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Seasonal Variation in Respirable Dust Concentration in U.S. Coal Mines

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UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot
mg/m^3	milligram per cubic millimeter
wt%	weight percent

SEASONAL VARIATION IN RESPIRABLE DUST CONCENTRATION IN U.S. COAL MINES

By Nevin Greninger,[1] Welby Courtney,[2] and Edward Divers[3]

ABSTRACT

The Bureau of Mines examined the possibility of a seasonal variation of respirable dust concentration in U.S. coal mines. The first step was to review company and MSHA-inspector dust samples that had been collected during the past several years in 14 selected mines for compliance purposes. Results indicated severe scatter in data; most standard deviations of the dust concentrations measured in winter and summer months were comparable in magnitude with the mean values of dust concentrations for the seasons. Therefore, a detailed statistical analysis was conducted.

At the 90% confidence level, the company samples of three mines had winter means 0.15 to 0.54 mg/m^3 higher than the summer means; six mines had negligible seasonal variations; and five mines had winter means that ranged from higher to lower than the summer means. Inspector data, however, were too sparse for analysis. In view of both the low frequency of occurrence of a seasonal effect and its wide scatter in several of the mines, the study was ended with the conclusion that seasonal variation in respirable dust levels, in general, is an insignificant factor.

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INTRODUCTION

A seasonal variation in the respirable dust concentration during a coal mining operation would interfere with a lengthy field study of the effectiveness of a new dust control technique for that operation but would perhaps offer insight into phenomena that may affect the respirable dust level.

In the early 1970's a brief Bureau of Mines study of respirable dust levels in several mines, as measured by Federal inspectors, suggested that in some mines respirable dust concentrations appeared to be higher in winter than in summer, but that this was not true for other mines. However, the study generally did not indicate a large seasonal variation, and this area was abandoned for higher priority activities.

It was recently decided to review more recent respirable dust data in greater depth to better assess whether a seasonal variation in respirable dust concentration does indeed exist. This report presents the results of this review.

ACKNOWLEDGMENT

Special acknowledgment is given to the Mine Safety and Health Administration (MSHA) field offices at Birmingham and Bessemer, AL, Morgantown, WV, and Indiana, Hastings, and Johnstown, PA, for providing information on company and MSHA respirable dust samples.

Acknowledgment also is given to Robert Franks, electrical engineer, Pittsburgh Research Center, for computer assistance.

APPROACH

Company and MSHA-inspector data routinely collected for compliance purposes in room-and-pillar mining were used in this study. The study was limited to data for the continuous mining machine (CMM) operator, since a higher dust concentration for this high-risk occupation should be more likely to show a seasonal variation than would an occupation having a lower dust level.

Visits were made in the early summer of 1984 to local MSHA offices in West Virginia, Pennsylvania, and Alabama to select mines and acquire company and inspector data. Review of the initial data indicated severe scatter and that a statistical analysis of a large amount of data would be required to determine a seasonal variation with any degree of confidence. The local MSHA inspectors were asked to select candidate large mines, which would have more data and which in their opinion appeared to be drier in winter than in summer. In practice, the local MSHA inspectors were uncertain about any seasonal variation in mine dryness. A total of 14 mines were selected, three in West Virginia (labeled WV1, WV2, and WV3), three in Alabama (AL1, AL2, AL3), and eight in Pennsylvania (PA1..PA8). All company and inspector data obtained for the CMM operators in these mines from mid-1980 (the earliest time for which data could be easily retrieved) to the early summer of 1984 were acquired.

RESULTS

Figure 1 plots the raw company data for the AL1 mine. "Day" is the number of days after December 31, 1979,[4] that the dust sample was taken. The circled number is the number of dust samples for that day having that concentration of respirable dust; e.g., for day 866 (May 15, 1982), there were two samples having a respirable dust concentration of 0.1 mg/m^3, one sample having 0.7 mg/m^3, one sample having 3.0 mg/m^3, and one having 4.0 mg/m^3. Figure 1 shows the typical degree of scatter of company data.

