Will Single Full-shift Samples of Respirable Dust Accurately Represent the Long-term Compliance Status for Respirable Coal Mine Dust Exposures?

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Executive Summary

MSHA and NIOSH recently issued a joint statement regarding the appropriateness of using single shift personal air samples to assess compliance with the MSHA respirable dust standard, 2.0 mg/M^3. To accomplish this MSHA is attempting to change the current regulatory basis of their compliance program. The current operator and inspector sampling programs are described in detail below.

MSHA is seeking to delete wording from the original notice of finding published on July 17, 1971 and again on February 23, 1972. This wording eschews the use of single personal breathing zone samples to determine the "average" dust concentrations to which each miner is exposed. In the 1971 and 1972 findings, MSHA determined that "a single shift measure would not, after applying **valid statistical techniques**, accurately represent the atmospheric conditions to which the miner is continuously exposed." MSHA and NIOSH are now proposing that "a single full-shift measurement after applying **valid statistical techniques** to such measurements accounting for the precision of the analytical and sampling errors, will accurately represent the atmospheric conditions with regard to the respirable dust concentration during the shift in which it was taken."

MSHA/NIOSH indicated that the "new" sampling program will not only use the average of five or more samples collected, but they will also evaluate compliance on the value of a single sample within the five above. They also indicate that they have changed the statistical basis for compliance. In the past, MSHA has used the 86% confidence interval to assess compliance. The basis for this change appears to be the incorporation of the NIOSH/OSHA sampling strategy (this strategy is also used in Metal and Non-metal mining enforcement efforts). After applying what MSHA and NIOSH have deemed to be appropriate sampling and analytical errors to anticipated air sampling results, a table of non-compliance results has been created. This table established the values of either single samples or averages of up to and including five samples that would result in a non-compliance or compliance determination.

The MSHA/NIOSH proposal states that based on a one-side 95% confidence interval test (Upper 95% CL) that any single sample with a dust concentration greater than 2.33 mg/M^3 (MRE) or average of five samples greater than 2.17 mg/M^3 (MRE) would result in the issuance of a violation.

This approach is in error for the following reasons;

- The use of inappropriate assumptions regarding sampling and analytical variation,
- Inappropriate assumptions regarding the underlying distribution of dust sampling

results,

- Inappropriate assumptions conceming the impact of spatial and temporal variability (environmental variability),

- They are attempting to control long term average exposures by looking at short term results,

- Operators will have a high degree of having a citation for non-compliance when they are, in fact, in compliance with the respirable dust standard, and, finally,

- MSHA has only addressed the precision, e.g. sampling and analytical error. of the exposure estimate, they have not addressed the key issue, **the accuracy of the exposure estimate**.

Additionally, the need for a long-term (yearly average) approach for the determination of compliance or non-compliance with the respirable dust standard will be discussed.

The conclusions of this study are:

- The sampling and analytical error assumed by MSHA is a very conservative estimate based on unpublished data and data that are not reflective of the variation observed in most studies of exposure to respirable coal mine dust.

- MSHA assumed that the distribution of respirable mine dust concentrations is normally distributed. The majority of scientific literature indicate the respirable mine dust measurements are log-normally distributed. The result of this assumption is to reduce the estimation of the variance. This will lead to decisions of non-compliance when the samples actually demonstrate compliance with the respirable mine dust standard.

- The number of samples, 1 or 5, proposed by MSHA are significantly less than number of samples required to ensure that the sample mean is within $\pm$20% of the population mean (90% confidence). Our estimates, based on long term sample results (one year) indicate that one must collect a minium of 6 samples in some mines, but more than 30 in many others. The reason for this disparity is the range of variation seen in the sampled mines.

- MSHA has severly underestimated the sampling and analytical error associated with the measurement process.

- MSHA has ignored enviromental variability which means that their estimate of the total variability associated with the measurement process is grossly overconservative.

- MSHA is attempting to regulate long term exposures on a short term basis. The approach proposed by MSHA does not reflect the chronic nature of the dust hazard. The exposure result of a single day has little impact on the cumulative average exposure and, therefore has little meaning with regard to controlling chronic health hazards.

Study Outline and Methods

In order to evaluate the impact of the proposed changes in the respirable coal mine dust program, we have:

1. Reviewed the statistical basis for the proposed approach;

2. Collected respirable coal mine dust samples from active mines employing continuous and longwall mining methods to assess intraday variability; and

3. Using valid statistical techniques, evaluated the MSHA/NIOSH proposal to assess compliance;

a. the probability of assessing non-compliance when the mine is in a state of compliance,

b. the impact of distributional assumptions on the determination of compliance or non-compliance.

History of Program to Assess Respirable Mine Dust Exposures

In 1969, the Mine Safety and Health Act was passed. One intent of the Act is to protect coal mine workers from the development or progression of pneumoconiosis in miners exposed to respirable coal mine dust. Specifically, the Act states "that each operator shall continuously maintain the **average** concentration of respirable dust in the mine atmosphere during each shift to which each miner is the active workings of such mine is exposed at or below 2.0 milligrams of respirable dust per cubic meter of air."

The definition of average is dependent on the assumption of an underlying distribution of sample results that can be either normal or some deviation from normal, e.g. log-normal. Recognizing that average can be interpreted in several ways, the Secretary of Labor sought comments from interested parties regarding this issue. This effort was conducted twice, 1971 and 1972.

The Federal Coal Mine Safety and Health Act of 1969 first established the respirable coal mine exposure monitoring program. In this legislation, the monitoring requirements for respirable coal mine dust focused on collection of 10 consecutive shift air samples to establish the "average" exposure for respirable coal mine dust. Ten consecutive shift samples were demonstrated as the minimum number of samples necessary to encompass with certainty (100%) the "average" dust concentration in the breathing zone of miners "which accurately represent the atmospheric conditions with regard to respirable dust to which each miner in the active workings of a mine is exposed." The recommendation of 10 air samples was based on a Bureau of Mines study of 2,179 air samples collected from active section that were in compliance with the dust standard on the date of analysis. The average dust concentrations were compared with the average of the two most recently submitted samples of respirable dust, then with three, four, five, six, seven, eight, nine and ten most recently submitted samples of respirable dust. This study demonstrated that the average of two recently submitted respirable dust samples was statistically comparable to the overall average only 9.6% of the time. In other words, 93.4% of the time the average of two respirable dust samples would not accurately represent the "average" respirable dust concentrations in the mine. With regard to a single sample, this study clearly demonstrated that a "single shift measurement of respirable dust, after applying valid statistical techniques, would not represent the atmospheric conditions to which the miner is continuously exposed." [1]

In 1972, the Office of the Secretary for the Department of Health, Education, and Welfare issued a "Notice of Finding" that further clarified this issue by rejecting comments that questioned the validity of this approach. In this publication, the Secretary indicated that the "Departments intended to revise Part 70 of Title 30, Code of Federal Regulations, to improve dust measuring techniques in order to ascertain more precisely the dust exposure of miners." The revisions were intended to allow for the collection of a single shift dust sample to determine compliance after taking into account (1) the variation of dust and instrument conditions inherent in coal mining operations, (2) the quality control tolerance allowed in the manufacture of personal sampler capsules, and (3) the variation in weighing precision allowed the Bureau of Mines laboratory in Pittsburgh." [2]

In 1977, the Federal Coal Mine Safety and Health Act of 1969 was amended and became known as the Federal Mine Safety and Health Act. It was in these amendments that the current respirable dust sampling program was established. The current program call for "the average concentration of respirable dust in the mine atmosphere during each shift to which each miner in the active working of a mine is exposed must be continuously maintained at or below 2.0 milligrams of respirable dust per cubic meter of air as measured with an approved device."

