A COMPARATIVE EVALUATION OF THE DIFFERENTIAL-PRESSURE-BASED RESPIRABLE DUST DOSIMETER WITH THE PERSONAL GRAVIMETRIC RESPIRABLE DUST SAMPLER IN UNDERGROUND COAL MINES

R.V. Ramani
The Pennsylvania State University

J.M. Mutmansky
Honglin He
The Pennsylvania State University

J.C. Volkwein
National Institute for Occupational Safety and Health

V.A. Marple
B. A. Olson
P.C. Luna
University of Minnesota

ABSTRACT

The development of a sampling instrument for the assessment of an underground coal miner's exposure to airborne respirable coal mine dust on a continuous and real-time basis has been long identified as essential for timely initiation of control actions. A respirable dust dosimeter (RDD) which operates on the principle of increasing pressure across a filter media with increasing dust mass on the filter has been developed by the National Institute for Occupational Safety and Health. Comparisons of the performance of the RDD with an U.S. approved gravimetric respirable dust sampler (GRD) have shown that the RDD may meet the requirements for measuring miners' exposures on a cumulative, near real-time basis such as mid-shift and end of shift exposures. Recently, the performances of the RDD and GRD were compared by conducting side-by-side area sampling experiments in a controlled experimental environment in the laboratory and in underground coal mines under normal operating conditions. In this paper, the results from the in-mine study are presented and discussed. The experimental design for the in-mine study included two mines in different coal seams in different geographic coal regions. To ensure a wide range of concentrations, the experiments were conducted in a continuous miner section in Mine 1, and a longwall face in Mine 2. Airborne dust sampling was conducted for four different shifts at each mine. In each shift, two samples of different exposure durations were collected from two different locations. Each sample consisted of the readings of three dosimeters and the exposed filters from the three paired GRD samplers. As a result, a total of 96 comparative samples were obtained, 48 for each mine. The data were analyzed for the precision of the RDD and GRD measurements and for the relationships between the differential pressure of the RDD and the mass of dust on the paired GRD filter. The analyses indicate that, on the average, the RDD and the GRD track the airborne respirable dust concentrations well, exhibiting both a high correlation between the two measurements and a reliable predictive relationship of one from the other. Details of the experimental design, data analyses procedures, results, conclusions and recommendations of the underground experiments are presented in this paper.

KEYWORDS

Airborne respirable dust, continuous sampling, area sampling; real-time sampling, respirable dust dosimeter, personal gravimetric sampler, underground and laboratory experiments

INTRODUCTION

Since the enactment of the Coal Mine Health and Safety Act of 1969, the assessment of airborne respirable dust (ARD) concentrations in U.S. underground coal mines has been a subject of much discussion. The issues have centered around such topics as personal, occupational, and area sampling; continuous versus discrete sampling; sampling accuracy; adequacy of sampling; and timeliness of results. The need for the development of a real-time continuous respirable dust monitor, which can provide an assessment of the miner's exposure on a continuous basis, has been apparent for a longtime and identified in several recent reports by Mine

Safety and Health Administration (MSHA, 1992), National Institute for Occupational Safety and Health (NIOSH, 1995), and the Secretary of Labor's Dust Advisory Committee (MSHA, 1996). The respirable dust dosimeter (RDD) described by Volkwein et al. (1997, 2000) appears to be a promising development in dust exposure measurement.

The respirable dust dosimeter (RDD) consists of: (1) a detector tube which contains a respirable-size classifier and a pressure-drop-filter media, [Figure 1], and (2) a low-flow pump which pulls the dust-laden air through the tube and which has an integral pressure transducer with display. As the dust mass loading on the filter increases, the pressure drop (i.e. the differential pressure) across the filter increases. NIOSH's comparison of the RDD differential pressure increases with personal gravimetric mass loadings appear to fit well a regression relationship of the type $y=ax^b$, where y=differential pressure, x=mass loading, and a and b are constants (Volkwein et al., 2000). The fit is better at higher mass loadings.

