumoconiosis · Respirable coal dust · Dust sampling

1 Introduction

Inhalation of respirable-sized coal mine dust, which is defined as less than 10 µm [1, 2], can result in coal workers' pneumoconiosis (CWP), commonly known as black lung. If respirable crystalline silica is contained in the coal mine dust, miners can contract silicosis. Both of these lung diseases are disabling and can be fatal in their most severe form, progressive massive fibrosis (PMF) [3]. Once contracted, there is no cure for these lung diseases so controlling dust exposure is the key for protecting the health of miners.

In the USA, the Federal Coal Mine Health and Safety Act of 1969 (Public Law 91-173) established a respirable coal mine dust standard of 2.0 mg/m^3, required periodic sampling by mine operators and federal inspectors, established a federal black lung benefits program, and required the development of a national health-screening program for underground coal mine workers.

In 1970, the National Institute for Occupational Safety and Health (NIOSH) established the Coal Workers' Health Surveillance Program (CWHSP) and continues to run this program today. In this program, new miners receive a chest x-ray at the start of their employment. Thereafter, miners can voluntarily receive a chest x-ray approximately once every five years at no cost to the miner. Standards developed by the International Labour Office (ILO) [4] are used to classify the presence and severity of CWP on the x-rays, with Category 1 considered the earliest signs of CWP. NIOSH provides the findings from these x-rays only to the participating miner. The goal is to provide the earliest possible indication of disease development so action can be taken

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to minimize additional dust exposure and disease progression. Throughout the program's history, the industry-wide participation rate during each five-year period has fluctuated but averages around 40% [5].

NIOSH compiles the data collected in the CWHSP to assess trends in CWP development throughout the industry. The data, with personally identifiable information removed, can be accessed on the NIOSH website [6]. Figure 1 summarizes data across five-year timelines that shows the prevalence of CWP Category 1 or greater for underground coal miners that volunteered to be examined in the CWHSP. As shown, the greatest prevalence of CWP occurs in miners with the longest working tenure. For miners with 25 or more years of experience examined in the first surveillance period after the 1969 Act, nearly one in three were diagnosed with CWP. Over the next 25 years, a steady decline in the prevalence of CWP was observed across the industry resulting in 4.1% of the longest tenured miners being diagnosed with CWP in the 1995–1999 surveillance period. However, over the last 20 years, a steady increase in CWP rates has been observed with 14.5% of the longest-tenured miners examined in the 2015–2019 surveillance round diagnosed with CWP.

A similar trend has been observed in the prevalence of PMF as shown in Fig. 2. For miners examined in the CWHSP, the percentage diagnosed with PMF dropped from 2.2% in the first surveillance period to a program low of 0.1% in the 1990–1994 surveillance period. Since that time, the downward trend has reversed and over 1%

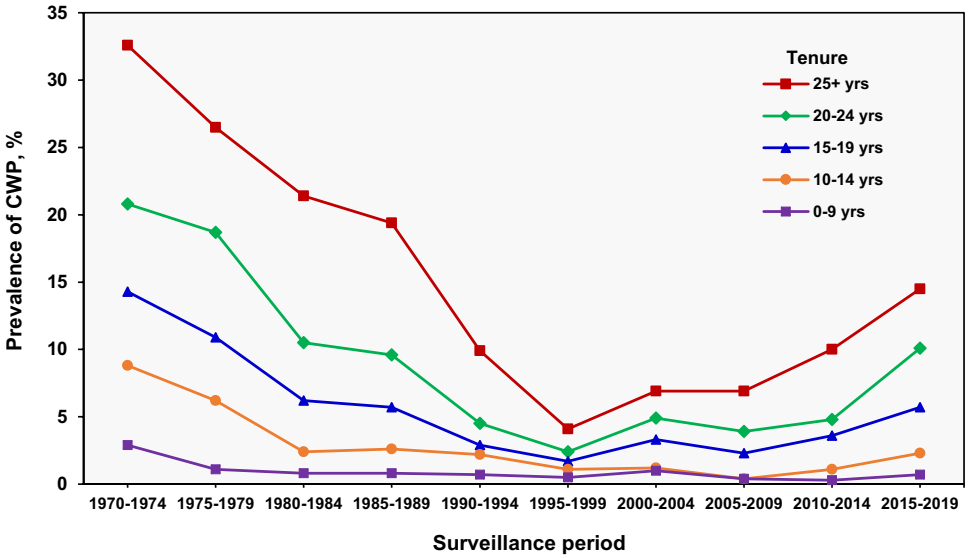


Fig. 1 Miners examined in the CWHSP with CWP Category 1 or greater by tenure in mining