Historical Approach to Respirable Coal Mine Dust Exposure Assessment

National Bureau of Standards Study (1975)

In 1975, the National Bureau of Standards issued a report on the sources of variability associated with the proposed mine dust sampling program administered by the Mine Enforcement and Safety Administration (MESA).[3] MESA is the predecessor to MSHA. This study reviewed current studies conducted by other agencies and or by the coal industry, made visits to operating coal mines, conducted an investigation on the approved dust sampling equipment and conducted a series of weighing experiments to estimate the variability associated with the analytical processes. Within this investigation, the variability associated with dust sampling in coal mines was quantitated.

The sampling protocol in use in the mines (as specified by 30CFR, Parts 60, 70, and 90) dictated that a miner wear the personal sampling pump from portal to portal for a full eight hour shift (480 minutes), and that the flow rate be set at 2.0 L/min. The flow rate was checked after the first hour. At the end of the sampling period, the mine operator (or MESA inspector) removes the filter cassette, and fills out the dust card with information on production rate, length of sampling period, and mine identification. The dust cassette and card are then sent to the Pittsburgh Technical Support Center for analysis. This protocol is not significantly different from that used today.

This study concluded that errors associated with respirable mine dust estimates was approximately 32% or $\pm$ 0.64 mg/M^3. They also concluded that for 10 samples, the uncertainty in the exposure estimate could be reduced to $\pm$ 20% or $\pm$ 0.4 mg/M^3.

National Academy of Sciences/National Research Council Study

In 1980, the National Academy of Sciences published a review of the science surrounding control and measurement of respirable mine dust.[4] The results of this investigation indicate that for "trained personnel who can afford to devote the same range of care and attention to the instruments that were exercised by the research scientists involved in this study" the expected average uncertainty (expressed by the standard deviation, s.d.) is estimated to be around 0.6 mg/M^3, or approximately 30% for samples indicating airborne dust concentrations of 2.0 mg/M^3. This result was obtained with a series of 10 consecutive air samples.

Regulatory Agency and the American Industrial Hygiene Association Approach to Assessing Exposure

OSHA

OSHA uses a regulatory strategy that is based on the collection of one or more exposure estimates.[5] Specifically, OSHA's policy for assessing exposure states that the safety and health compliance officer shall "take a sufficient number of samples to obtain a **representative estimate of exposure. Contaminants concentrations can vary seasonally, with weather, with production levels and in a single location or job class.**" (Emphasis added) (Chapt. 1, Compliance Safety and Health Officers (CSHOs) Manual 1994). The manual goes on to state that the number of samples taken depends on the error of measurement (**SAE**) and difference in results (**environmental variation**). Paragraph 5 of Chapter 1, also states that "If an employer has conducted air sampling and monitoring in the past, review the results." This statement is further clarified in the CHSOs Technical Manual. In Chapter 1, paragraph 4, of this manual, OSHA guidance is that:

> Environmental Variables. Environmental variables generally far exceed sampling and analytical errors. Samples taken on a given day are used by OSHA to determine compliance PEL's. However, where samples are taken over a period of time (as is the practice of some employers), the CSHO should review the long term pattern and compare it with the results he/she obtains. Where OSHA's samples differ substantially from the historical pattern, the CSHO should investigate the cause of their difference and perhaps conduct additional sampling.

It is clear this review from that OSHA considers long term exposure estimates and patterns to have substantial weight in the assessment of compliance with PELS. It is also clear that where these data exist that OSHA intends to consider these data as more representative of **average** exposure than the measurement of a single days exposure.

MSHA historical approach

The dust sampling strategy used by the Mine Safety and Health Administration (MSHA) involves two separate programs. These are the Inspector and Operator sampling programs. Under the Operator sampling program, the mine operator must collect bimonthly samples on the "designated occupation or area" to ascertain compliance. These samples must be collected on five consecutive production shifts or days. The "designated occupation" is that occupation which is thought to have the highest exposure of miners on the face.

The dust sampling strategy used in the Inspector sampling program has the Inspector sampling every face occupation on the first day of an inspection. The sampling protocol may be modified after the Inspector has reviewed the results of the first days monitoring. If the results of the sampling indicate that some of the face occupations are less than the permissible level (Table 1, page 1.12, MSHA Inspectors Manual, 1989)[6] then those occupations are considered to be in compliance and further sampling is not conducted. At the very least, the Inspector must collect 5 or more valid samples on the section.

Specifically, the MSHA Inspectors Manual states that:

> (1) The combined average of five or more valid samples taken on the first day of sampling on all occupations is equal to or less than the applicable standard for the designated occupation, provided no sample is greater than the applicable standard for the designated occupation.
>
> (2) The average dust concentration of five or more valid samples taken over 2 to 5 days on all occupations is equal to or less than the applicable standard for the designated occupations.

(3) The average dust concentration of valid samples taken over 2 to 5 days on one occupation (collected as a result of a previous sample which was greater than the applicable standard) is equal to or less than the "In Compliance" value shown in Table 1.

(4) The average dust concentration of less than five valid samples (which must include the designated occupation) taken on all occupations on the first day is equal to or less than the "In Compliance" value shown under the applicable standard column in Table 1, provided no sample is greater than the applicable standard for the designated occupation.

It is clear that both MSHA and OSHA have recognized that sample variability, in particular, environmental variability (spatial and temporal) plays a key role in assessing compliance with applicable standards. Additionally, it is clear from the above, that neither administration believes that a single exposure assessment will provide scientifically defensible evidence of overexposures.

The American Industrial Hygiene Association

The American Industrial Hygiene Association recently published a manual for development of sampling strategies in the occupational setting.[7] In this manual, the AIHA Occupational Sampling Strategies Committee discuss the basic underlying assumptions of the recommended sampling strategies which includes a discussion of the expected distributions of exposure results, the results of sample numbers on decisions such as compliance determinations, etc. This work updates the earlier efforts of Lidel and Bush (NIOSH, 1976) and provides a sampling rationale which accounts for all sources of variation, environmental (temporal and spatial), sampling and analysis.

In this report, the committee recommends that the minimum number of samples that need to be collected to obtain accurate estimates of the "true" average exposure is between **6 and 10 samples**. The report states that less than 6 samples results in large potential losses in accuracy. Two samples is minimum number of samples that can be used to assess exposure according to the report. Additionally, the committee demonstrated the effect of sample size on the estimate of the variance. The use of 4 or fewer air sampling can result in severe underestimates (factors ranging from 8-10) of the variation.

Sampling Assumptions and Statistics

The purpose of a sampling strategy can be to assess compliance with occupational exposure levels or PELs, to assess the effectiveness of environmental controls, e.g. local exhaust ventilation, or to characterize working population exposures. Each of these expected outcomes can result in a different approach to sampling. In the case of assessing compliance with the respirable coal mine dust standard, a worst case scenario has be adopted as the strategy. In any case, the results obtained from respirable dust monitoring can not be assumed to be constant.

Assumptions

Distribution of Air Monitoring Results

Normal Distribution

The normal distribution is depicted as a bell shaped curve with mean (average) which describes the most likely value, and the standard deviation (s.d.) which describes dispersion in the sampling results. Figure 1 is a typical normal distribution with a mean equal to 2 and a standard deviation equal to 1.