Recently an independent evaluation of the RDD's performance in comparison to that of the approved gravimetric respirable dust sampler (GRD) was performed. The evaluation consisted of an assessment of the correlation that exists between RDD differential pressures and GRD mass loadings when the two types of instruments (RDD and GRD) are mounted side by side in the laboratory and in mines. Penn State, in cooperation with the University of Minnesota (UMINN), performed the laboratory and in-mine evaluations of the NIOSH-developed respirable dust dosimeter (Ramani, 1998).

The laboratory evaluations were performed at the University of Minnesota's Particle Technology Laboratory and the in-mine evaluations at two underground coal mines in Pennsylvania. Investigators from both Penn State and UMINN were involved in the laboratory and in-mine evaluation stages and in the interpretation of the results. In this paper the details, results and conclusions of the underground experiments are presented.

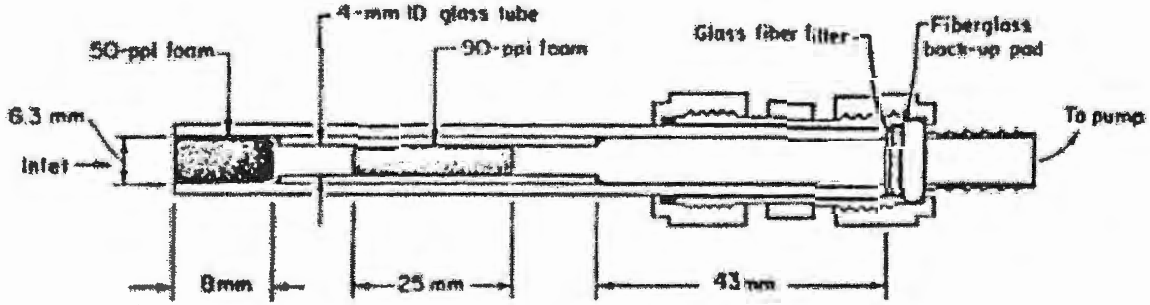

Figure 1. Respirable Dust Detector Tube

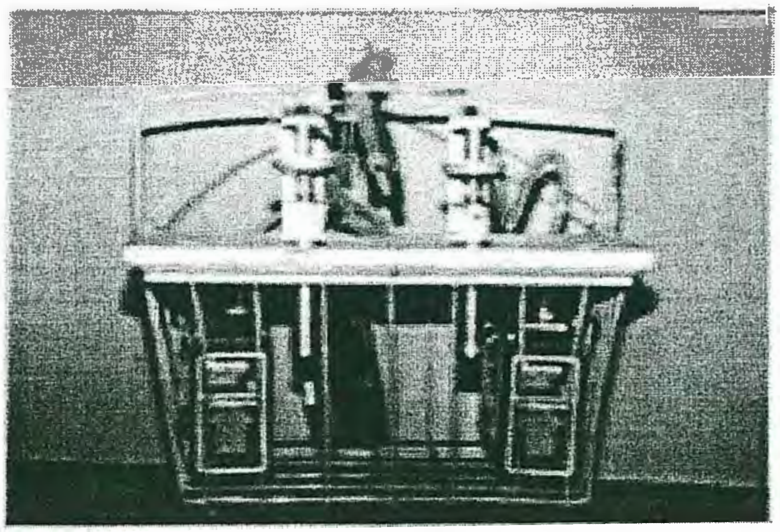

Figure 2. Photograph showing two gravimetric samplers and one respirable dust dosimeter

EXPERIMENTAL DESIGN

The underground mine experiments were designed to obtain area samples with side-by-side dosimeter and gravimetric samplers under a variety of operating conditions and dust concentrations. To achieve this objective, field tests were performed at two mines in two different coal seams. The first mine (Mine A) utilized a room-and-pillar system of mining, a single-split ventilation system, and a dust scrubber on the continuous miner. The second mine (Mine B) used the longwall mining system with a shearer for coal production. Two sampling locations in each mine were chosen so that one was in a position with a high dust concentration and the second in a location with a low to moderate dust concentration. The locations, while out of the path of moving equipment, were in the main flow of air through the section.