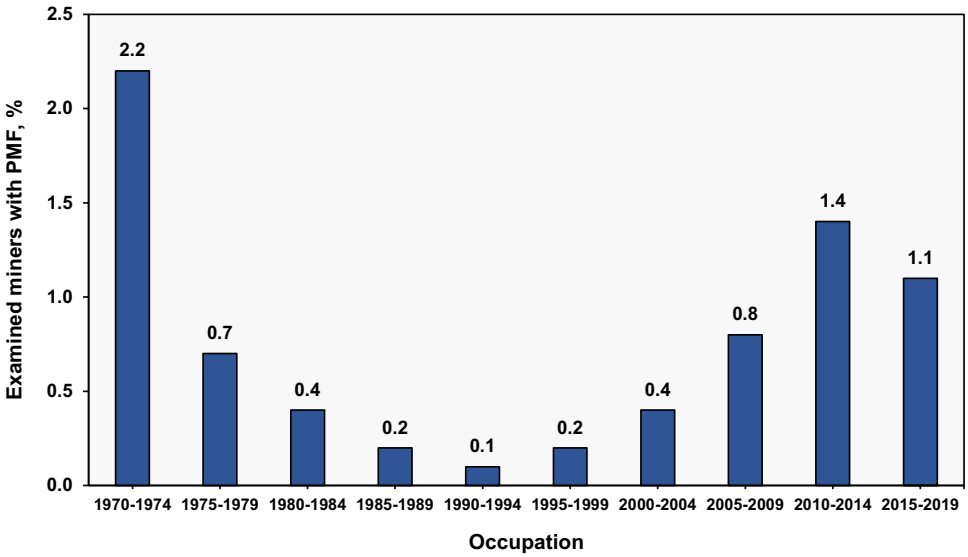


Fig. 2 Miners examined in the CWHSP diagnosed with PMF

of the miners examined during the last two surveillance periods have been diagnosed with PMF.

The Federal Black Lung Program provides monthly compensation to coal miners who are totally disabled from pneumoconiosis as a result of their employment and to survivors of coal miners whose deaths are attributable to CWP. Medical expense payments for the treatment of lung disease are also provided by this program. Coal mine operators are required to pay an excise tax into a trust fund for each ton of coal mined as the primary source of funding for the program [7]. The Office of Workers Compensation within the Department of Labor (DOL) administers this program and documents yearly costs. In 2020, over $220 million in benefits were paid, with a total of over $47.3 billion paid from 1971 through 2020 [8].

The presented data show that CWP has had and continues to have a significant impact on the health of miners, as well as, creating a significant financial burden for miners, the industry, and the federal benefits program.

2 2014 MSHA Dust Rule

In an effort to further reduce the respirable dust exposure of coal mine workers, MSHA promulgated a new federal dust rule in 2014 [9]. This new dust rule reduced the respirable coal mine dust standard to 1.5 mg/m^3, required mine operators to use a CPDM for compliance sampling, and incorporated a number of other sampling changes with several of these key changes listed in Table 1. Most of the provisions in this dust rule were effective on August 1, 2014. However, mine operators were not required to use the CPDM until February 1, 2016 and the 1.5 mg/m^3 standard did not go into effect until August 1, 2016.

As noted in Table 1, operators are now required to collect more samples per year from each mechanized mining unit (MMU). Also, samples must be collected over the entire working shift and 80% of the previous 30-shift average production must be obtained during the sampling shift for the dust sample to meet the minimum production for a valid sample. In the 1969 Act, respirable dust samples that contained over 5% quartz signaled excessive silica exposure and resulted in a reduced dust standard calculated with the formula shown in Table 1. In the new rule, a respirable silica limit of 100 µg/m^3 is defined with exceedances triggering a reduced dust standard calculated with the same formula as in the 1969 Act. Operators are now required to take immediate corrective action if the silica or respirable dust limits are exceeded. From a health perspective, the new rule expands the health surveillance program by including surface coal miners and adding spirometry testing during the medical examinations. The new sampling requirements are designed to provide a more realistic measure of miners' dust exposures.