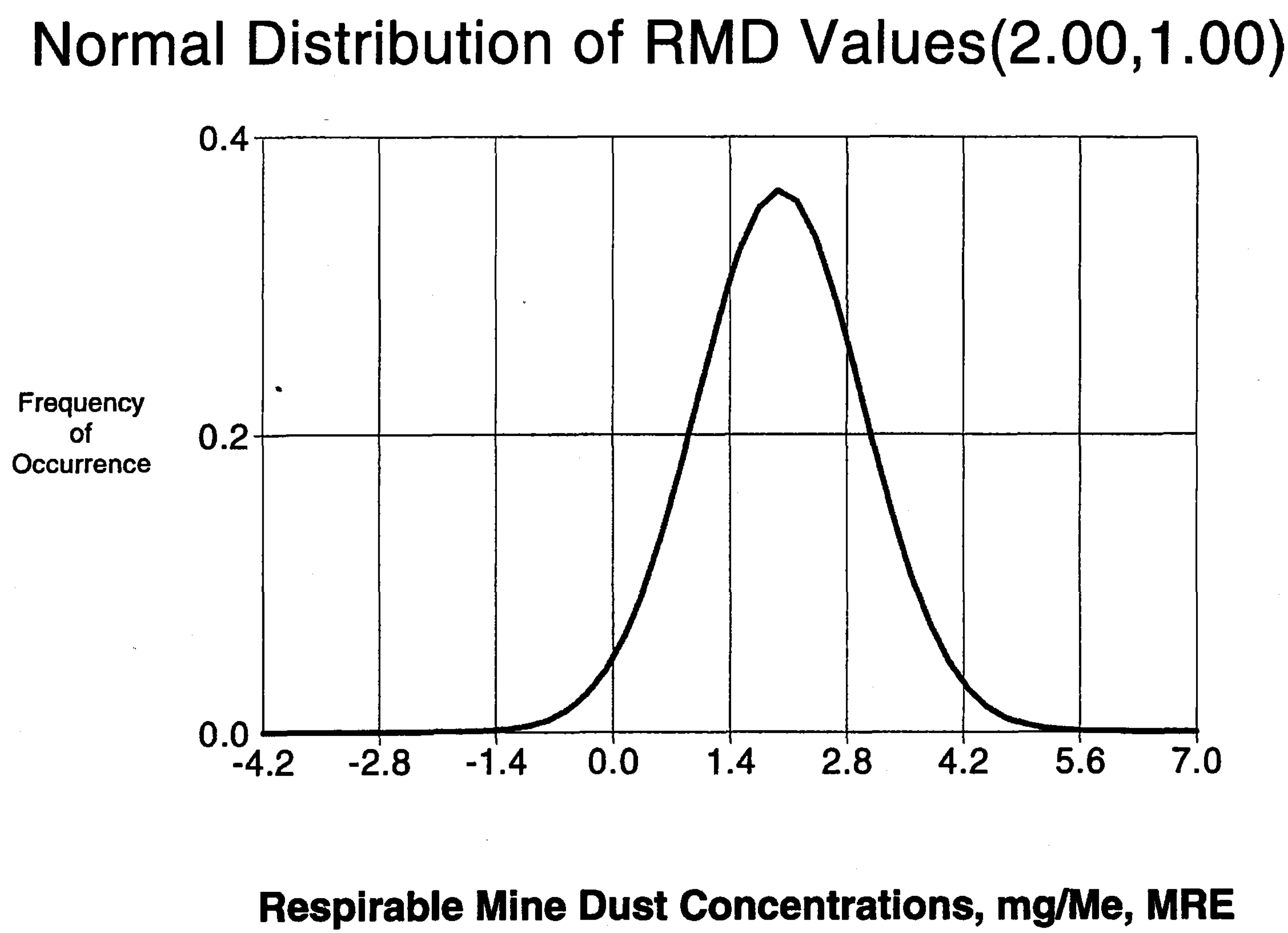
In the MSHA/NIOSH proposal, they have assumed that the "average" respirable mine dust exposure is that exposure that the miner encounters during the course of a single shift. They have built a rationale around an assumption that if one accounts for the dispersion in the data that is known or quantifiable, referred to as the sampling and analytical error, then the compliance status for the monitored occupation can be ascertained. MSHA/NIOSH have also assumed that the results of respirable coal mine sampling are best described by a normal distribution. This assumption is unsupported by the scientific literature.[8,9,10] Use of this distribution to describe air sampling results that are more appropriately log-normally distributed can result in severe underestimation of the "true" variation in the sampling data.

Log-normal Distribution

The log-normal distribution has been described as the distribution that typically best describes occupational and environmental sampling data.[8,10,11] The reasons given for this assumption center on the processes affecting the generation of contaminants, how workers are exposed, etc. The typical log-normal distribution can be characterized by the geometric mean and geometric standard deviation (GSD). A typical log-normal distribution with a geometric mean of 2 and a geometric standard deviation is shown in figure 2. The geometric mean indicates the most likely value while the GSD is a measure of the dispersion of sampling results. The smaller the GSD the more likely that the sample results are normally distributed.

In the research of Hall, et al., air samples from 6 mines demonstrated geometric standard deviation ranging between 1.08 and 4.22, indicating significant dispersion in the air sampling results. The median GSD for these mines was 1.86.