The airborne respirable dust concentrations at the two locations were sampled for four shifts, each shift lasting about six hours. At each location, there were three dosimeters and six gravimetric samplers in specially designed baskets. Essentially each dosimeter was matched with two gravimetric samplers (Figure 2). The sampling baskets were hung either on roof bolts or on shields.

The dosimeters were read several times during the shift. However, the most important readings were those used in the side-by-side comparisons with the gravimetric samplers. The first of these comparison readings, taken after approximately three hours of sampling, is matched with the mass of dust on the first gravimetric sampler to be turned off. The dosimeter and gravimetric readings taken at this time are called the half-shift readings. The second comparison is made after approximately six hours of operation. These values are termed the full-shift readings. Essentially, one half-shift reading and one full-shift reading were associated with each dosimeter used. Each dosimeter was used for only one shift during the field experiments.

This plan results in 48 dosimeter data measurements at a mine, each matched with the mass of dust on a corresponding gravimetric sampler filter. Further, this sampling arrangement allowed the calculation of the averages of the three dosimeter readings, and compare it to the average of the masses on the three GRD sampler filters. There were sixteen pairs of averages for the comparative analysis.

The data obtained from the mines were analyzed for ascertaining the association between the dosimeter (RDD) pressure increase and the mass of dust on the filter of the corresponding personal gravimetric sampler (GRD). Specifically, three analyses were performed.

1) The pressure increase observed in each dosimeter was compared with the mass on the filter of the corresponding gravimetric sampler.
2) The average pressure increase observed in a group of three dosimeters was compared with the average mass on the filters of the three gravimetric samplers.
3) From the three observations of the RDDs at a station, the values for the standard error of the mean (SEM) and the relative standard deviation (RSD) were calculated. Similarly, from the three observations of the GRDs at a station, the values of SEM and RSD were calculated. The global averages for SEM and RSD were calculated from the individual data.

For each analysis, the procedures included (i) drawing scatter plots of the pairs of data, (ii) fitting least-square linear and non-linear equations to the data, and (iii) calculating the prediction and confidence intervals for the fitted equation..

Mine A Experiments

Mine A was a room-and-pillar operation in Indiana County, PA, located in the Lower Freeport coal seam. Two sections were sampled in this study. Both sections utilized a Joy continuous miner to mine the coal and a Long-Airdox full-dimension mining system to provide section coal transport. The full-dimension mining system utilized three bridge conveyors and two mobile carriers to transfer the coal from the face to the section belt conveyor. No pillaring was performed.

The section layout and the ventilation plan of the first section are shown in Figure 3. The intake in this section comes up the #1 entry and returns via the #5 entry unless it is diverted into the adjacent section. The second section sampled used a similar single-split ventilation plan except that the air was coursed from right to left rather than left to right. Both of the sections were planned to have 18,000 cfm (8.5m^3/s) moving through the section. The face ventilation was controlled by brattice with most of the faces having 3000 to 5000 cfm (1.4 to 2.4 m^3/s) in the face area.

The layout shown in Figure 3 indicates the location of the intake and return sampling stations. The intake baskets were placed in the #3 entry beside the conveyor belt. The baskets were located at breathing level near the ribline opposite from where the full-dimension conveyor system was operating. The dust levels at that location were considered to be appropriate for collection of small to moderate masses of dust.

The return sampling station was typically set up around one to four breaks downwind of the continuous miner location. In this mine, the return sampling station was thus about 50 to 200 ft (15 to 60 m) from the continuous miner. A typical location is shown in Figure 3. Note that the return air in the section sampled was coursed through an adjacent panel. The continuous miner was moving from face to face. Thus, the return sampling station was occasionally moved to keep the samplers at about the same position relative to the continuous miner. The return location was chosen to obtain higher masses of dust in the gravimetric samplers and dosimeters. Total ventilation in the section was measured at 17,300 cfm (8.1 m^3/s) in the crosscut where the air was diverted into the next panel and was measured at 3000 to 4000 cfm (1.4 to 1.8 m^3/s) in the faces. Measurement was difficult in the face area due to a restricted cross-sectional area.

