# Silica Adds to Respirable Dust Concerns

*What if you could know the silica dust levels in a coal mine after every shift?*

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While sampling respirable dust in mines, miners who spend their shift working in dusty conditions typically have the same questions at the end of a shift: "What is the level of dust in my area?" and "when will I know the results of the samples from my section?" These questions are logical, personal and reflect a health-related interest in the air quality of the work environment where miners spend a good amount of their time. Most miners are fully aware that exposure to high concentrations of respirable dust and crystalline silica (hereafter simply silica) can affect their health and future life, and many miners with longer tenure have co-workers who suffer from lung diseases caused by dust present in mines. In coal mines, these lung diseases have very well-known names — coal workers' pneumoconiosis (CWP), or black lung, and silicosis.

It is very disheartening for researchers and mine operators not to have immediate answers to these questions. The traditional dust monitoring approach entails the collection of dust samples on a filter medium, and the analysis of the dust collected and silica content are conducted in a certified laboratory with sophisticated instrumentation. Generally, days or weeks pass before results can be summarized in a report to be shared with the mine, and eventually with the workers who asked those important questions.

Many health and safety managers at coal mines collect respirable dust samples in the mine to check the silica dust levels, even though the new coal dust rule does not require them to do so. This reflects a growing health and safety culture that goes beyond just being in compliance with the Mine Safety and Health Administration (MSHA) dust rule — coal mines want to protect their workers by keeping silica dust levels low. Low levels can be achieved efficiently and cost-effectively with established control technologies, especially if mines have timely access to data on silica levels. Today's mines need a new solution to check silica levels and to have data by the end of the shift — one that is accurate, portable, fast and user-friendly — so that any engineering or operational adjustment can be implemented within the next few shifts.

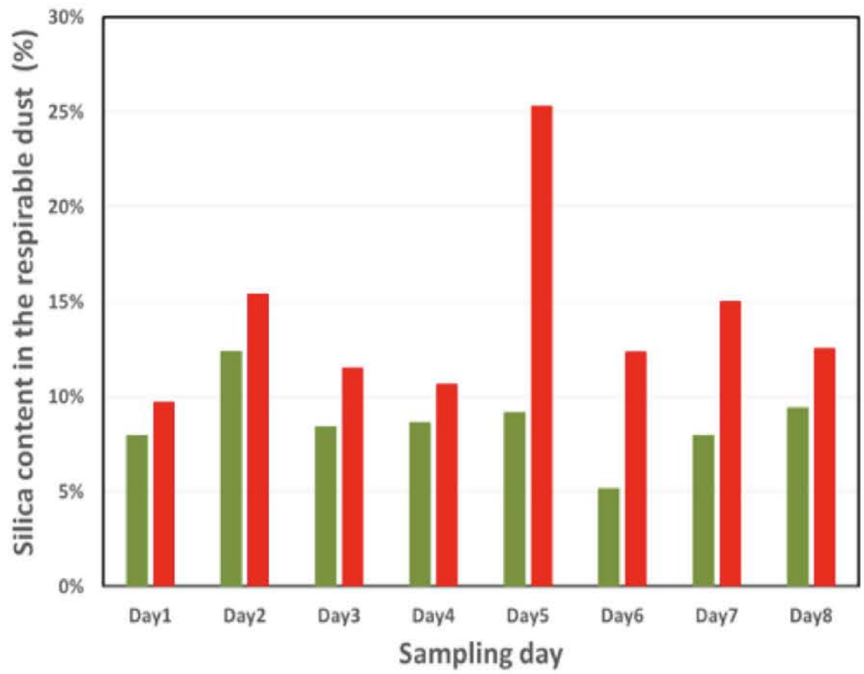


Figure 1 — Silica content in respirable dust samples collected in an underground coal mine in eight consecutive days. Minimum (green) and maximum (red) silica content is displayed for each day.

## Recent Monitoring Improvements

The introduction of the personal dust monitor (PDM) in coal mines has changed the traditional dust level measurement paradigm for the first time. Now every worker wearing a PDM will have an indication of his or her exposure to respirable dust during the shift, and accurate information on the shift average exposure at the end of the workday. The data stored in the PDM can also be used to identify tasks with high dust concentration levels and allow operators to act before the following shift.

While the PDM is a revolutionary improvement over the traditional dust monitoring approach, it is not selective in monitoring the components inside the dust — specifically silica. Exposure to silica in coal mines is the major cause for the development of silicosis and lung cancer, and a significant contributor to black lung. Silica is an inherent part of the dust present in a coal mine, but the silica content in the dust is highly variable both in space and over time. Because of this variability and the serious health effects related to the exposure, MSHA has included in the new dust rule a stand-alone exposure limit for silica concentration, in addition to the adjustment of the allowed dust exposure limit.