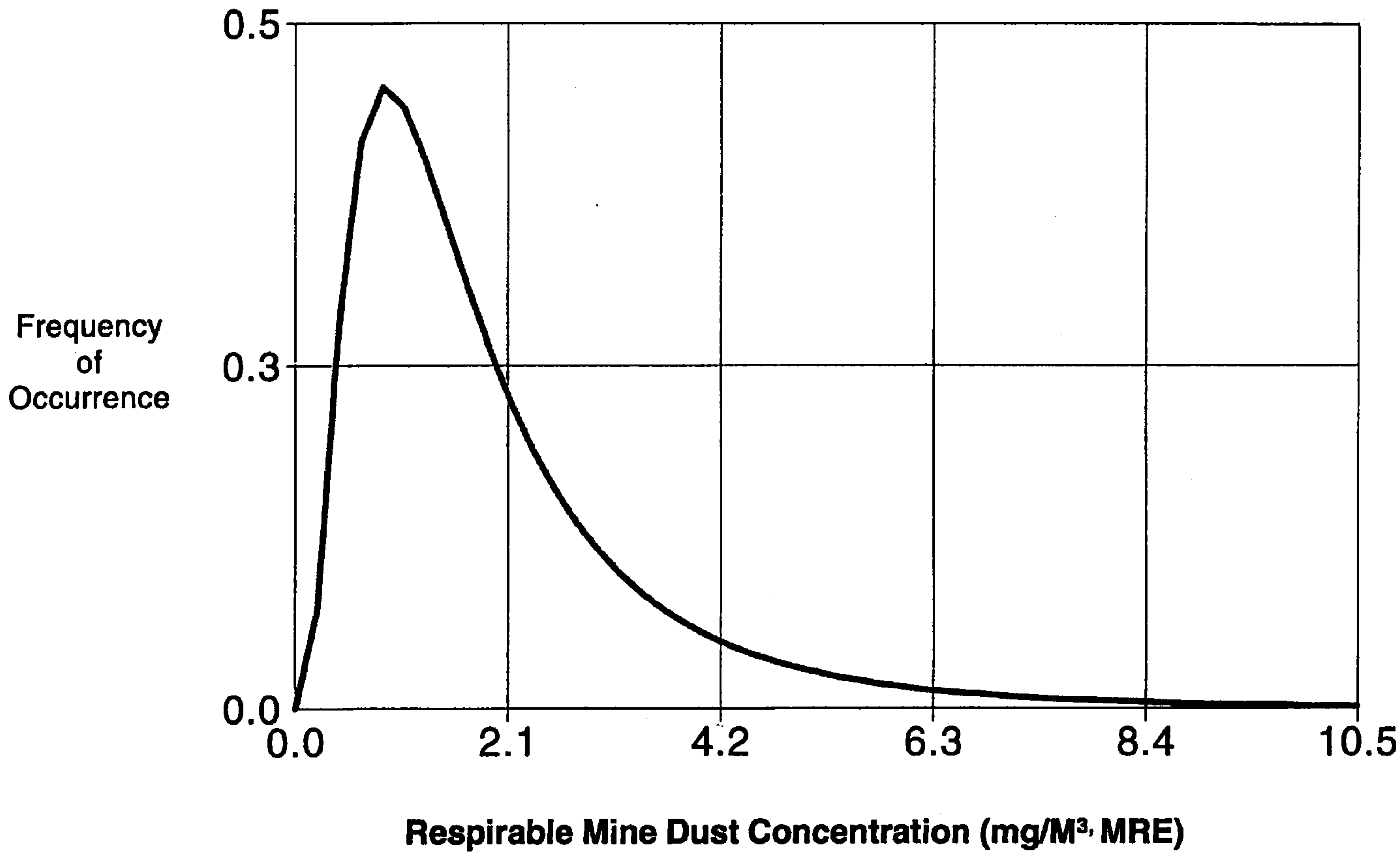
Figure 1



Normal Distribution of RMD Values(2.00,1.00)
0.4
0.2
0.0
Frequency of Occurrence
-4.2
-2.8
-1.4
0.0
1.4
2.8
4.2
5.6
7.0
Respirable Mine Dust Concentrations, mg/Me, MRE

Figure 2

Lognormal Distribtuion of RMD Values(2.00,1.70)



Average (Mean) or Geometric Mean

A common statistical problem centers on how one can obtain a representative estimate of the average or expected value from a distribution of potential values, in this case respirable mine dust exposures. The "true" distribution of respirable mine dust concentrations can never really be determined because there are potentially infinite number of outcome possibilities. To solve this problem, scientists typically collect a sample from the infinite distribution and infer from this sampling the characteristics, mean (average) and dispersion (as the standard deviation) of sampling results. This dispersion results from error associated with the sampling and analysis process (random errors). At issue is how accurate and precise are the sampling results such that inferences, such as how the sample mean compares to the "true" mean (accuracy) and how reproducible are the sample results (precision). Each of these issues and how MSHA assumptions affect estimates of the "average" exposure.

Because it is typically not possible to obtain all of the potential sample results that comprise the distribution of respirable mine dust exposures, a sample is taken from this distribution and inferences are made about the distribution, the mean or average exposure, etc. A key question is how many samples does one need to take to obtain a reliable estimate of the average or mean. The estimate of the mean is dependent on the number of samples used to make the estimate and the variation of the distirbution that best describes the dust sampling results. Small numbers of samples can result in inaccurate and imprecise estimates. In Table II and III, the summaries of historical sampling results, the number of samples necessary to be at least 90% confident that the estimate of the average or mean exposure is within 20% of the true population mean.

Variation (Precision and Accuracy)

Variation is a measure of the dispersion of data about some central value, typically, the mean. Variation is comprised of sources of error, the error associated with the sampling and analysis process (SAE) and environmental (temporal and spatial) variability, [5,8] Typically, worker activities, e.g. moving in and out of zones of varying contaminant concentration, impart the largest component of observed errors in the measurement process. Typical estimates of the contributions to variability from these sources clearly indicate the SAE contributes the smallest component to the total. While SAE is typically assumed to be less than 10-25% of the total variability, the variability associated with space and time (inter and intraworker variability) is in the range 90-250%.[13] Although environmental variability provides the greatest contribution to observed variability, it is the most difficult to estimate. The MSHA/NIOSH approach has assumed that because of the difficulty associated with the estimation of this parameter, it can be ignored if the exposure monitoring results of a single day's exposure can be used to assess compliance.

Sampling and analytical errors include the error or variation associated with the pump calibration, pump flow, adjustment of the pump while underground, and weighing errors in the analytical laboratory. In this approach, the sampling and analytical errors are assumed to be normally distributed.

NIOSH has estimated that the SAE associated with the MSHA exposure assessment process is approximately 10%. This assumption is based on assumed errors associated with the calibration of pump flow rates (5%), flow rate adjustments in the mine (5%) and weighing the filters (approximately 8%). The variability or error associated with the filter weighing process is well understood and is probably accurate. The variability associated with the two other components is not as well defined.

A review of the scientific literature does not support the MSHA/NIOSH assumption on variability associated with pump flow rate calibration or pump flow adjustments conducted in the mine. In particular, the National Academy of Sciences conducted a thorough review of the variability, SAE, associated with the respirable mine dust program. They concluded that the variability estimated used by MSHA were for highly skilled scientists exercising meticulous care and that more variability could be expected from less well-trained persons. This study concluded that a more reasonable estimate of the SAE was 30%;[4] almost twice the estimate used by MSHA to account for precision.

The largest potential source of errors in the assessment of exposures is that resulting from the variability associated with space and time. This is usually described as environmental variability. This variability is also the most difficult to quantify.

Estimates of variability are particularly sensitive to distributional assumptions. If the underlying distribution is log normal, the variability associated with exposure measures will be underestimated if number of samples used to estimate the variation is small. If we assume that the air sampling data are log normally distributed with a geometric standard deviation of 2.7, the number of samples required to obtain a reliable estimate of the variation is approximately 30. If five samples were collected from this distribution, the actual or "true" GSD could be underestimated by a factor of 2 [12]. The result of this underestimation will increase the probability of Type I errors. That is declaring a workplace not in compliance with the respirable dust standard when it is actually in compliance.

The research of Hall, et al., demonstrated that the average difference between paired respirable mine dust samples results collected from a variety of selected longwall and continuous mining sections was 150%.[13] Because this was a paired sample study (each miner wearing a respirable dust sampler on each lapel), the observed variation is that which relates inter and intra worker variability (temporal and spatial variability). The number of paired samples necessary to obtain a standard deviation of 0.2 mg/M^3 (approximately 10% at a respirable mine dust concentration of 2.0 mg/M^3) was 6. These authors reported that the greatest contributor to the total variation was the variation associated with measurements made across time (within worker). This variation was reported to account for 33% of the observed variation. The SAE for respirable mine dust was reported to be approximately 21% of the total observed variability. These authors also reported that sampler position (which side of lapel, on man or machine, etc) was the key factor in the observed dispersion.

Evaluation of MSHA's Proposed Compliance Strategy

In order to test the impact of the proposed MSHA compliance monitoring strategy a series of mines currently producing coal were sampled for up to 10 consecutive shifts. A total of 67 valid respirable mine dust samples were collected from 5 longwall and 3 continuous mining sections. These samples were collected using standard MSHA procedures for the Operator sampling program. The occupation monitored was the designated occupation at each section according to MSHA's regulations. This position was the continuous miner operator for continuous mining sections and the shearer operator (headgate or tailgate) for longwall sections. In mines where the shearer cuts in both directions the tailgate shear operator was the sampled position. The sampling protocol and sample results are presented in Appendix I.