For MSHA, their inspectors continue to use gravimetric samplers for compliance sampling. This type of sampler has been used since the passage of the 1969 Act and provides an average respirable dust concentration over the entire sampling period. The benefit of using the gravimetric sampler is that the filter can be analyzed for silica content. As a result, MSHA sampling is used to determine compliance with the 100 µg/m^3 silica standard.

Table 1 Comparison of sampling requirements in the 1969 Act and 2014 MSHA dust rule

Key sampling changes	1969 Act	2014 Rule
Frequency of operator sampling on each MMU	Bimonthly	Quarterly
Sampling duration	8 hours	Full shift
Number of valid samples per period	5 consecutive days or shifts for the DO[a]	Consecutive sampling to obtain 15 valid shifts for the DO[a] and then 15 valid shifts for the ODO[a] (not concurrent)
Number of valid DO samples per year	30 (5 samples x 6 sampling periods)	60 (15 samples x 4 sampling periods)
Production required for sample to be valid	50% of average production from the last 5 valid bimonthly samples	80% of average production over the last 30 production shifts
Silica dust	If quartz > 5%, reduce the respirable dust standard (10 ÷ % quartz)	If quartz > 100 µg/m^3, reduce the respirable dust standard (10 ÷ % quartz)[b]
Health surveillance	Chest x-rays for underground miners	Chest x-rays and spirometry for underground and surface miners
Operator dust sampler	Gravimetric	CPDM (effective 2-1-2016)
Respirable dust standard	2.0 mg/m^3 (effective 12-30-1972)	1.5 mg/m^3 (effective 8-1-2016)

[a] Designated occupation (DO) and other designated occupation (ODO) are defined in section 4

[b] Reduced respirable dust standard cannot exceed the 1.5 mg/m^3 standard

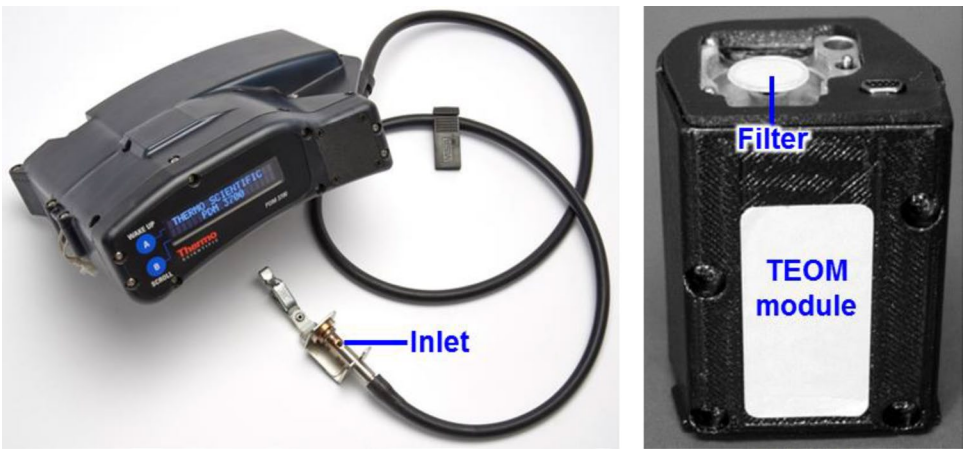
3 Continuous Personal Dust Monitor (CPDM)

A key component of the 2014 dust rule is the requirement for underground coal mine operators to use a CPDM for compliance dust sampling. Surface coal mine operators can continue using the gravimetric sampler or voluntarily choose to use a CPDM. Currently, the Thermo Fisher Scientific PDM3700 [10], Fig. 3 left, is the only sampler certified by MSHA as intrinsically safe and by NIOSH for meeting the CPDM requirements specified in the Code of Federal Regulations (CFR), Title 30, Part 74 [11].