[4]A convenient reference date.

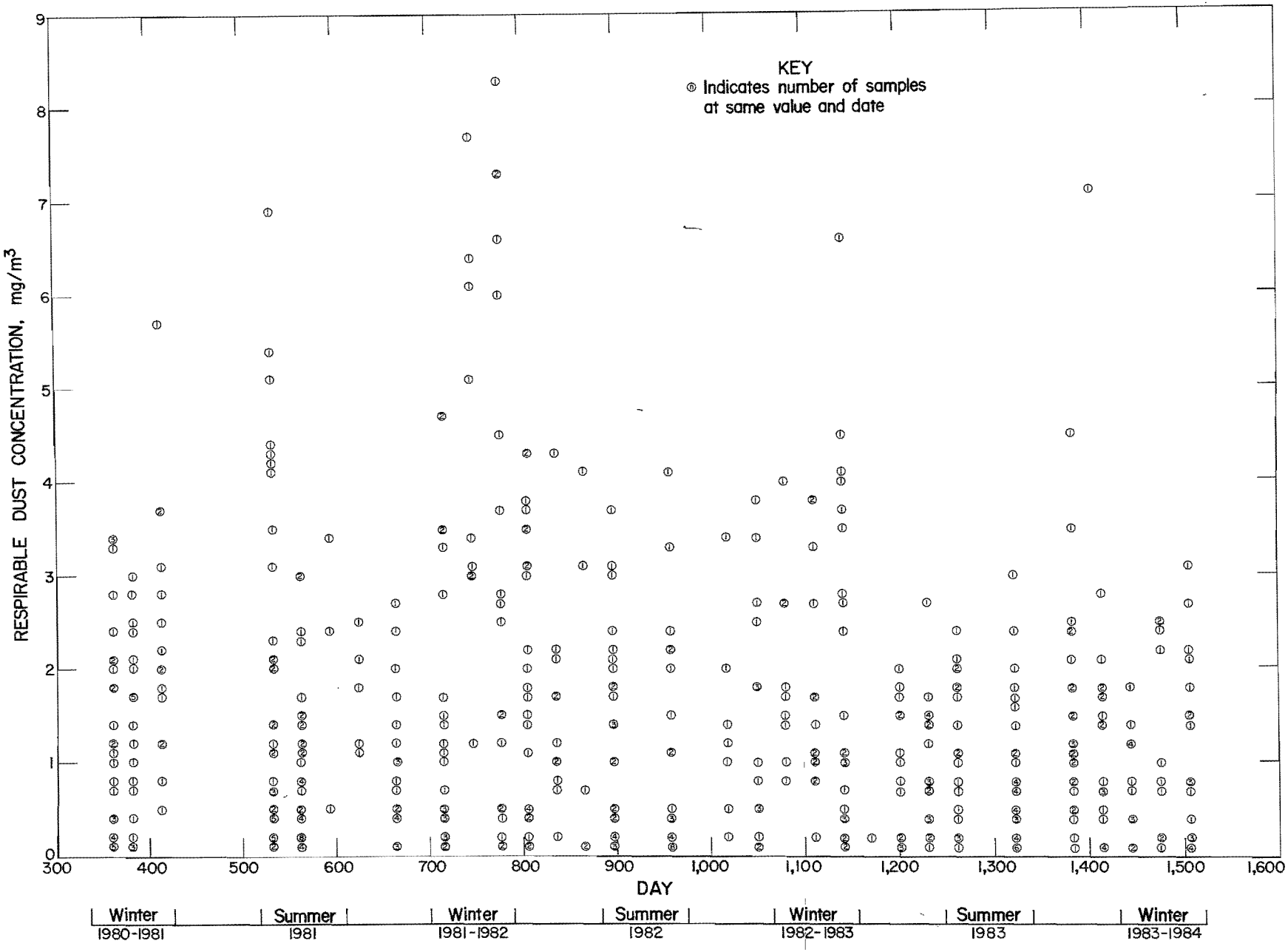

FIGURE 1. - Respirable dust concentration data for AL1 mine measured by mine operator.