The results of this sampling indicate that all of the sampled sections demonstrated "average" (arithmetic mean) exposures ranging from 0.86 to 2.13 mg/M^3 MRE. Short term (one day) exceedances were demonstrated in all but one of the sections sampled. Three of the sampled sections had exceedances on more than one sampled day. However, only one section had a mean exposure for all days sampled, 2.13 mg/M^3 MRE that exceeded the current respirable coal mine dust standard.

The coefficient of variation for the estimates of the mean in these data sets ranged from 10-67% with a mean value of 40%.

All but one of the sampled sections showed tendency towards log normally distributed air sampling results. The GSDs ranged from 1.1 to 2.53 with a mean GSD of 1.6 (median GSD = 1.5). This value is consistent with those reported in the scientific literature.

Table I shows the summary statistics of short term current respirable dust sampling results for longwalls in this study. Table II shows the summary statistics from the historical respirable mine dust concentrations from operator samples from 1992. Table III shows the summary statistics of short term current respirable dust sampling results for continuous mining sections in this study. Table IV shows summary statistics from the historical respirable mine dust concentrations from continuous mining operator samples from 1992.

Where historical and current respirable mine dust summary statistics were available from the same mine comparisons were made using Student's "T" tests. These results clearly demonstrate that the long term sampling results from longwall mining operations, e.g. larger sample sizes, provide statistically significant different ($p = 0.05$) estimates of the average dust exposure and of the estimates of dispersion. Because of the larger number of samples covering a longer period of time, these data should provide a more stable and accurate assessment of the mean or average exposure and the dispersion.

A pertinent question to ask of this data is "what is the probability of a single sample indicating an overexposure when, in fact, overexposure is not occurring. Assuming that each sampling event is independent and that the probability of the event happening is between 0 and 1, we can calculate the expected probabilities from the cumulative distribution curves of the historical respirable mine dust samples. Using the results of the historical sampling on long walls and continous mining section it can be seen that there is at least a 1 in 6 or 17% probability that any single sample can show a potential overexposure when one does not exist.

Table I. Results of Current Sampling in Active Longwall Operations

Mine #	1	2	3	4
Type	Longwall	Longwall	Longwall	Longwall
Sample Size	10	9	10	5
AM	1.70	1.60	2.00	1.80
Stnd. Dev.	0.43	0.87	0.66	0.16
GM	1.50	1.40	2.00	1.80
GSD	1.20	1.60	1.20	1.10
N	13	52	30	2

N = the number of samples necessary to estimate the mean ± 20% with 90% confidence. $n = 2.72\sigma^2/L^2$
σ = population standard deviation
L = L ± 20%, $L^2 = 0.04$

Table II. Results of Historical Sampling in Active Longwall Operations

Mine #	2	3	4	5
Type	Longwall	Longwall	Longwall	Longwall
Sample Size	30	20	41	16
AM	1.50	1.10	1.60	1.80
Stnd. Dev.	0.67	0.71	0.65	0.90
GM	1.06	1.02	1.50	1.70
GSD	2.10	1.70	1.50	1.50
N	30	35	30	55

N = the number of samples necessary to estimate the mean ± 20% with 90% confidence. $n = 2.72\sigma^2/L^2$
σ = population standard deviation
L = L ± 20%, $L^2 = 0.04$

Table III. Results of Historical Sampling in Active Continuous Mining Operations

Mine #	1	2	3	4	5
Type	Continuous Mining	Continuous Mining	Continuous Mining	Continuous Mining	Continuous Mining
Sample Size	30	98	75	46	19
AM	1.50	1.20	1.20	0.70	0.70
Stnd. Dev.	0.67	0.85	1.0	0.36	0.46
GM	1.38	0.97	0.95	0.61	0.57
GSD	1.60	2.00	2.30	1.67	2.00
N	30	50	70	9	15

N = the number of samples necessary to estimate the mean ± 20% with 90% confidence. $n = 2.72\sigma^2/L^2$
σ = population standard deviation
L = L ± 20%, $L^2 = 0.04$

Table IV. Results of Current Sampling in Active Continuous Mining Operations

Mine #	1	3	4	5
Type	Continuous Mining	Continuous Mining	Continuous Mining	Continuous Mining
Sample Size	6	10	9	5
AM	1.20	1.60	1.10	0.80
Stnd. Dev.	0.84	0.87	0.34	0.52
GM	0.90	1.40	1.10	0.60
GSD	2.20	1.60	1.30	1.50
N	48	48	8	18

N = the number of samples necessary to estimate the mean ± 20% with 90% confidence. $n = 2.72\sigma^2/L^2$
σ = population standard deviation
L = L ± 20%, $L^2 = 0.04$

Conclusions

The issue of using a single air sample to estimate compliance with PELs has received much attention in the scientific literature.[8,14,16] The published literature has demonstrated that a single day's measure of exposure does not provide an accurate representation of long-term exposure, is not relevant to health outcomes from exposure to chronic toxins and can lead to misleading interpretations with a high possibility of making an incorrect decision regarding the compliance or non-compliance status of the environment.

The central issue in question is the accuracy of a single sample in assessing the long term exposure of miners to respirable mine dust. As described earlier, respirable mine dust concentrations show great variability. The more variability that exists in the distribution of respirable mine dust concentrations the smaller the probability that a single day's sample will accurately describe the "average" exposure of a miner. As Hall, et al., demonstrated in their study of respirable mine dust variability, it is not uncommon to observe differences in measured respirable mine dust concentrations of 250-350%.[13] Clearly, if a single sample is used to assess exposure to respirable mine dust, placement of the sampling port could have a major impact on the outcome. Although NIOSH has reported that a single sample is an unbiased estimate of the "true" exposure, they have not addressed the issue of how accurate the sample is in describing the "true" exposure. **An unbiased estimate does not mean accurate.**

The approach MSHA/NIOSH have proposed is based on "superimposing a measure of the precision of the measurement on the value of a single measured exposure." This approach does not account for the actual variability in respirable mine dust concentrations. Additionally, the estimate of SAE used by MSHA is unsupported by the scientific literature. The basis for the assignment of a 5% error in pump flow due to underground adjustment is unclear. Based on this review and that of the National Academy of Sciences/National Research Council, the assignment of a 16% SAE appears low. A more defensible estimate is approximately 30% [9].

Rappaport evaluated the impact of sample size based on the underlying distribution of expected contaminant concentrations.[15] Additionally, he assessed the importance of a single day's exposure on the outcome of exposure to a chronic health hazard. In this research the probability of obtaining an exposure measurement that indicates non-compliance when only one exposure out of 189 days exceeded the applicable standard was 10%. From the historical data collected from longwall mining operations used in this study, it can be seen that the probability of collecting a sample that would lead to a non-compliance determination (measured concentration > 2.33 mg/M^3 MRE) when the yearly average (1.66 mg/M^3, MRE) is significantly less (Upper 95% Confidence Limit = 1.85 mg/M^3 MRE) than the current respirable mine dust standard is 1 in 6 or 17%. This means that for every single respirable mine dust sample collected there is a 1 in 6 probability of the mine operator receiving a violation when mine conditions probably have not varied outside of the norm.