The Office of Mine Safety and Health Research (OMSHR), part of the National Institute for Occupational Safety and Health (NIOSH), has recently started an initiative to provide mines and mine workers with an innovative solution for measuring silica levels in airborne respirable mine dust and obtaining results at the end of the shift. When optimized, this new approach will use a small portable instrument into which a dust sample cassette will be inserted, and in a few minutes the silica present on the filter will be quantified. With just a few simple steps — including measuring flowrate and

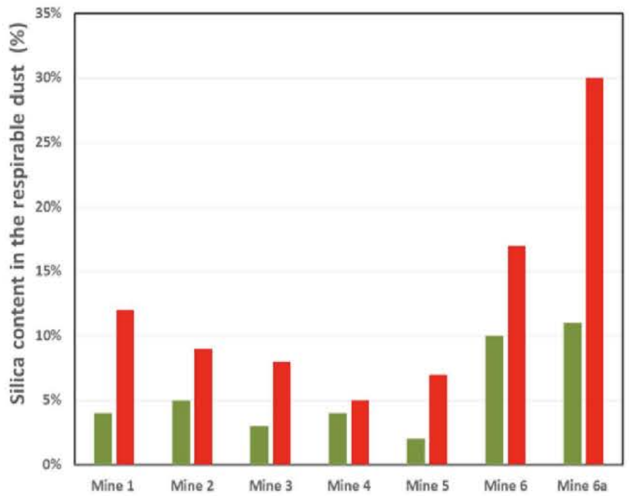


Figure 2 — Silica content in respirable dust samples collected in six different coal mines. Minimum (green) and maximum (red) silica content is displayed.

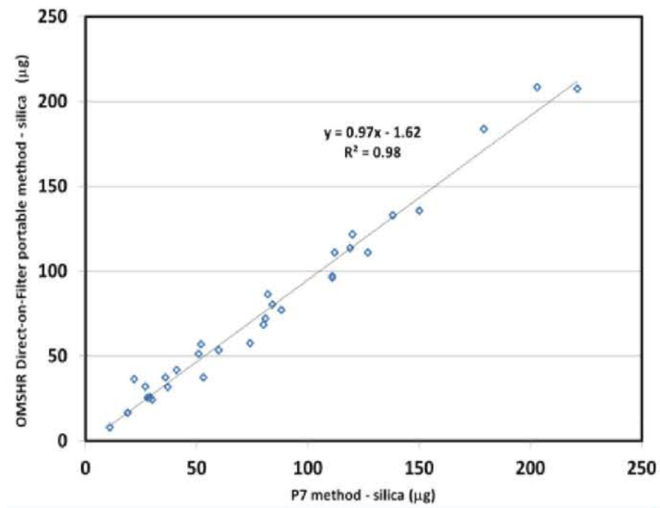


Figure 4 — Comparison of OMSHR direct-on-filter estimation of silica in dust samples collected in an underground coal mine with the results of the P7 standard analysis.

recording the sampling time — the average silica concentration in the area where the sample was collected can be calculated. This process can be done in just a few minutes at the end of a shift, rather than the few weeks required to complete the traditional practices.

## Why a New Monitoring Solution is Needed

The importance of measuring silica at the end of shift is driven by the fact that just knowing dust levels is not enough — since the amount of airborne silica in the dust can vary significantly in both space and time, exposure to dust is not always indicative of silica exposure. As an example, measurements of silica made in the same area of a mine over multiple days show considerable variation (see Figure 1).

Figure 1 shows the results, in terms of silica content (%), in respirable dust samples collected for eight consecutive days in the same continuous miner section of an underground coal mine. Four samples were collected each day in different locations of the same section. The minimum (green) and maximum (red) percent of silica found in the samples each day are shown. While the daily silica content in the samples was on average quite consistent — around 10% — a large spatial variability can be noticed, especially after day four.

In this case, did the mine operator know there would be a relatively high silica content in the respirable dust? Probably. For example, miners know that silica levels will be higher when they need to mine more roof rock to accommodate equipment clearance. What the miners generally don't know is how the silica content in the dust will vary, both in space and over time. Figure 1 is a good example of the high temporal and spatial variability of the silica content in the respirable dust generally present in a coal mine.

Figure 2, which depicts the minimum (green) and maximum (red) silica content in respirable dust samples collected in six mines, demonstrates clearly a mine-to-mine variability. For each mine, samples (10 or more) were collected over one or two days. For some mines — for example, Mine 4 — the silica content in the samples is quite constant. For other mines — for example, Mine 6a — the silica content can vary from 12% to 30%. Importantly, note that one of the mines was sampled twice in two different years (Mine 6 and Mine 6a), and the data show significant difference in airborne silica for the two visits.

