Analysis of U.S. Small-Mine Compliance Feasibility with Proposed New Respirable Dust Standards and Implications for Better Dust Control Methods

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Introduction

- MSHA hearings on proposed new coal mine respirable dust rule – 2010
- Proposes:
  - ✓ 1/mg/m^3 respirable dust standard
  - ✓ 0.1 mg/m^3 respirable quartz standard
  - ✓ Single-shift compliance sampling

Introduction

- Small mines largely comprise the 'hot spots' where dust diseases of the lungs increased dramatically over the past decade

- This paper presents findings on the feasibility of small mines' compliance with proposed new standards by:

  ✓ MSHA district
  ✓ Seam height
  ✓ Selected 'hot spot' counties

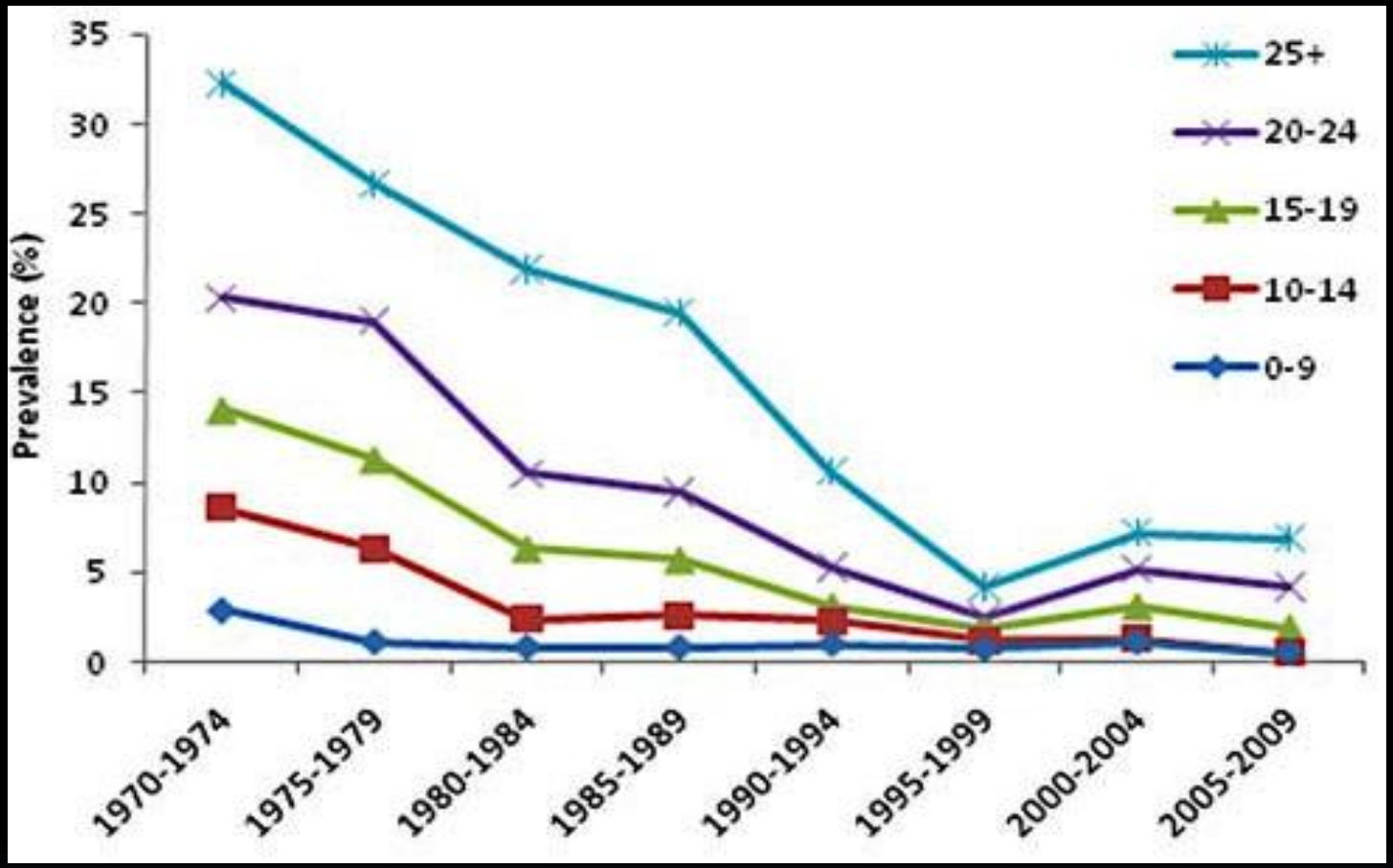


Figure 1. Percentage of miners examined with CWP category 1 or greater from the NIOSH Coal Workers' X-ray Program from 1970–2009, by tenure in coal mining (NIOSH, 2011b).

Background

- NIOSH criteria document (1996) recommended 1.0 mg/m^3 respirable coal dust standard; separate 0.05 mg/m^3 respirable quartz standard
- MSHA Dust Advisory Committee (1996) recommended reduction of standard with a phase-in approach; separate silica standard
- *Dust, Deception and Death* series in Louisville Courier-Journal (1998) was a harbinger of findings in recent Impact Inspections

Background

- Need for action highlighted by Upper Big Branch victim autopsy results: 71% had some form of dust disease of the lungs

- Potentially endemic and systematic problems in hot spots; Impact Inspection findings allude to serious problem with dust control ventilation

Background

- With final rule imminent, the questions are:
  - ✓ How well can the industry comply with the new standards?
  - ✓ Will the standards achieve the objective of reducing disease prevalence?
  - ✓ How will the new standards impact small mines? Focus of this study.

Data Collection, Preparation, and Analysis Methods

- Base data for study downloaded from two MSHA web URLs and a CDC-NIOSH web URL

- On 184 small mines with production in 2009, data includes: MSHA ID, mine name, state, county, tons mined, employee hours worked, injury and citation data, respirable dust sampling data – both operator and MSHA data – quartz levels; and disease prevalence data