Respirable coal mine dust is considered a chronic toxin and the long term average exposure is the best measure of the risk of chronic disease. The meaning of a single day's exposure above the standard is highly questionable. Rappaport addressed this issue with the following statement when discussing variability and a single day's measure of exposure:

> The day-to-day variability observed for occupational exposures relates to the evaluation and regulation of chronic hazard. It suggests that, when daily exposures are used, the inspector can obtain accurate estimates of overall levels and variability only by measuring relatively many exposures over relatively long periods of work...... More importantly, this great variability suggests that compliance outcomes based on a few point estimates may have little to do with the degree of chronic hazard.

Because over or excessive exposure to respirable mine dust is a chronic hazard and the concentrations of respirable mine dust are highly variable the meaning of a single day's sample is of little value. Rappaport recommended that a long term sampling and exposure assessment will provide the necessary information for regulation of mine dust exposures, yet also allow for the expected variability. [15] Rappaport recommended that "decision periods, extended from a single day, to perhaps 3, 6, 13 months would also allow data to be weighted which reflect not only the current situation, but also trends involving seasonal differences or improvements in control."

The goal of exposure monitoring is the reduction of workers at risk for developing disease. The changes proposed by MSHA would not accomplish this goal. In fact, it is likely that the health risk to miners may worsen because MSHA's proposed strategy will have operators "chasing" excursions in respirable mine dust concentrations that are a part of the process variation. This can result in the operator diverting resources to try and obtain control of an exposure that is already under control.

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Appendix I
Methods and Materials for Assessment of Respirable Mine Dust Variation

Assessment of Repirable Mine Dust Variation at Various Mines using Longwall and Continous Mining Methods

Introduction: In order to test the hypothesis that a single respirable coal mine dust air sample does not provide an accurate estimate of the "average" exposure of a coal miner, a series of respirable mine dust samples were collected from longwall and continous mining section at active coal mines.

Protocol:

Participation: Participating mines were selected from a group of mines with longwall and continous mining sections volunteered by participating coal mine operators. All of the mines were in the Morgantown, WV and Southeastern WV areas. A total of five mines, 5 longwall and 5 continous mining sections, participated in the study. Either 5 or 10 consecutive respirable mine dust samples were collected from each section. Three mines were able to collect a series of 10 respirable mine dust samples.

MRE Equivalent Concentrations of Respirable Coal Mine Dust
Current Sampling Data

Mine ID	Occupation Code	Date of Sample	MRE Equivalent	Production Rate
5	036	03/29/94	0.58	0245
5	036	03/30/94	1.44	0171
5	036	03/30/94	1.26	0205
5	036	03/30/94	0.14	0433
5	036	03/31/94	0.86	0371
5	044	04/04/94	1.83	4022
5	044	04/05/94	1.70	4827
5	044	04/05/94	1.94	5229
5	044	04/06/94	1.52	5631
5	044	04/06/94	1.81	5631
4	036	03/29/94	0.96	0546
4	036	03/29/94	1.90	0462
4	036	03/30/94	1.29	0611
4	036	03/30/94	1.08	0411
4	036	03/30/94	0.93	0501
4	036	03/31/94	1.38	0643
4	036	03/31/94	0.95	0579
4	036	03/31/94	0.88	0333
4	036	04/01/94	0.83	0514
4	036	04/01/94	Not Valid Sample	0675
4	044	03/29/94	1.83	2550
4	044	03/30/94	2.29	1650
4	044	03/30/94	1.28	1350
4	044	03/30/94	2.26	2550
4	044	03/31/94	3.39	1650
4	044	03/31/94	1.88	2250
4	044	03/31/94	2.11	2550
4	044	04/01/94	1.11	2250
4	044	04/01/94	1.84	0900
4	044	03/29/94	3.29	2250
3	036	04/04/94	0.76	0239
3	036	03/29/94	0.89	0403
3	036	04/04/94	0.92	0194
3	036	04/07/94	1.04	0591
3	036	04/08/94	1.04	0597
3	044	03/29/94	1.81	5181
3	044	04/04/94	1.75	1122
3	044	04/08/94	2.73	1122
3	044	04/04/94	3.16	6300
3	044	04/07/94	1.81	9257
2	036	04/13/94	1.24	0765
2	036	04/13/94	1.90	0697
2	044	04/14/94	1.39	4702
2	044	04/13/94	0.98	2738
2	044	04/15/94	2.56	4372
2	044	04/14/94	1.90	4372
2	036	04/14/94	0.75	0518
2	044	04/14/94	1.94	4058

MRE Equivalent Concentrations of Respirable Coal Mine Dust
Current Sampling Data

Mine ID	Occupation Code	Date of Sample	MRE Equivalent	Production Rate
2	036	04/14/94	1.31	0600
2	036	04/13/94	1.45	0675
2	044	04/13/94	1.55	4470
2	044	04/13/94	0.75	5190
1	036	04/12/94	0.30	0128
1	036	04/13/94	1.21	0678
1	036	04/15/94	1.21	0307
1	036	04/18/94	2.67	0487
1	036	04/19/94	0.53	0000
1	036	04/21/94	1.51	0353

MRE Equivalent Concentrations of Respirable Coal Dust
Historical Data

Mine ID	Occupation Code	Sample Date	MRE Equivalent	Production Rate
4	044	06/01/92	2.7	3825
4	044	06/03/92	2.2	1575
4	044	06/08/92	1.2	3750
4	044	06/08/92	1.9	1875
4	044	06/10/92	1.4	2850
4	044	07/28/92	1.2	2625
4	044	07/30/92	2.8	2250
4	044	07/31/92	1.4	4500
4	044	08/04/92	1.8	3750
4	044	08/05/92	1.4	3000
4	044	10/12/92	3.3	2625
4	044	10/13/92	2.1	2625
4	044	10/13/92	1.8	2250
4	044	10/14/92	2.8	2625
4	044	10/23/92	2.5	1500
4	044	11/02/92	1.2	2250
4	044	11/02/92	1.4	2250
4	044	11/03/92	1.7	2625
4	044	11/04/92	1.1	3300
4	044	11/04/92	1.5	1875
4	044	01/25/93	1.4	2250
4	044	01/26/93	2.0	1800
4	044	02/02/93	1.4	1800
4	044	02/03/93	1.8	2250
4	044	02/04/93	2.1	1875
4	044	03/29/93	1.7	3750
4	044	03/30/93	0.5	1125
4	044	04/01/93	1.0	1500
4	044	04/05/93	2.2	3000
4	044	04/06/93	2.7	3000
4	044	01/26/94	0.8	1050
4	044	01/26/94	1.0	1125
4	044	01/27/94	2.0	2550
4	044	01/27/94	1.4	1050
4	044	01/28/94	1.7	1500
4	044	03/14/94	1.0	0750
4	044	03/15/94	1.5	1200
4	044	03/16/94	1.8	0900
4	044	03/16/94	1.2	0900
4	044	03/17/94	0.5	0900
4	044	07/21/93	0.8	1500
4	036	05/26/92	0.8	0369
4	036	05/27/92	0.4	0558
4	036	05/27/92	0.7	0612