Air is drawn into a lapel-worn inlet at a flow rate of 2.2 liters per minute and through a Higgins-Dewell cyclone to obtain the respirable fraction of dust. The dust-laden air then travels through a heated circuit designed to remove moisture. The dust-laden air then passes through a filter that is mounted on top of a hollow tube, which operates as a tapered element oscillating microbalance (TEOM). The TEOM and attached filter are vibrating at a known frequency at the start of the sampling period. As dust deposits on the filter, a change in TEOM frequency occurs, which is directly related to the deposited mass. The quantified mass, sampling time, and flow rate are used to calculate a respirable dust concentration. The TEOM is contained in a module that is removed from the instrument to change the filter. Figure 3 right shows the TEOM module removed from the instrument with a filter installed on top of the TEOM.

Respirable dust concentrations are recorded each minute and stored internally in two files. One file (with a .msha filename extension) must be transmitted to MSHA for compliance determination and contains a checksum field that is used for data verification. The other file is stored as a comma-separated value (csv) file, which can be downloaded by the mine operator and analyzed to identify high dust periods or other periods of interest.

In addition to the stored data, the unit has a display that provides the wearer with information on their dust exposure by scrolling through three different screens. The first screen, Fig. 4 left, shows the dust concentration over the past 30 minutes and the cumulative concentration to that point in the sampling shift. The second screen, Fig. 4 center, displays the shift dust limit, which defaults to the 1.5 mg/m^3 specified in the 2014 rule. However, if a reduced dust standard is in effect due to elevated silica levels, the reduced standard can be entered while programming the instrument for the shift. The second screen also displays the percent of the dust limit that has been reached to that point in the shift. This information will provide an indication of a potential overexposure. For example, if the percent of limit reached is 42% as shown in Fig. 4 but the miner is only two hours into a 10-hour shift,



Photos by Thermo Fisher Scientific

Fig. 3 PDM3700 dust sampler (left) and TEOM module removed from sampler to show dust filter (right)

Fig. 4 Information displayed by the PDM3700. The first screen shows 30-minute and cumulative dust concentrations (left), with the second screen showing the shift dust limit and the percentage of the limit that has been reached (center) and the third screen showing a bar chart of 30-minute average dust concentrations (right)

an overexposure is likely to occur if changes to controls or operating procedures are not made that reduce dust levels. The third screen, Fig. 4 right, provides a bar chart with each bar representing the average dust level for 30-minute sampling periods. This provides a simple view of the fluctuations in dust levels throughout the shift and identifies the periods with the highest dust levels.

After approximately one year of using the CPDM for compliance sampling, NIOSH had interviewed miners from six mines to gain insight into the use of the data being provided by the PDM. A number of miners indicated that they were using the feedback provided by the CPDM to make adjustments to lower their dust exposures [12]. To quantify the longer-term impact of using the CPDM, MSHA compliance sampling data have been analyzed by NIOSH.

4 Compliance Dust Sampling Results

MSHA compiles the results from compliance dust samples collected by inspectors and coal mine operators and makes this information available to the public on their website [13]. NIOSH downloaded the coal dust sample data set and analyzed the sampling results for four occupations that have historically been at risk for elevated dust exposure. As such, these were the occupations specified by MSHA in the 2014 dust rule as designated occupations (DO) or other designated occupations (ODO) for which operators must collect compliance samples. These occupations include continuous miner operator (DO), roof bolter operator (ODO), tailgate-side shearer operator (DO), and jacksetter (ODO).

To assess the impact of the CPDM on compliance sampling, NIOSH compared inpsector and operator sampling data from two five-year time periods. The first period represents the last five years of sampling before any portion of the 2014 dust rule was implemented and encompasses samples collected between August 1, 2009 through July 31, 2014. During this period, the gravimetric sampler was used for compliance sampling by MSHA inpsectors and mine operators, with the dust standard at 2.0 mg/m^3. The second five-year period represents sampling after all portions of the 2014 dust rule had been implemented and encompasses samples collected between August 1, 2016 through July 31, 2021. During this period, MSHA continued to use the gravimetric sampler but mine operators used the CPDM, with the dust standard lowered to 1.5 mg/m^3. The downloaded data were further filtered by: operator or inspector collected sample, sample not voided, and occupation code. The MSHA occupation codes [14] used were 036 for continuous miner (CM) operator, 044 for tailgate-side (TG) shearer operator, and 041 for jacksetter (JK). For the roof bolter (RB) operator, occupation codes 012, 014, 019, 046, and 048 were selected to obtain samples for the different types of bolting machines being used in the industry (e.g., dual boom, single head, mounted). In addtion, prior to being identified as the ODO in the 2014 dust rule, the RB occupation was often identified as a designated area (DA) sample that had to be collected by mine operators. Consequently, the DA samples identified as RB operators were included in the first five-year period for operator-collected samples.