Results and Discussion – Descriptive Statistics

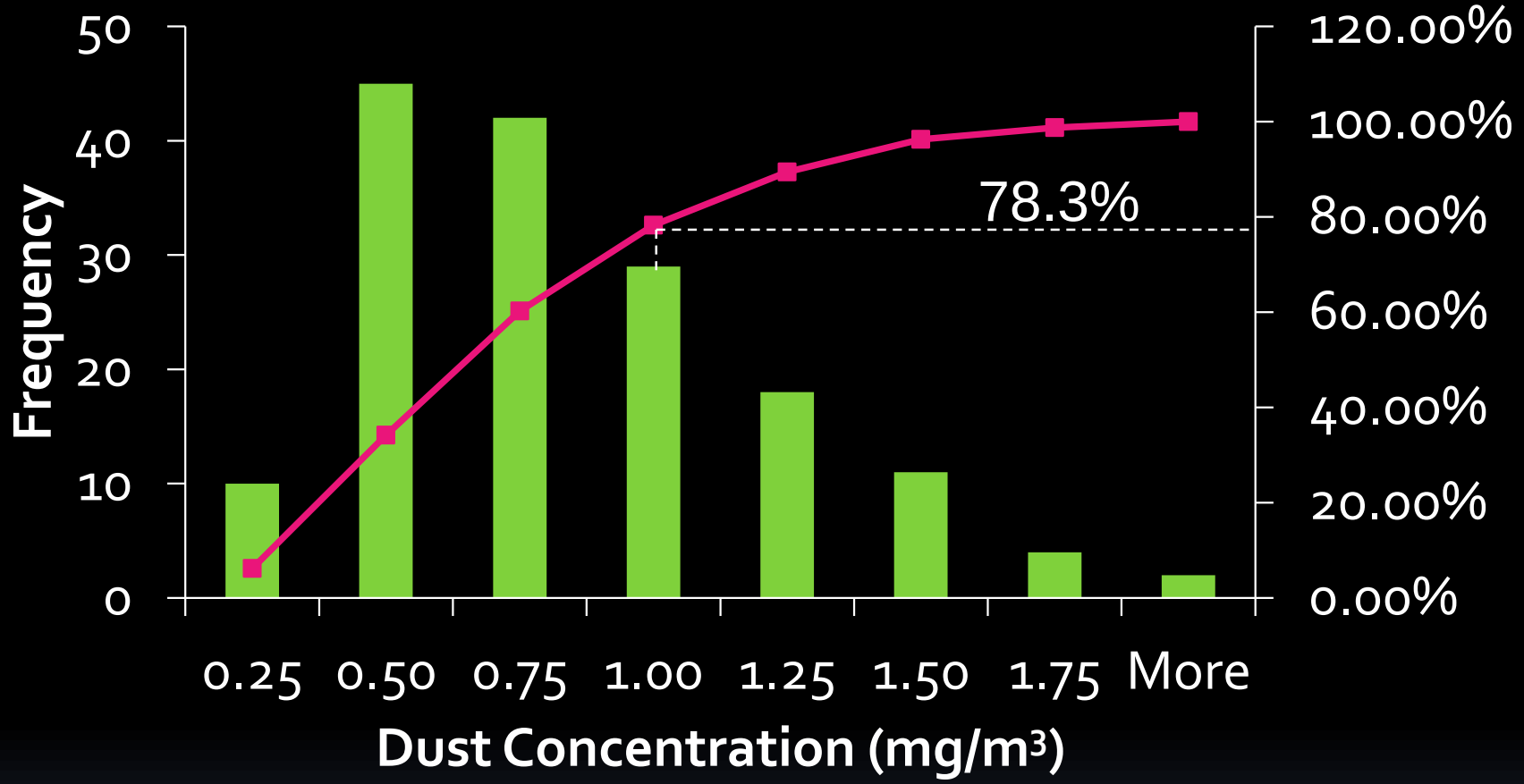
Measure	Mean	Median	Range
Seam Height (inches)	57.1	50	30-132
Tons/Employee Hour	2.46	2.21	0.76-8.22
MSHA Concentration (mg/m^3)	0.713	0.736	0.090-2.90
MSHA Tons (per shift)	655.7	603.0	173.5-1584.0
Operator Concentration (mg/m^3)	0.621	0.661	0.152-4.149
Operator Tons (per shift)	681.4	625.4	220.2-1775.9
Percent Quartz	6.37	5.75	0.70-21.60
MSHA Total Quartz ($\mu g/m^3$)	50.34	39.4	0.0-281.3
Operator Total Quartz ($\mu g/m^3$)	45.38	33.3	0.0-226.2
Percent Noncomply	6.3	3.3	0.0-62.5

Results and Discussion – Descriptive Statistics

Distribution of percent noncompliance with 2 mg/m^3 standard of 2009 operator samples on continuous miner operators in small mines