For each mine, the mean of all company CMM operators data obtained during three winter months (December, January, February) was compared with the mean of all data obtained during three summer months (June, July, August); i.e., all winter data for all CMM operators of a mine were collected together and treated as the winter season, and all summer data were similarly collected together and treated as the summer season. Two outliers were identified and excluded from the present analysis: 42.6 mg/m^3 for the winter season in the AL1 mine, where the mean was 1.80 mg/m^3; and 19.2 mg/m^3 for the summer season in the PA2 mine, where the mean was 1.19 mg/m^3.

Table 1 summarizes the company data for the winter and summer seasons and gives the number of samples collected during the winter and summer seasons (W and S), the means for each season (WM and SM), and the statistical standard deviations for these seasons (WD and SD). For example, for the AL1 mine, a total of 564 samples were collected between December 15, 1980, and February 15, 1984. The winter season had 219 samples whose mean value of respirable dust concentration was 1.80 mg/m^3 with a standard deviation of 1.66 mg/m^3. The summer season had 178 samples with a mean of 1.07 mg/m^3 and a standard deviation of 1.00 mg/m^3. Table 1 lists the mines in descending order of winter-to-summer apparent variation; e.g., for the AL1 mine, the winter mean was 0.73 mg/m^3 higher than the summer mean.

The scatter in the data is indicated by standard deviations that are comparable in magnitude with the mean concentrations for that season. The net result is that a simple comparison of winter and summer mean dust concentrations, as in the last column of table 1, can be misleading because of the severe scatter in the data. A more realistic comparison of winter and summer data is obtained by calculating the confidence level (CL) that the difference between winter and summer means is at least a certain value.

Table 2 provides this comparison based on conventional statistical techniques. Of the 14 mines in the study, one (AL1) had a winter mean about 0.54 mg/m^3 higher at the 90% confidence level than the summer mean, and two (WV1 and PA1) had winter means about 0.15 mg/m^3 higher; six mines (AL2, AL3, WV2, PA2, PA3, and PA4) had winter means comparable with their summer means; and five (WV3, PA5, PA6, PA7, and PA8) had winter means that could be considerably higher or lower than the summer mean.

TABLE 1. - Summary of company data

Mine	Winter			Summer			Simple difference of means (WM-SM)
	Samples (W)	Mean conc, mg/m^3 (WM)	Std dev, mg/m^3 (WD)	Samples (S)	Mean conc, mg/m^3 (SM)	Std dev, mg/m^3 (SD)	
AL1	219	1.80	1.66	178	1.07	1.10	0.73
WV1	141	.92	1.01	111	.63	.59	.29
PA2	154	1.48	1.64	126	1.19	1.40	.29
PA1	146	.82	.82	121	.57	.49	.25
WV2	42	1.26	.83	39	1.01	.66	.25
PA3	96	1.18	1.26	80	.94	1.42	.24
WV3	42	2.09	1.85	55	1.89	1.99	.20
PA4	48	.94	.72	78	.83	.73	.11
AL3	193	.73	.79	154	.67	.81	.06
AL2	120	.81	.54	102	.76	.65	.05
PA5	225	1.19	1.33	155	1.19	1.48	.00
PA6	143	1.08	.98	95	1.17	.89	-.09
PA7	132	.77	.65	130	.94	.70	-.17
PA8	73	.63	.44	64	.84	.84	-.21

TABLE 2. - Confidence level (CL) that difference between winter and summer means is at least a certain value

(Milligrams per cubic meter)