Figure 5 shows the percentage of MSHA inspector samples that exceeded the applicable dust standard for the five-year periods before (Grav 2.0) and after (Grav 1.5) implementation of the 2014 dust rule. The CM operator samples showed a 19% reduction in the percentage of samples exceeding the standard under the 2014 dust rule. For the other three occupations, the percentage of samples exceeding the standard increased between 15% and 73%. Increases

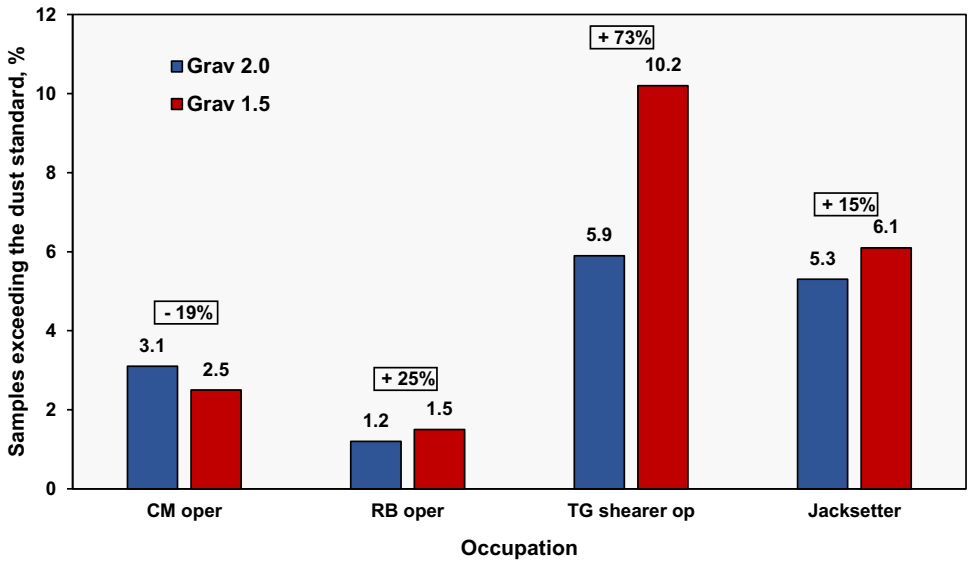


Fig. 5 MSHA inspector sampling results for the five years before and after the 2014 dust rule changes

in overexposures are not totally surprising when considering the more stringent sampling requirements that were in place, such as the lowered dust standard, higher required production levels, full shift sampling, and more shifts being sampled. Also, the gravimetric sampler provides no in-shift feedback on dust levels to the wearer and was used in both sampling periods.

As shown in the graph, greater difficulty in maintaining compliance with the lowered dust standard was observed for the longwall occupations. Historically, this has been the case for these occupations and likely results from higher production levels from longwalls and the close proximity of the shearer operators and jacksetters to two major dust sources on longwall faces, which are the shearer cutting and shield advance [15].

Figure 6 shows the percentage of mine operator samples that exceeded the applicable dust standard for the five-year periods before (Grav 2.0) and after (CPDM 1.5) implementation of the 2014 dust rule. For the four occupations, the percentage of samples exceeding the standard dropped between 63% and 86% with operators using the CPDM, even under the more stringent sampling requirements noted above. This is a substantial contrast to the MSHA results. As with the inspector samples, the longwall occupations had more samples exceeding the standard than the continuous mining occupations, but the difference was not as great in the operator samples.

For the data shown in Figs. 5 and 6, it can be seen that prior to the 2014 rule a higher percentage of operator samples exceeded the 2.0 mg/m^3 standard when compared to inspector samples, except for the tailgate shearer operator for which the exceedances were nearly equal (5.7% for operators versus 5.9% for inspectors). However, with the operators using the CPDM, the percentage of operator samples exceeding the 1.5 mg/m^3 standard was lower than inspector samples for all four occupations, with the largest difference of 8.1% found for the tailgate shearer operator (10.2% versus 2.1%).