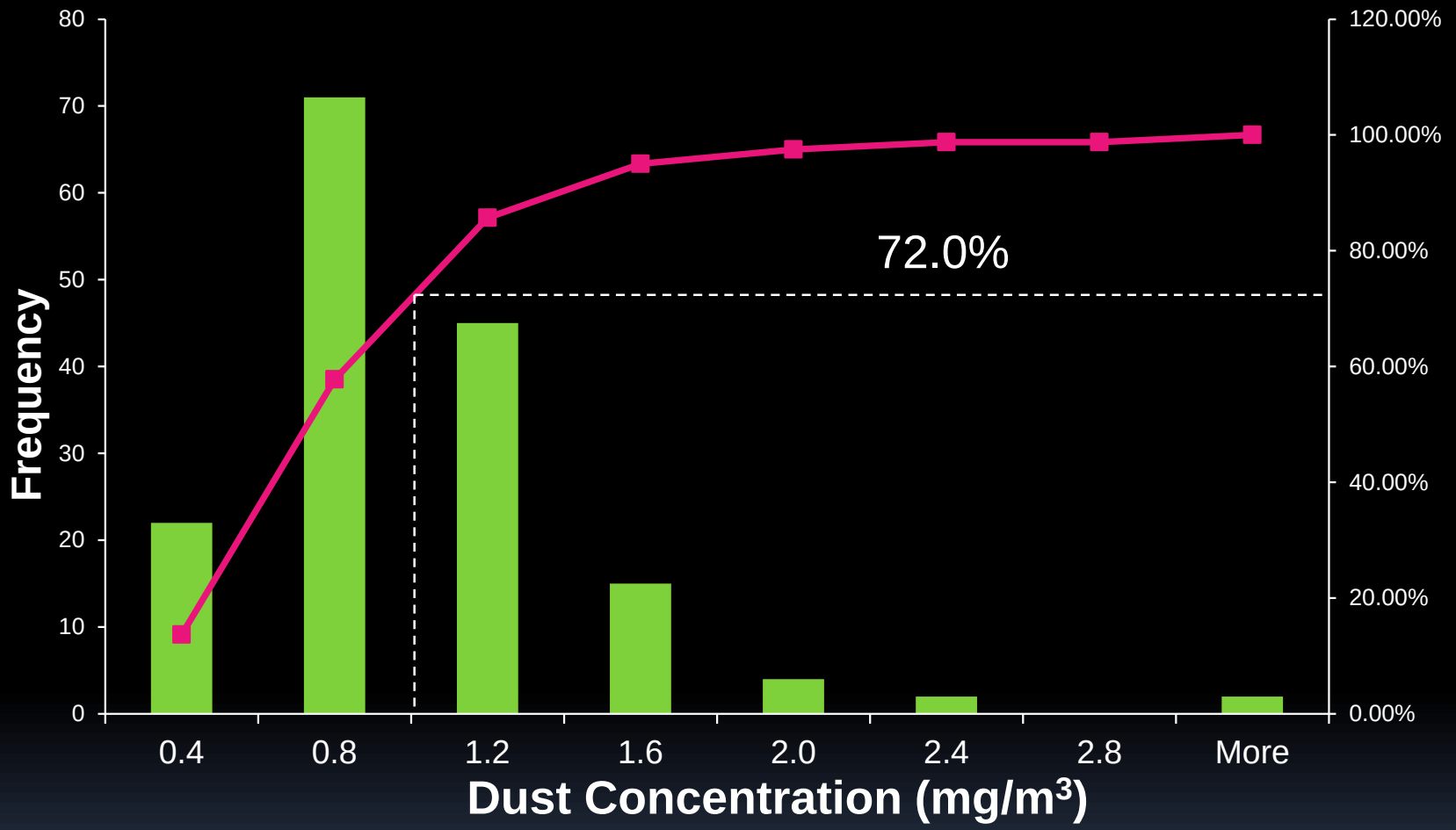
Interval	Number of Mines	Percent	Cumulative Percent
> 15.0%	20	12.4	12.4
> 5.0%, ≤ 15.0%	44	27.3	39.7
> 0.0%, ≤ 5.0%	24	14.9	54.6
Equal 0.0%	73	45.5	100.0

Results and Discussion – Descriptive Plot



Frequency and cumulative frequency plots of 2009 operator average dust concentration data for continuous miner operations in small underground coal mines

Results and Discussion – Descriptive Plot



Frequency and cumulative frequency plots of 2009 inspector average dust concentration data for continuous miner operations in small underground coal mines.

Results and Discussion –

Probabilities of Non-compliance with 1.0 mg/m^3 Standard

- Use geometric mean and geometric standard deviation
- Calculate standard Z-values as follows:

$$Z = ln(ECV/\hat{\mu}_g)/ln(\hat{\sigma}_g)$$

where: ECV – specified MSHA Excessive Concentration Value, 1.26 for 8-hr shift and 1.05 for 10-hr shift

$\hat{\mu}_g$ – geometric mean

$\hat{\sigma}_g$ – geometric standard deviation

Results and Discussion –

Probabilities of Non-compliance with 1.0 mg/m^3 Standard

- For operator samples (all mines):

$$\hat{\mu}_g = 0.621 \quad \text{and} \quad \hat{\sigma}_g = 1.408$$

- Then the standard Z-value is 2.069 for an 8-hr shift
- The probability of noncompliance is 1.92%, on average, for an 8-hr shift
- This does not apply for a specific mine