Knowing that the silica content in the dust can be variable — even in the same section of a coal mine — and that it can also change over time, it is clear why the traditional silica monitoring approach is not able to provide a timely picture of worker exposure or dust levels in an area. Put simply, the silica concentration, expressed as micro-

Figure 3 — Three steps for the new monitoring solution: (left) open the sampling cassette; (center) insert the cartridge in a holder; and (right) place the holder in the portable instrument.

grams per cubic meter (μg/m³) of air, can be as variable as the silica content in the dust. Obviously, then, by the time the results of the traditional method are back from the laboratory, dust and silica levels in the mine might be completely different, and because of the variability in silica content, even the PDM can provide only very limited information on silica levels.

## How the New Solution is Going to Work

The new monitoring solution being developed by OMSHR combines the current practice of collecting respirable dust samples for silica analysis with the use of a portable instrument for the immediate determination of silica collected in each sample.

Since coal mines already have personal sampling pumps and dust samplers, this initiative builds on the availability of these devices and their already established use for sampling silica in the mine. Even the sampling cassette currently used in coal mines will be the same. In the future, an optimized cassette or a new sampler might be useful for the in-field determination of silica in the dust sample (in fact, efforts are already in progress to investigate possible options), but the immediate goal is to minimize any change in current practices for mine operators.

What will be different? At the end of the shift, the person in charge of the dust sampling will simply open the plastic portion of the sampling cassette and insert the filter cartridge in the compartment of a portable instrument (see sequence in Figure 3). Within one minute, the instrument will provide an estimation of the amount of silica collected and an average silica concentration in the section where the sample was collected.

OMSHR is currently testing several commercially available instruments for their use with this new monitoring solution, and they are all lightweight enough to be transported in a Pelican case, while still being robust enough to be used in the field. The portable instrumentation will be an infrared analyzer that uses what is commonly known as a direct-on-filter technique, which means that the dust sample does not need to be removed from the filter to be analyzed (such as is done in lab-based methods). An infrared beam simply passes through the dust-laden filter and is analyzed by a sensitive detector on the other side. A mathematical protocol optimized by OMSHR will be used to quantify the silica based on the detector response.

The first and foremost benefit is the quickness of the overall process. In a short period of time and with little effort, it will be possible to measure silica level for multiple samples, which translates to increased power of the results. When a section foreman knows the level of silica dust within a few hours of the end of the shift, an intervention to address high levels can be implemented right away, and the effect of the intervention could be assessed within a few shifts.

## Development of the New Monitoring Solution

OMSHR has thoroughly investigated the use of a portable infrared instrument for the direct-on-filter analysis of silica in coal dust samples, and our positive test results have generated increasing confidence in the success of this new approach. A calibration for the new method using samples prepared from standard silica materials was developed. Performance of the method was further verified using coal dust samples collected in a dust chamber at the OMSHR laboratory in Pittsburgh. That evaluation included dust samples from different coal sources, all containing silica.

Once the method was verified with dust samples generated in a controlled dust chamber environment, they decided to challenge the methodology with samples collected in active mines. So far the method has been tested with more than 150 samples collected in several coal mines, including surface mines. The in-field study is providing data to adjust the calibration of the method, to study the sensitivity of the analysis, and to verify that the method can work for samples collected in mines with different geologies. While this effort is still in progress, the technique has shown sufficient sensitivity to provide accurate estimation of silica in the dust samples, down to less than 20 μg of silica. This amount corresponds to an average silica concentration of 20 μg/m³ for a full 8-hour shift — well below any action limit enforced by MSHA in coal mines. In our tests, the accuracy of the estimation for each sample is always verified with the MSHA P7 method for silica quantification, which is possible because the OMSHR in-field technique does not destroy or disturb the sample.

The samples collected for the data in Figure 1 were analyzed using both methods, and the results generated with our direct-on-filter technique compared well with the P7 method results (see Figure 4), with a coefficient of 0.97 — very close to the ideal 1 for a perfect correlation. This very strong correlation is also true for "lightly loaded" samples (i.e., containing less than 50 μg of silica).

## Implementing the Solution

OMSHR researchers are continuing to develop the direct-on-filter method with the intent of encouraging mine companies to adapt it as part of their strategy to help reduce exposure to silica. Future research includes:

1. Verification of the technique with dust samples collected in more coal mines, both underground and in surface operations. The goal is to optimize the calibration process to cover any possible variability in geology. For this reason, any collaboration with active coal mines is welcomed.