As mentioned, more stringent sampling requirements related to sampling time and tonnage were enacted in the 2014 dust rule. Table 2 summarizes the average sampling times and tonnages for the CM and TG shearer operators for both sampling periods. For the CM operator, post-2014 sampling tonnage increased by approximately 200 tons per shift, while sampling time increased by 80 minutes or more. For the TG shearer operator, post-2014 tonnage increased by over 3,200 tons per shift, while sampling time increased by 97 minutes or more. These data confirm that sampling time

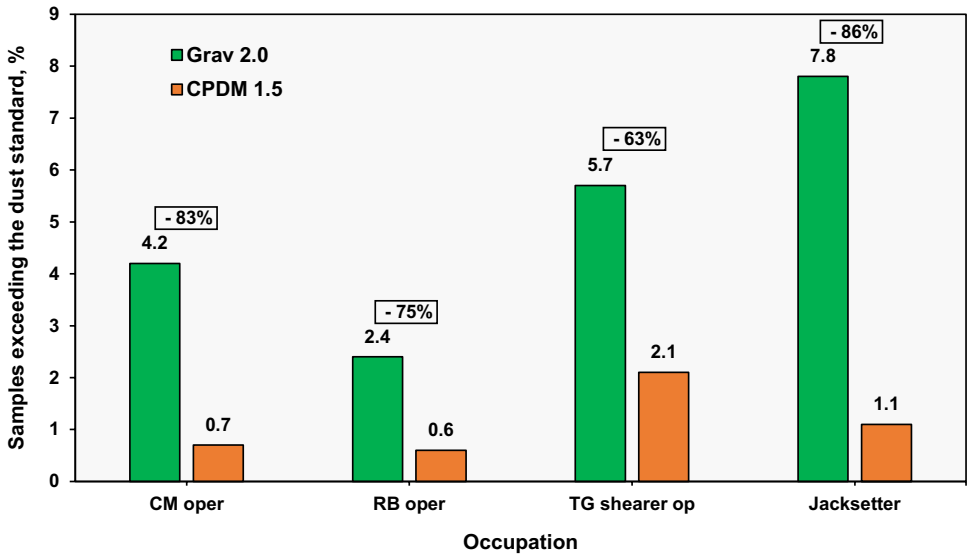


Fig. 6 Mine operator sampling results for the five years before and after the 2014 dust rule changes

Table 2 Impact of the 2014 dust rule on average sampling time and tons produced during sampling

Occupation	Sample type	2009–2014 averages		2016–2021 averages		Change with 2014 rule	
		Tons	Time, mins	Tons	Time, mins	Tons	Time, mins
CM operator	Mine operator	678	479	906	559	+ 228	+ 80
	MSHA inspector	698	480	891	570	+ 193	+ 90
TG shearer operator	Mine operator	6193	478	9911	575	+ 3718	+ 97
	MSHA inspector	6182	479	9463	592	+ 3281	+ 113

and tonnage have increased during sample collection under the 2014 dust rule.

Another change in the 2014 dust rule involved the number of samples that were to be collected by mine operators. Prior to the rule, mine operators were required to collect 30 valid samples per year for the DO occupations on each MMU. After the 2014 dust rule, mine operators were required to collect 60 valid samples per year for the DO occupations on each MMU. Table 3 lists the total number of samples collected by inspectors and mine operators for the CM operator and TG shearer operator for each of the sampling periods. As shown, the number of samples collected by inspectors after the 2014 dust rule dropped by 37% to 48% and reflects the drop in active MMUs as coal demand fell and mines closed [16]. However, the number of operator-collected samples increased by 17% to 123% during this same time period. The larger increase for the tailgate shearer operator likely results from the jacksetter having been identified as the DO on some MMUs prior to the 2014 rule. As previously noted, the 2014 rule specifically defines the tailgate side shearer operator as the DO for longwalls.

Figure 7 shows the average respirable dust concentrations calculated for each sampling period for the four occupations. Average dust concentrations were below 0.8 mg/m^3 for all sampling periods and both occupations from CM sections. Except for the RB operator samples collected by the mine operators, average dust concentrations were slightly lower after implementation of the 2014 dust rule. For the longwall occupations, average dust levels decreased by 0.1 to 0.4 mg/m^3 after implementation of the 2014 dust rule. These decreases in average dust levels occurred despite the increases in tonnage produced and time sampled as noted in Table 2.