Results and Discussion –

Probabilities of Non-compliance with 1.0 mg/m^3 Standard

- For operator samples (all mines):

$$\hat{\mu}_g = 0.621 \quad \text{and} \quad \hat{\sigma}_g = 1.408$$

- Then the standard Z-value is 1.536 for an 10-hr shift
- The probability of noncompliance is 6.23%, on average, for an 10-hr shift
- This does not apply for a specific mine

Results and Discussion –

Probabilities of Non-compliance with 1.0 mg/m^3 Standard

- For MSHA samples (all mines):

$$\hat{\mu}_g = 0.713 \quad \text{and} \quad \hat{\sigma}_g = 1.343$$

- Then the standard Z-value is 1.665 for an 8-hr shift
- The probability of noncompliance is 4.80%, on average, for an 8-hr shift
- This does not apply for a specific mine

Results and Discussion –

Probabilities of Non-compliance with 1.0 mg/m^3 Standard

- For MSHA samples (all mines):

$$\hat{\mu}_g = 0.713 \quad \text{and} \quad \hat{\sigma}_g = 1.343$$

- Then the standard Z-value is 1.133 for a 10-hr shift
- The probability of noncompliance is 12.86%, on average, for a 10-hr shift
- This does not apply for a specific mine

Results and Discussion – Probabilities of Non-compliance with 1.0 mg/m^3 Standard on Mine Basis

- Analysis of operator samples for 32 randomly selected mines
- Near-representation percent-wise by state
- Geometric mean and standard deviation generally larger
- Probabilities for noncompliance for 8-hr and 10-hr shifts are significantly higher

Results and Discussion – Probabilities of Non-compliance with 1.0 mg/m^3 Standard on Mine Basis

- Probabilities for noncompliance particularly high for mines having a percent noncompliance with a 2 mg/m^3 standard at 3.5% or higher

- For an 8-hr shift, 13 of 32 mines had a probability of noncompliance at 19.96% or higher; 7 mines at 29.95% or higher

- For a 10-hr shift, 19 of 32 mines had a probability of noncompliance at 19.92% or higher; 12 mines at 32.99% or higher

Results and Discussion – Probabilities of Non-compliance with 1.0 mg/m^3 Standard on Mine Basis

- Because of the variation among mine samples, some faithfully compliant mines will likely have a significant number of samples out of compliance, at least for a while

- These findings support the wisdom of the phase-in periods proposed in the current rule: 1.7 mg/m^3 after 6 months and 1.5 mg/m^3 after another 6 months

Results and Discussion – Probabilities of Non-compliance on MSHA District Basis

MSHA District	Mean Operator Conc.	Probability of Noncompliance 8-hour/10-hour	Mean MSHA Conc.	Probability of Noncompliance 8-hour/10-hour
2 (n=15)	0.690	3.92/10.99	0.836	8.21/21.97
3 (n=6)	0.782	8.17/19.46	0.648	1.20/5.08
4 (n=29)	0.595	1.42/4.85	0.604	0.63/4.04
5 (n=13)	0.670	3.25/9.46	0.791	5.72/16.85
6 (n=33)	0.538	0.65/2.54	0.811	6.76/19.05
7 (n=28)	0.715	4.89/13.07	0.585	0.47/2.37
12 (n=32)	0.536	0.62/2.47	0.771	4.79/14.76

Results and Discussion – Probabilities of Non-compliance on Seam Height Basis

Seam Height (in)	Mean Operator Conc.	Probability of Noncompliance 8-hour/10-hour	Mean MSHA Conc.	Probability of Noncompliance 8-hour/10-hour
> 72 (n=26)	0.539	0.65/2.56	0.697	2.23/8.24
> 60, ≤ 72 (n=20)	0.663	3.03/8.95	0.864	10.04/25.43
> 54, ≤ 60 (n=26)	0.646	2.55/7.78	0.655	1.33/5.48
> 47, ≤ 54 (n=32)	0.601	1.53/5.14	0.624	0.86/3.88
> 40, ≤ 47 (n=21)	0.740	6.00/15.32	0.794	5.87/17.16
≤ 40 (n=35)	0.596	1.43/4.90	0.737	3.45/11.51

Results and Discussion – Probabilities of Non-compliance on Selected County Basis