Mine	Difference of means (WM - SM)				
	Simple	Statistical, at CL of--			
	(table 1)	80%	90%	95%	99%
AL1	0.73	0.60	0.54	0.49	0.39
WV1	.29	.21	.16	.12	.05
PA2	.29	.13	.05	-.02	-.14
PA1	.25	.18	.15	.11	.06
WV2	.25	.10	.03	-.03	-.15
PA3	.24	.07	-.02	-.10	-.24
WV3	.20	-.14	-.32	-.46	-.74
PA4	.11	-.00	-.06	-.11	-.20
AL3	.06	-.02	-.06	-.09	-.15
AL2	.05	-.02	-.05	-.08	-.13
PA5	.00	-.12	-.19	-.24	-.34
PA6	-.10	-.20	-.26	-.30	-.39
PA7	-.17	-.23	-.27	-.30	-.35
PA8	-.21	-.30	-.35	-.40	-.47

TABLE 3. - Individual seasonal variation of mean values of respirable dust concentrations of several mines

Mine and season	Samples	Mean conc, mg/m^3	Std dev, mg/m^3
AL1:			
Winter 1980-81..	66	1.55	1.20
Summer 1981.....	77	1.34	1.47
Winter 1981-82..	52	2.53	2.42
Summer 1982.....	51	1.10	1.11
Winter 1982-83..	49	1.87	1.50
Summer 1983.....	55	.90	.74
Winter 1983-84..	43	1.03	.88
PA2:			
Winter 1981-82..	59	1.32	1.75
Summer 1982.....	66	1.41	1.68
Winter 1982-83..	85	1.60	1.60
Summer 1983.....	60	.94	.95
Winter 1983-84..	10	1.32	1.36
WV3:			
Winter 1980-81..	6	1.88	2.82
Summer 1981.....	9	2.10	2.30
Winter 1981-82..	21	2.17	1.64
Summer 1982.....	24	2.32	2.37
Winter 1982-83..	15	2.05	1.83
Summer 1983.....	22	1.34	1.23

Table 3 presents individual seasonal variation company data for one mine in each of the above categories: AL1, PA2, and WV3; these data are plotted in figures 2, 3, and 4, respectively. The following discussion provides details of just how much the refined data adjusted the results from simple difference of means.

For example, the winter mean from the AL1 mine company data was 0.73 mg/m^3

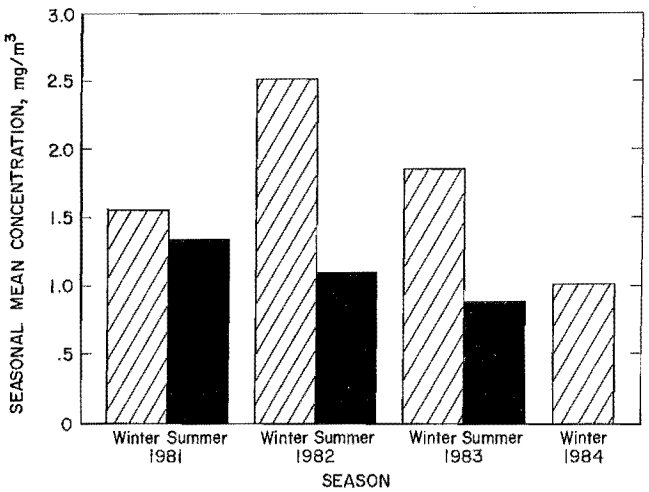

FIGURE 2. - Variation of seasonal respirable dust mean concentration for AL1 mine.