5 Summary

In 2014, MSHA enacted a dust rule that reduced the respirable dust standard to 1.5 mg/m^3, required mine operators to use a CPDM for compliance sampling, and changed a number of other sampling requirements. The CPDM approved for use by MSHA and NIOSH has a display that provides in-shift information on respirable dust exposure to the wearer. Prior to using the CPDM, miners collected compliance dust samples with a gravimetric sampling pump that only displayed airflow rate and sampling time. MSHA inspectors continue to use the gravimetric sampler in order to use the filter for silica analysis. NIOSH wanted to determine if miners and mine operators could use the dust exposure information provided by the CPDM to improve on maintaining compliance.

Table 3 Number of samples collected by MSHA and mine operators before and after the 2014 rule

Occupation	Sample type	2009–2014 total	2016–2021 total	Change, %
CM operator	Mine operator	119,316	139,840	+ 17
	MSHA inspector	18,701	9,685	- 48
TG shearer operator	Mine operator	4,792	10,681	+ 123
	MSHA inspector	1,147	725	- 37

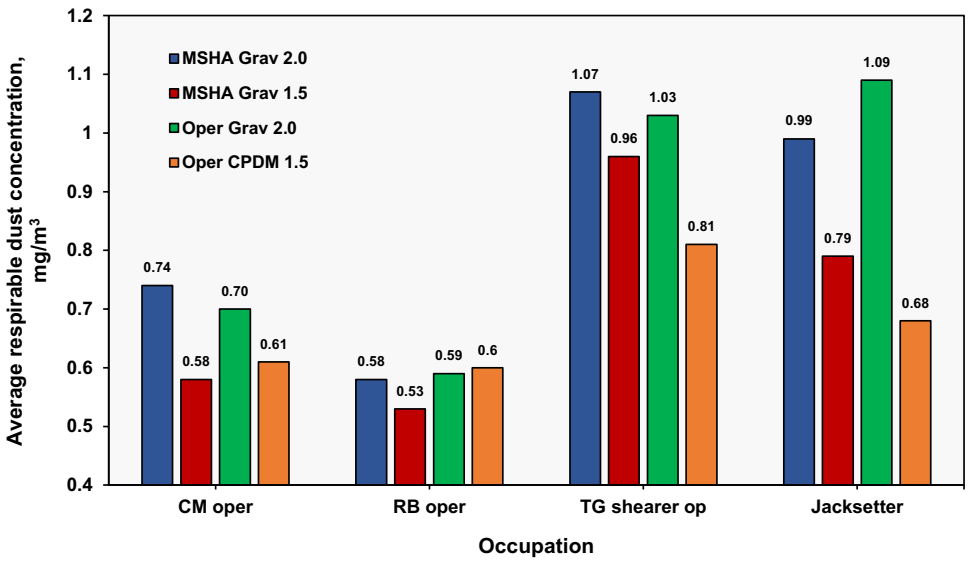


Fig. 7 Average respirable dust concentrations for five years before and after the 2014 dust rule

NIOSH downloaded compliance dust samples collected by inspectors and mine operators from the MSHA website for the five-year period prior to implementing the 2014 dust rule and the five-year period after all provision of the dust rule had been implemented. Dust samples for continuous miner operators, roof bolter operators, tailgate-side shearer operators, and jacksetters were analyzed.

The percentage of samples exceeding 1.5 mg/m^3 collected by MSHA inspectors was between 15% and 73% higher than the percentage of samples exceeding the previous 2.0 mg/m^3 standard for the roof bolter operator, tailgate-side shearer operator, and jacksetter occupations. The continuous miner operator samples showed a decrease of 19% fewer overexposures for MSHA samples.

However, with mine operators using the CPDM for compliance sampling, the percentage of samples exceeding the 1.5 mg/m^3 standard when compared to the percentage exceeding 2.0 mg/m^3 for these four occupations was reduced by 63% to 86%. These substantial reductions were realized despite the more stringent sampling requirements of the 2014 dust rule, such as the lowered standard, higher production requirements, full-shift sampling, and an increase in the number of samples required. These data suggest that miners and mine operators are utilizing the in-shift dust exposure information provided by the CPDM to substantially reduce overexposures.

Declarations

Conflicts of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Disclaimer The findings and conclusions in the report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company name, product, or software does not constitute endorsement by NIOSH.

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