State - County	Mean Opr. Conc.	Probability of Noncompliance 8-hour/10-hour	Mean MSHA Conc.	Probability of Noncompliance 8-hour/10-hour
KY-Bell (n=4)	0.585	1.25/4.37	0.498	0.08/0.57
KY-Harlan (n=15)	0.741	6.05/15.41	0.583	0.45/2.30
KY-Letcher (n=7)	0.634	2.24/7.02	0.691	2.08/7.80
KY-Martin (n=5)	0.490	0.29/1.30	0.497	0.08/0.56
KY-Pike (n=17)	0.603	1.56/5.25	0.767	4.62/14.34
PA-Armstrong (n=4)	0.676	3.44/9.90	1.032	24.92/47.65
PA-Indiana (n=6)	0.583	1.22/4.28	0.814	6.92/19.41

Results and Discussion – Probabilities of Non-compliance on Selected County Basis

State - County	Mean Opr. Conc.	Probability of Noncompliance 8-hour/10-hour	Mean MSHA Conc.	Probability of Noncompliance 8-hour/10-hour
VA-Wise (n=8)	0.751	6.53/16.38	0.870	10.46/26.17
WV-Boone (n=9)	0.549	0.76/2.90	0.463	0.03/0.27
WV-Kanawha (n=8)	0.831	11.20/24.70	0.791	5.72/16.85
WV-Logan (n=7)	0.545	0.72/2.77	0.974	19.13/39.94
WV-McDowell (n=10)	0.553	0.80/3.05	0.774	4.93/15.06
WV-Mingo (n=10)	0.499	0.34/1.49	0.788	5.57/16.53
WV-Wyoming (n=5)	0.644	2.49/7.65	0.705	2.45/8.83

Results and Discussion – Regression Models for Total Quartz Content

ln (T Quartz) = 1.714 + 1.663 Opr Conc
+ 0.139 %Quartz – 0.275 McDowell
– 0.186 District 2 – 0.0024 Seam Height
– 0.227 District 3 – 0.008 %Noncomply

R^2 = 0.9342 Well-behaved residuals

α = 0.05 for variables to enter model (forward selection)

Results and Discussion – Average Total Quartz Content and Probability of Meeting 0.1 mg/m^3 Standard

Interval	Number of Mines	Percent	Cumulative Percent
> 150 µg/m^3	6	3.77	3.77
> 100 µg/m^3, ≤ 150 µg/m^3	10	6.29	10.06
> 75 µg/m^3, ≤ 100 µg/m^3	9	5.66	15.72
> 50 µg/m^3, ≤ 75 µg/m^3	26	16.35	32.07
> 25 µg/m^3, ≤ 50 µg/m^3	55	34.60	66.67
≤ 25 µg/m^3	53	33.33	100.00

Results and Discussion – Average Total Quartz Content and Probability of Meeting 0.1 mg/m^3 Standard

- $\hat{\mu}_g = 33.985\ \mu_g/m^3$; $\hat{\sigma}_g = 1.831$
- Probability of noncompliance with 0.1 mg/m^3 standard, on average, is 3.72%
- Probability of noncompliance with 0.05 mg/m3 standard, on average, is 26.17%

Results and Discussion – Disease Prevalence in hot spots; other data

State-County	Seam Height	MSHA Conc.	Opr. Conc.	% Non-Comply	Total Quartz (µg/m³) Opr	Total Quartz (µg/m³) MSHA	Disease Prev.
KY-Bell	68.8	0.498	0.585	8.9	58.16	55.11	4
KY-Harlan	51.9	0.583	0.741	8.7	53.4	38.87	7.4
KY-Letcher	52.3	0.691	0.634	3.1	39.98	47.31	7.8
KY-Martin	63.6	0.497	0.49	2.7	59.6	58.37	4.5
KY-Pike	55.2	0.767	0.603	6	47.2	52.6	9.7
PA-Armstrong	40.5	1.032	0.676	5.4	21.02	30.31	1.6
PA-Indiana	49	0.814	0.583	2.7	18.97	27.92	0.8