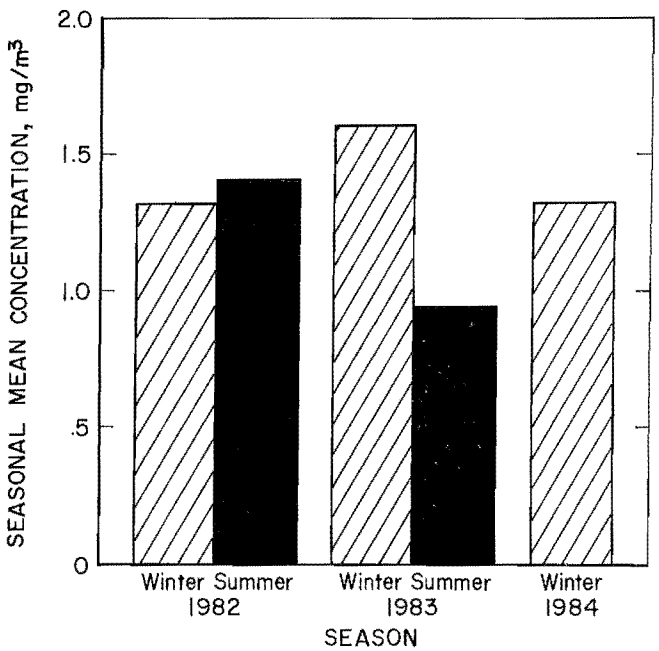

FIGURE 3. - Variation of seasonal respirable dust mean concentration for PA2 mine.

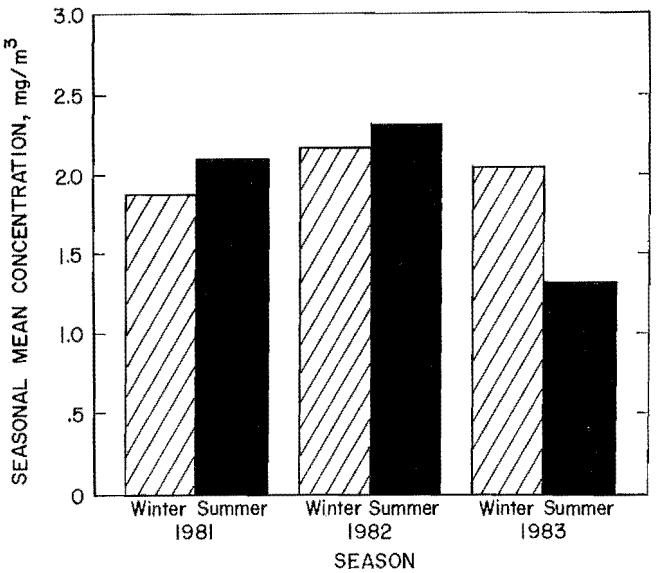

FIGURE 4. - Variation of seasonal respirable dust mean concentration for WV3 mine.

higher than the summer mean. At a 90% confidence level, however, the statistical analysis lowered this difference to only 0.54 mg/m^3. Similarly, for the PA2 mine, simple difference shows a 0.29-mg/m^3 higher winter mean, compared with almost no difference from winter to summer at the 90% CL by statistical analysis.

For the WV3 mine, however, which showed a minimal (0.2 mg/m^3) simple difference from winter to summer, the statistical analysis showed a -0.32 mg/m^3 figure at the 90% CL. In practice, this result implies that it is uncertain whether the winter mean is higher or lower.

Several attempts were made to further reduce the scatter of the data. One attempt rejected as outliers 19 winter samples for the AL1 mine that showed mean concentrations >4.0 mg/m^3.[5] This winter mean then was 0.20 mg/m^3 higher than the summer mean at the 90% confidence level (compared with 0.54 mg/m^3, as cited in table 2); this reinforces the above conclusion that the winter mean for this mine actually was higher than the summer mean. Exclusion of mean concentrations <0.5 mg/m^3 as outliers did not significantly impact the results presented in table 2. Company data for individual CMM's had about the same scatter as the combined data but were too sparse for analysis.

The MSHA-inspector data are summarized in table 4. The inspector data had about the same scatter as the company data but were also too sparse for analysis.[6]

DISCUSSION

Three of the 14 mines examined here (AL1, WV1, PA1) had a positive seasonal variation, wherein the winter mean respirable dust concentration was higher than the summer mean concentration; six mines had negligible seasonal variation; and for five mines the seasonal effect was uncertain. Although infrequent, the occurrence of a positive seasonal effect might perhaps be a result of lower relative humidity (RH) in the mine ventilation air in winter, which could occur because of the general warming of the incoming ventilation air in the winter and the cooling of the ventilation air in the summer.