MRE Equivalent Concentrations of Respirable Coal Dust
Historical Data

Mine ID	Occupation Code	Sample Date	MRE Equivalent	Production Rate
4	036	05/27/92	0.8	0495
4	036	05/28/92	0.4	0450
4	036	07/21/92	0.5	0486
4	036	07/22/92	0.2	0270
4	036	07/22/92	0.6	0369
4	036	07/22/92	0.5	0338
4	036	07/24/92	0.7	0495
4	036	09/22/92	0.8	0450
4	036	09/23/92	1.1	0520
4	036	09/23/92	1.0	0288
4	036	09/23/92	0.8	0560
4	036	09/24/92	0.8	0360
4	036	12/08/92	1.0	0372
4	036	12/09/92	0.8	0469
4	036	12/10/92	1.0	0488
4	036	12/10/92	0.5	0321
4	036	12/10/92	1.0	0514
4	036	01/25/93	1.1	0560
4	036	01/26/93	0.8	0480
4	036	01/29/93	1.0	0604
4	036	02/05/93	0.7	0308
4	036	02/17/93	0.8	0411
4	036	03/29/93	0.5	0408
4	036	03/30/93	2.4	0469
4	036	03/31/93	0.2	0527
4	036	04/01/93	0.2	0353
4	036	04/05/93	0.4	0520
4	036	05/24/93	0.5	0462
4	036	05/24/93	0.4	0514
4	036	05/25/93	0.4	0514
4	036	05/25/93	0.2	0482
4	036	05/25/93	0.7	0540
4	036	01/05/94	1.0	0649
4	036	01/06/94	0.5	0386
4	036	01/06/94	0.7	0579
4	036	01/07/94	0.4	0450
4	036	01/07/94	0.7	0437
4	036	03/08/94	0.4	0521
4	036	03/08/94	0.8	0450
4	036	03/09/94	0.8	0598
4	036	03/09/94	1.0	0334
4	036	03/09/94	0.4	0411
4	036	03/08/94	0.5	0342
5	036	05/29/92	1.8	0288

MRE Equivalent Concentrations of Respirable Coal Dust
Historical Data

Mine ID	Occupation Code	Sample Date	MRE Equivalent	Production Rate
5	036	06/02/92	0.8	0360
5	036	06/03/92	0.5	0280
5	036	06/05/92	1.0	0158
5	036	06/05/92	1.8	0324
5	036	05/04/93	0.5	0405
5	036	05/05/93	0.5	0456
5	036	05/06/93	0.4	0353
5	036	05/07/93	0.4	0399
5	036	01/10/94	0.5	0210
5	036	01/11/94	0.4	0210
5	036	01/13/94	0.7	0285
5	036	01/15/94	0.2	0217
5	036	01/18/94	0.5	0490
5	036	01/27/93	0.8	0324
5	036	01/28/93	0.4	0300
5	036	01/28/93	0.2	0256
5	036	01/29/93	0.2	0256
5	036	02/01/93	2.2	0440
5	044	11/18/92	1.4	3564
5	044	11/18/92	1.1	3640
5	044	11/19/92	1.2	2718
5	044	11/19/92	4.5	4750
5	044	11/19/92	0.8	2814
5	044	01/25/93	2.1	2757
5	044	01/26/93	1.4	2078
5	044	01/28/93	1.8	2970
5	044	01/29/93	1.8	4158
5	044	02/01/93	2.4	3168
5	044	05/24/93	2.5	6436
5	044	01/27/94	1.5	6626
5	044	01/28/94	1.1	5580
5	044	01/31/94	1.7	6114
5	044	02/02/94	1.1	3545
5	044	02/17/94	2.7	5534
2	036	02/11/92	1.0	0396
2	036	02/11/92	1.0	0352
2	036	02/12/92	2.0	0297
2	036	02/13/92	3.0	0407
2	036	02/24/92	2.7	0615
2	036	02/24/92	0.4	0418
2	036	02/25/92	0.4	0605
2	036	02/25/92	1.2	0506
2	036	02/26/92	1.0	0605
2	036	04/15/92	2.1	0385

MRE Equivalent Concentrations of Respirable Coal Dust
Historical Data

Mine ID	Occupation Code	Sample Date	MRE Equivalent	Production Rate
2	036	04/16/92	1.5	0550
2	036	04/17/92	1.5	0682
2	036	04/20/92	1.5	0572
2	036	04/21/92	1.1	0572
2	036	04/23/92	0.5	0220
2	036	04/24/92	2.5	.264
2	036	04/28/92	1.7	0462
2	036	04/29/92	0.5	0308
2	036	04/30/92	5.0	0330
2	036	06/15/92	1.2	0636
2	036	06/15/92	0.8	0242
2	036	06/16/92	0.7	0374
2	036	06/16/92	1.7	0385
2	036	06/17/92	0.4	0242
2	036	06/18/92	0.5	0330
2	036	06/19/92	1.5	0286
2	036	06/19/92	0.8	0374
2	036	06/23/92	0.5	0605
2	036	06/23/92	0.4	0440
2	036	06/24/92	1.2	0484
2	036	06/24/92	1.2	0550
2	036	06/25/92	0.8	0550
2	036	06/25/92	1.1	0550
2	036	08/18/92	0.7	0154
2	036	08/19/92	0.7	0330
2	036	08/19/92	0.8	0418
2	036	08/19/92	1.5	0330
2	036	08/19/92	0.7	0660
2	036	08/20/92	0.1	0330
2	036	08/20/92	1.1	0308
2	036	08/20/92	0.4	0528
2	036	08/21/92	0.4	0407
2	036	08/21/92	0.5	0396
2	036	08/21/92	2.0	0407
2	036	08/21/92	2.0	0396
2	036	08/21/92	0.7	0572
2	036	08/24/92	0.5	0308
2	036	08/24/92	1.0	0550
2	036	10/06/92	1.1	0517
2	036	10/07/92	1.2	0891
2	036	10/07/92	0.8	0462
2	036	10/07/92	0.5	0550
2	036	10/07/92	1.4	0297
2	036	10/07/92	1.4	0297

MRE Equivalent Concentrations of Respirable Coal Dust
Historical Data

Mine ID	Occupation Code	Sample Date	MRE Equivalent	Production Rate
2	036	10/08/92	1.0	0726
2	036	10/08/92	0.7	0594
2	036	10/08/92	1.0	0682
2	036	10/08/92	0.8	0550
2	036	10/09/92	0.7	0495
2	036	10/12/92	1.2	0737
2	036	10/12/92	1.0	0440
2	036	10/12/92	1.0	0385
2	036	10/13/92	2.1	0638
2	036	10/13/92	1.1	0286
2	036	10/14/92	1.0	0484
2	036	10/14/92	1.2	0462
2	036	10/14/92	1.4	0297
2	036	10/15/92	2.7	0374
2	036	10/15/92	1.5	0561
2	036	11/16/92	1.2	0407
2	036	11/17/92	1.2	0715
2	036	11/18/92	1.2	0605
2	036	11/19/92	3.8	0627
2	036	11/19/92	3.4	0616
2	036	11/20/92	1.8	0517
2	036	11/20/92	1.2	4401
2	036	11/23/92	1.5	0550
2	036	11/24/92	0.8	0385
2	036	11/30/92	0.7	0495
2	036	11/30/92	0.4	0396
2	036	12/01/92	2.5	0440
2	036	12/01/92	1.0	0440
2	036	12/02/92	0.4	0330
2	036	12/02/92	1.5	0374
2	036	12/02/92	0.5	0330
2	036	12/03/92	0.5	0396
2	036	12/07/92	0.2	0220
2	036	12/09/91	1.4	0385
2	036	12/09/91	0.8	0418
2	036	12/09/92	0.1	0330
2	036	12/10/91	1.4	0462
2	036	12/10/91	4.0	0605
2	036	12/10/91	0.2	0418
2	036	12/11/91	1.5	0462
2	036	12/11/91	0.5	0528
2	036	12/11/91	1.8	0352
2	036	12/11/91	2.0	0418
2	036	12/28/92	0.5	0308