Results and Discussion – Disease Prevalence in hot spots; other data

State-County	Seam Height	MSHA Conc.	Opr Conc.	% Non-Comply	Total Quartz (µg/m³) Opr	Total Quartz (µg/m³) MSHA	Disease Prev.
VA-Wise	54.3	0.87	0.751	8.7	58.77	65.31	7.6
WV-Boone	63.8	0.463	0.549	6.2	59.44	52.7	7.8
WV-Kanawha	76.9	0.791	0.831	6.1	58.94	64.8	6.2
WV-Logan	47.3	0.974	0.545	4.2	49.32	90.23	5.8
WV-McDowell	40.2	0.774	0.553	6.5	24.65	33.32	14.3
WV-Mingo	69.6	0.788	0.499	3.2	44.74	61.4	7.0
WV-Wyoming	41.6	0.705	0.644	7.5	51.91	57.88	8.3

Results and Discussion – Disease Prevalence Correlations with Other Variables (hot spots)

- Correlations with disease prevalence:
  - ✓ Tons per employee hour (-0.688)
  - ✓ MSHA-reported tons/sampling shift (-0.468)
  - ✓ Operator-reported tons/shift (-0.584)

Results and Discussion – Disease Prevalence Correlations with Other Variables (hot spots)

- Moderately strong inverse relationship between disease prevalence and productivity
- Moderately strong direct relationship between productivity and seam height
- Intuitively, a lower seam height would relate to a higher level of rock being mined => giving an increased level of quartz => an increased level of lung disease

Conclusions

- In 2009, level of complete compliance with 2.0 mg/m^3 standard, on average, is 45.4% for all 161 mines
- Only 12.4% of mines had greater than 15% of their samples out of compliance during 2009
- Only 27.3% of mines had between 5% and 15.0% noncompliance

Conclusions

- Using operator data, based on single-shift samples, 78.3% of mines would have complied, on average, with a 1.0 mg/m^3 standard

- Using MSHA data, 72.0% would have complied, on average, with a 1.0 mg/m^3 standard

Conclusions

- For operator data, considering statistical variation, the probability of noncompliance with a 1.0 mg/m^3 standard was 1.92% for an 8-hr shift and 6.23% on a 10-hr shift

- Using MSHA data, it was 4.80% and 12.86%, respectively, for an 8-hr and 10-hr shift

Conclusions

- On a mine-by-mine basis, probabilities for noncompliance were particularly high for mines with 3.5% or more of samples out of compliance with a 2.0 mg/m^3 standard
- Of 161 mines, 39.7% had over 5.0% of their samples out of compliance
- This information supports the wisdom of the proposed phase-in periods for the new standard

Conclusions

- MSHA districts 2, 3 and 7 will have a bigger challenge to achieve compliance based on operator sampling data
- MSHA districts 2, 5, 6 and 12 will have the greater challenge based on MSHA data
- Based on operator data, mines with coal seam heights > 40 in, ≤ 47 in will have tougher compliance challenge

Conclusions

- Based on MSHA data, mines with coal seam heights > 60 in, ≤ 72 in will have tougher compliance challenge

- Based on MSHA data, greater challenge in meeting 2.0 mg/m^3 standard was in Pike, Armstrong, Indiana, Wise, Kanawha, Logan, McDowell, and Mingo counties with 14.34% or higher probability of noncompliance

Conclusions

- Armstrong county and Logan county will have the toughest challenge of all with, on average, 46.65% and 39.94% noncompliance, respectively

- The full analysis of noncompliance indicates that better and new technologies for dust control, and quartz dust control, will be important in many mines

Conclusions

- For the proposed 0.1 mg/m^3 quartz standard, 10.06% of mines, on average, will not comply
- For a hypothetical 0.05 mg/m^3 quartz standard, 68.0% of mines, on average, will comply with it
- Using statistical variability on a mine-by-mine basis, the probability of noncompliance with the proposed quartz standard is 3.72%; for the hypothetical 0.05 mg/m^3 standard it is 26.71%

Conclusions

- Mining rock in thin seams operated by small mines appears to be the source of quartz that is likely the primary culprit for the increase in dust diseases of the lungs over the past decade

- The proposed 0.1 mg/m^3 quartz standard is largely complied with by the vast majority of small mines now

- If true, then a quartz standard of 0.05 mg/m^3 appears necessary to reduce disease prevalence