2. Creating a step-by-step process or standard operating procedure to guide mine operators and health and safety managers through the use of this new technique. When the technique is deployed, these individuals will ultimately be in charge of the analysis. The process will include the periodic verification of the technique with standards, the interpretation of the results, and basic data analysis.

3. Creating a user-friendly software that will contain the step-by-step process described above. This software will be most likely a NIOSH product, freely distributed to the coal mine industry.

4. Beta testing the new solution in coal mines so that we can get feedback and comments are received on how the analytical process and software interface can be optimized for usability. For this purpose, again, OMSHR is very interested in collaboration with active coal mines.

This new monitoring solution has the potential to help reduce worker exposure to silica, and thereby reduce the number of future cases of silicosis in coal miners. It will also empower mine workers and health and safety managers to help them achieve one of their shared goals — to protect the health of coal miners in the present and the future.

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## Disclaimer

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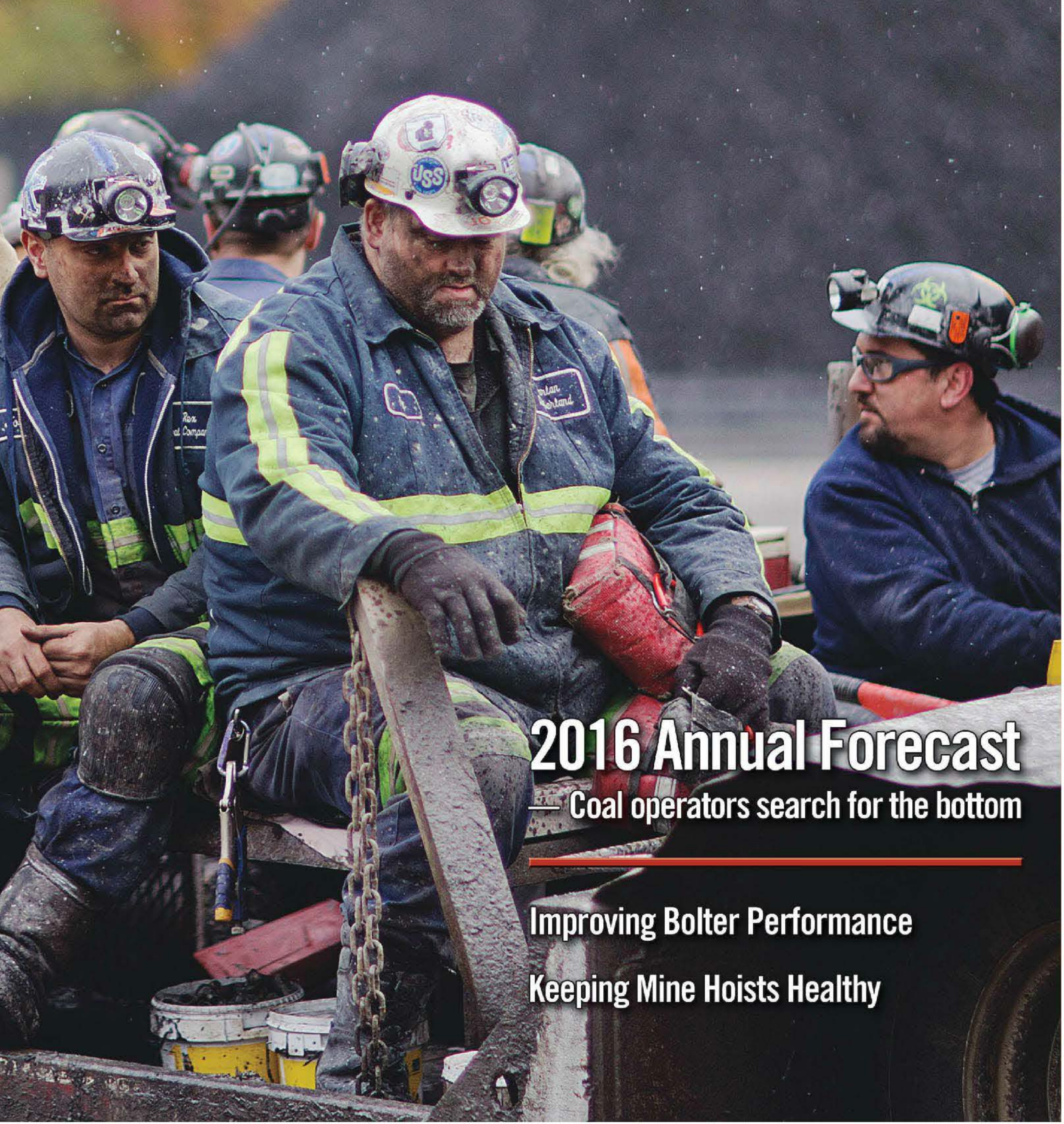

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