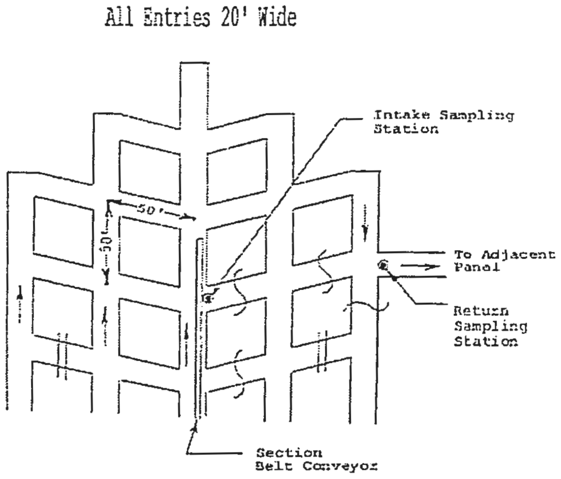

Figure 3. Typical location of the intake and return sampling stations in Mine A

In the second section, second ventilation went from right to left (entry #5 to entry #1) instead of from left to right. Face ventilation details were similar to that in the first section. The ventilation quantity in this section was measured at 18,000/cfm (8.5 m^3/s) in the return. Quantities at the face were not measured.

The production varied from about 460 tons (363 t) to 500 tons (454 t) for the periods sampled. The sampling in this mine proceeded without major problems with the sampling instruments. However, a limitation on the duration of sampling was imposed by mantrip logistics. As a result, the dust loadings were not as high as was desired.

Experimental Results

The data obtained from Mine A experiments are presented in Table 1. In all, 48 sets of comparative data were obtained. The examination of all the data after the laboratory mass weighing and dosimeter pressure drop calculations indicated two consistency problems with the collected data. The masses on two gravimetric personal samples were inconsistent with the other two personal samples at the same locations. The cause was not known, but these samples were not utilized in the

Table 1. Raw Data on Dosimeter Pressure Increase and Sample Mass for Mine A Experiments

Day	INTAKE				RETURN			
	Half Shift		Full Shift		Half Shift		Full Shift	
	Pres. Inc	Sample Mass	Pres. Inc.	Sample Mass	Pres. Inc.	Sample Mass	Pres. Inc.	Sample Mass
Mon.	0.4	0.00017	0.4	0.00028	0.5	0.00016	0.7	0.00030
	0.5	0.00020	0.7	0.00027	0.6	0.00014	0.9	0.00026
	0.7	0.00016	0.9	0.00028	0.7	0.00013	0.9	0.00029
Tues.	0.9	0.00039	0.9**	0.00048	0.7	0.00026	0.9	0.00045
	0.9	0.00036	0.9**	0.00049	0.9	0.00030	1.1	0.00049
	1.8	0.00003***	1.8**	0.00042	1.1	0.00021	1.6	0.00043
Wed.	0.9	0.00017	1.1	0.00030	0.9	0.00029	1.1	0.00043
	0.4	0.00014*	0.6	0.00006***	0.9	0.00027	1.2	0.00042
	0.7	0.00025	0.9	0.00030	0.8	0.00030	1.3	0.00046
Thur.	.05	0.00007	0.7	0.00011	0.7	0.00022	0.9	0.00021**
	0.5	0.00008	0.5	0.00017	0.6	0.00017	1.1	0.00018**
	0.3	0.00009	0.3	0.00010	0.9	0.00026	1.1	0.00005**

Dosimeter pressure increase (pres. inc.) is in millimeter of mercury (mm Hg) and sample mass in gram (g).

* This reading is suspect because the hose was found to be disconnected during the experiment.

** These data are inconsistent as dosimeter pressure readings or gravimetric mass readings did not change from half shift to full shift sampling.

*** These data are inconsistent with the data read from the other gravimetric samplers in the same group or basket.

analytical procedures. In addition, two groups of full-shift personal samples were nearly identical to the matching half-shift samples. As a result of the specific problems with these samples they were also excluded from further analysis. In summary, only 39 sets of comparative data from Mine A were used in the subsequent data analyses procedures.