MRE Equivalent Concentrations of Respirable Coal Dust
Historical Data

Mine ID	Occupation Code	Sample Date	MRE Equivalent	Production Rate
2	044	01/27/92	0.4	3850
2	044	01/27/92	1.4	2750
2	044	01/27/92	2.2	5580
2	044	01/28/92	2.4	4125
2	044	01/28/92	3.7	3700
2	044	04/20/92	1.8	6686
2	044	04/21/92	0.4	3006
2	044	04/21/92	1.1	2072
2	044	04/21/92	1.1	3269
2	044	04/22/92	3.0	8282
2	044	06/02/92	1.5	6900
2	044	06/03/92	2.2	6586
2	044	06/04/92	0.8	4950
2	044	06/05/92	2.2	5500
2	044	06/08/92	1.4	6022
2	044	10/12/92	1.0	4607
2	044	10/13/92	0.7	3666
2	044	10/13/92	1.1	4622
2	044	10/14/92	0.8	3229
2	044	10/14/92	1.8	6840
2	044	12/07/92	0.8	4813
2	044	12/07/92	0.2	3656
2	044	12/09/92	0.5	2386
2	044	12/09/92	1.0	5370
2	044	12/09/92	0.8	5027
2	044	12/10/91	0.7	3269
2	044	12/10/91	2.2	5138
2	044	12/11/91	2.2	6209
2	044	12/11/91	5.1	8408
2	044	12/11/92	0.4	3025
3	036	01/20/92	0.7	0297
3	036	01/20/93	0.2	0396
3	036	01/20/93	0.4	0550
3	036	01/21/92	0.5	0363
3	036	01/21/93	0.4	0330
3	036	01/21/93	1.0	0528
3	036	01/21/93	1.0	0638
3	036	01/22/92	1.8	0264
3	036	01/22/92	0.8	0275
3	036	02/08/93	1.2	0506
3	036	02/09/93	1.4	0286
3	036	02/09/93	0.7	0418
3	036	02/10/93	0.5	0407
3	036	02/11/93	0.1	0220

MRE Equivalent Concentrations of Respirable Coal Dust
Historical Data

Mine ID	Occupation Code	Sample Date	MRE Equivalent	Production Rate
3	036	02/23/93	2.1	0440
3	036	02/24/93	0.8	0407
3	036	02/24/93	0.5	0242
3	036	02/25/93	0.8	0440
3	036	02/25/93	1.0	0396
3	036	03/17/93	0.2	0308
3	036	03/19/93	0.5	0308
3	036	03/22/93	1.8	0286
3	036	03/23/93	1.8	0374
3	036	03/24/93	0.5	0396
3	036	04/06/93	1.2	0594
3	036	04/06/93	1.0	0616
3	036	04/07/92	1.7	0451
3	036	04/07/93	2.2	0231
3	036	04/07/93	0.7	0451
3	036	04/08/92	2.0	0462
3	036	04/08/93	1.5	0484
3	036	04/09/92	1.5	0341
3	036	04/09/92	1.0	0462
3	036	04/10/92	2.2	0352
3	036	04/13/93	0.5	0220
3	036	04/19/93	0.4	0220
3	036	04/20/93	2.7	0374
3	036	04/20/93	6.3	0132
3	036	04/21/93	2.0	0528
3	036	05/11/93	0.8	0330
3	036	05/11/93	1.1	0220
3	036	05/12/93	0.8	0220
3	036	05/13/93	0.7	0396
3	036	05/14/93	0.1	0264
3	036	06/08/93	1.4	0407
3	036	06/09/93	1.2	0605
3	036	06/10/93	2.4	0616
3	036	06/10/93	0.2	0330
3	036	06/11/93	2.0	0561
3	036	06/25/92	1.1	0297
3	036	06/25/92	1.1	0209
3	036	06/25/92	1.1	0297
3	036	06/25/92	1.1	0209
3	036	06/26/92	1.7	0330
3	036	06/26/92	1.4	0451
3	036	06/26/92	1.7	0330
3	036	06/26/92	1.4	0451
3	036	08/24/92	2.8	0352

MRE Equivalent Concentrations of Respirable Coal Dust
Historical Data

Mine ID	Occupation Code	Sample Date	MRE Equivalent	Production Rate
3	036	08/25/92	0.1	0088
3	036	08/25/92	1.5	0275
3	036	08/25/92	0.8	0352
3	036	08/26/92	0.8	0330
3	036	09/30/92	1.0	0264
3	036	10/01/92	1.1	0209
3	036	10/01/92	1.7	0374
3	036	10/01/92	1.8	0220
3	036	10/02/92	1.8	0429
3	036	11/09/92	0.2	0264
3	036	11/10/92	1.1	0440
3	036	11/10/92	1.0	0363
3	036	11/12/92	0.5	0231
3	036	11/12/92	0.4	0330
3	036	12/03/91	2.5	0517
3	036	12/03/91	1.7	.341
3	036	12/04/91	5.3	0561
3	044	01/10/94	1.5	4169
3	044	01/11/94	1.2	5040
3	044	01/12/94	0.7	3600
3	044	01/13/94	1.1	5292
3	044	01/14/94	1.5	5292
3	044	02/08/93	0.7	3812
3	044	02/09/93	0.7	1650
3	044	02/11/93	0.7	4074
3	044	02/11/93	0.4	1828
3	044	02/11/93	3.4	7664
3	044	04/05/93	0.7	3896
3	044	04/06/93	1.4	3914
3	044	04/08/93	1.0	4038
3	044	04/09/93	1.0	4100
3	044	04/12/93	0.4	5289
3	044	06/28/93	2.5	5668
3	044	06/29/93	1.4	2648
3	044	06/29/93	1.2	6855
3	044	06/30/93	1.2	5484
3	044	06/30/93	0.8	4078
1	036	02/15/94	0.5	0278
1	036	02/17/94	2.1	0324
1	036	02/18/94	1.5	0336
1	036	02/19/94	0.8	0464
1	036	02/21/94	1.1	0812
1	036	12/21/92	1.7	0324
1	036	12/22/92	2.2	0614

MRE Equivalent Concentrations of Respirable Coal Dust
Historical Data

Mine ID	Occupation Code	Sample Date	MRE Equivalent	Production Rate
1	036	12/28/92	0.7	0464
1	036	12/29/92	1.0	0820
1	036	12/30/92	1.5	0667
1	036	05/12/92	1.4	2590
1	036	05/13/92	1.2	3103
1	036	05/14/92	2.5	3866
1	036	05/15/92	1.2	3045
1	036	05/18/92	1.4	3278
1	036	08/10/92	0.8	2331
1	036	08/11/92	1.2	3219
1	036	08/11/92	0.8	1850
1	036	08/12/92	1.4	2960
1	036	08/24/92	1.7	2960
1	036	01/20/94	2.7	4300
1	036	01/20/94	2.3	4040
1	036	01/21/94	1.8	3700
1	036	01/21/94	3.3	5400
1	036	01/22/94	2.5	3150
1	036	02/07/94	1.4	4025
1	036	02/07/94	1.3	4200
1	036	02/08/94	1.8	3800
1	036	02/08/94	1.1	2500
1	036	02/09/94	0.7	2140