An early 1911 Bureau study (1) indicated that the RH of the air leaving the mine was about 90%. However, detailed information on seasonal variation of in-mine RH appears to be limited to a recent Bureau-funded study (2) in a single mine, which indicated a winter RH of 45% to 70% and a summer RH of 70% to 90%

[5]A large value of the chi-square statistic for the AL1 company data strongly indicated (95% confidence level) that the winter data involved a mixture of two normal distributions. Rejection of the distribution involving the higher dust concentrations (>4.0 mg/m^3) presents a conservative interpretation of the data. It should be noted that this approach is a mathematical exercise and that no physical explanation can be presented to rationalize the existence of two distributions.

[6]Raw company and MSHA-inspector data are available from the authors.

TABLE 4. - Summary of MSHA-inspector data

Mine	Winter			Summer			Simple difference of means (WM-SM)
	Samples (W)	Mean conc, mg/m^3 (WM)	Std dev, mg/m^3 (WD)	Samples (S)	Mean conc, mg/m^3 (SM)	Std dev, mg/m^3 (SD)	
AL1	6	1.70	0.73	0	NAp	NAp	NAp
WV1	3	1.03	.21	5	0.72	0.43	0.31
PA2	22	1.00	.90	10	.88	1.09	.12
PA1	1	.70	NAp	10	.64	.31	.06
WV2	2	1.20	.28	7	.90	.40	.30
PA3	14	1.47	.92	10	.66	.67	.81
WV3	2	.55	.21	1	.30	NAp	.25
PA4	5	.60	.31	2	.70	.00	-.10
AL3	5	1.00	.58	0	NAp	NAp	NAp
AL2	0	NAp	NAp	0	NAp	NAp	NAp
PA5	26	1.30	1.03	10	.50	.52	.80
PA6	8	1.08	.54	18	1.51	.52	-.43
PA7	5	.56	.18	10	.66	.26	-.10
PA8	7	.59	.20	5	.56	.30	.03

NAp Not applicable.

about 1,000 ft outby a longwall face. The lower RH in the winter would tend to reduce the water content of dust deposits in roadways, beltways, etc., and thereby perhaps lead to a greater rate of dust reentrainment.

An alternate explanation of a positive seasonal effect is a possible increase in the inherent moisture content of the coal seam in the summer. A Bureau study of water infusion (3) of coal seams indicated a 50% reduction in the formation of airborne respirable dust in the face area when the water content of the coal seam was increased from about 4 wt% before infusion to about 5 wt% after infusion. Also, some people feel that more dust is formed at the start of a shift after a weekend because the face had had an opportunity to dry out during periods of nonmining. However, no information appears to be available on the seasonal variation of inherent water content of the coal seams of the 14 mines examined here.

An explanation of a seasonal variation of respirable dust concentration would probably require measurement of in-mine RH and inherent moisture content of the coal seam for a period of several years. Such a study would be burdensome and would be of limited usefulness in view of the low frequency of occurrence of a seasonal effect. It was concluded that any seasonal effects are insignificant, and this study was ended.

REFERENCES

1. Rice, G. The Explosibility of Coal Dust. BuMines B 20, 1911, 204 pp.

2. Lucas, R. Salt Processes for Improvement of Health and Safety in Underground Mining. BuMines contract J0155180, VPI and State Univ., Blacksburg, VA; for inf., contact W. G. Courtney, TPO, BuMines, Pittsburgh, PA.

3. Cervik, J., A. Sainato, and E. Baker. Water Infusion--An Effective and Economical Longwall Dust Control. BuMines RI 8838, 1983, 14 pp.

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