Results

The scatter plot of 39 pairs of data (side-by-side comparison of individual RDD and GRD observations) revealed the problem in reading the dosimeter scale in mm of mercury (Hg). For small changes in the mass on the GRD filter, the scale reading is not sufficiently sensitive to show the changing pressure differences. This problem is particularly acute in Mine A as the amount of the mass on a filter was not only small but also within a small range, from 0.05 mg to 0.55 mg. Further, at mass loadings less than 0.5 mg, the precision of GRD measurements is less (Kogut *et. al.*, 1997) and this is reflected in low coefficient of determination of the data from this mine. However, the trend for pressure difference to increase with increase in the mass is evident. The best-fit linear equation is $y = 1.9x + 0.30$, where y = pressure increase in mm of Hg, and x = mass in mg and has a coefficient of determination (R^2) of 0.59. The best-fit non-linear equation is $y=1.70\ x^{0.57}$ with an R^2 value = 0.56.

The averages of the three dosimeter pressure increases and of the corresponding three gravimetric sampler masses were calculated for side-by-side comparison of the averages. Ideally, for the comparison of the averages, there should have been 16 data pairs. Due to the problems detected during data collection and analysis stages, only 14 pairs were available for this purpose. The relative standard deviation (RSD), calculated from the 14 gravimetric samples, was 0.1 (10 percent). The RSD values from the 14 dosimeter samples was 0.21.

A scatter plot of the averages indicates a strong linear trend which is confirmed by the linear regression equation ($y_1=2.23x_1+0.22$) where y_1 is the average of the three dosimeter pressure increases in mm of Hg and x_1 is the average of the mass on the filters of the three gravimetric samplers in mg. The non-linear regression equation fitting the same data is ($y_1=1.92x_1^{0.64}$). The R^2 values for both the equations are about 90%.

Conclusions

The higher average relative standard deviation (RSD) of the dosimeter pressure increases as compared to that of the gravimetric mass values indicates the higher variability in the dosimeter values. The side-by-side comparison of the individual dosimeter and individual gravimetric sampler observations resulted in a lower R^2 value for the fitted equation as compared to that from the comparison of the averages. This is to be expected as the averages smooth the individual variabilities. However, the lower resolution of the dosimeter pressure scale in mm of Hg and the low range of the masses collected on the filters may be additionally responsible for the low R^2 value in Mine A. Yet, it can be concluded that the dosimeter pressure increases as the mass on a gravimetric filter increases.

MINE B EXPERIMENTS

Mine B was a longwall operation mining coal in the Pittsburgh seam in Greene County, PA. The longwall at the mine was about 920 ft. (280m) long with 184 shields present on the face. The production was accomplished with bi-directional cutting by a Joy double-drum shearer. The shearer took 42" (1.1m) deep cuts of coal ranging from 5 ft. (1.5 m) to 6 ft. (1.8 m) in height. The variation in height was due primarily to ability to hold the immediate roof of the seam.

The layout of the longwall panel is shown in Figure 4. The two sampling stations were along the longwall face with the baskets attached to the shields. The baskets were hung on the shield side of the walkway with the inlets facing the walkway and in the main flow of ventilation air. The intake sampling station was located at shield #9. This location was considered to have moderate dust loading. The return sampling station was positioned at shield #140. The location was selected to allow the sampling crew to visit the baskets while the shearer was downwind. The dust loadings at this location were expected to be very high. The ventilation plan for the longwall is also shown in Figure 4.

The ventilation plan was designed to bring about 35,000 cfm (16.5 m^3/s) into the section. The intake air was measured to be about 28,800 cfm (13.6 m^3/s) at shield #9 and at about 11,200 cfm (5.3 m^3/s) at shield #140. The loss of air between the two stations is due to flow through the gob near the tailgate entries. The number of passes of the shearer along the face varied from 5 to 10 on the four sampling days. The coal mined during the sampling periods varied from about 3000 tons (2700 t) to about 6000 tons (5400 t) Some problems were encountered during the four days of sampling at this mine due to which some observations from the instruments were lost.

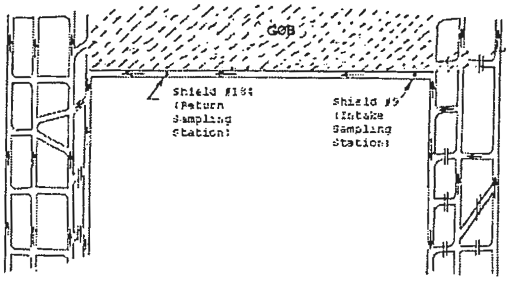

Figure 4. Location of intake and return sampling station in Mine B

Experimental results

The data obtained from Mine B experiments are presented in Table 2. As before, 48 sets of comparative data were collected. As a result of the problems experienced during the experiments which are indicated in the table, only 45 sets were useful for subsequent analyses.

The RDD and GRD data from Mine B was subjected to the same analysis procedures as the data from Mine A. The mass in the gravimetric filters ranged from about 0.35 mg to 4.5 mg, and the pressure increase in the dosimeters, from 0.5 mm of Hg to 20 mm of Hg. As with Mine A observations, an increasing trend of dosimeter pressure with increasing sample mass is evident in Mine B observations as well.

The scatter plot and the least-square linear regression of the gravimetric sample mass versus the dosimeter pressure increases for the side-by-side comparison of individual observations is shown in Figure 5. The linear and non-linear equations and their respective R^2 values are $y=1.75x + 0.29$ ($R^2 = 0.90$), and $y=1.96x^{0.99}$ ($R^2 = 0.90$), where y = dosimeter pressure increase in mm of Hg, and x = gravimetric mass in mg. Both equations have a high coefficient of determination ($R^2=0.90$), indicating a very good fit. The value of the exponent in the non-linear equation is 0.99, indicating that, within the range of values, the two variables have a high degree of linear association.

The averages of the three dosimeter pressure increases, and the corresponding three gravimetric masses were calculated. In the comparison of the averages, all 16 data pairs were utilized. In the case of samples 8, 15, and 16, only two observations were available for the calculation of the averages. The average relative standard deviations, calculated from the GRD and RDD averages, are 0.10 and 0.21. The scatter plot of the GRD mass versus RDD pressure increase, and the associated linear equation are shown in Figure 6. The linear and non-linear least -square regression equations are respectively $y_1=1.76x_1+0.28$; and $y_1=1.98x_1^{0.99}$. As before, y_1 and x_1 respectively stand for the averages of the pressures increases in the three dosimeters and the average of the masses on the three gravimetric filters at a station. Both equations have R^2 values of 95%. Clearly, the average pressure increase across the RDD filters is a good predictor of the average mass on the GRD filters. Further, the exponent of the non-linear equation is close to unity. Therefore the relationship is strongly linear in the range of mass loadings that was experienced in Mine B.

Table 2. Raw Data on Dosimeter Pressure Increase and Sample Mass for Mine B Experiments

Day	Shields 8-9				Shields 140-141			
	Half Shift		Full Shift		Half Shift		Full Shift	
	Pres. Inc	Sample Mass	Pres. Inc.	Sample Mass	Pres. Inc.	Sample Mass	Pres. Inc.	Sample Mass
Mon	0.6	0.00044	1.1	0.00064	3.9	0.00100	5.1	0.00180
	0.75	0.00045	1.12	0.00066	3.2	0.00121	4.3	0.00207
	0.93	0.00047	1.31	0.00064	2.24	0.00114	3.36	0.00187
Wed	0.9	0.00038	2.	0.00091	3.	0.00141	5.1	0.00357
	0.9	0.00035	1.1	0.00073	3.1	0.00183	6.	0.01520*
	0.9	0.00043	1.3	0.00085	2.9	0.00148	5.6	0.00354
Fri	0.8	0.00044	1.1	0.00091	5.3	0.00252	7.6	0.00429
	1.4	0.00049	1.6	0.00093	4.5	0.00255	7.2	0.00448
	1.1	0.00037	1.6	0.00080	5.5	0.00226	8.2	0.00396
Thur	0.5	0.00040	0.7	0.00044	**	0.00128	**	0.00192
	0.9	0.00034	1.2	0.00057	2.2	0.00099	4.2	0.00208
	0.6	0.00035	0.6	0.00053	2.7	0.00091	4.7	0.00193

Dosimeter pressure increase (pres. inc.) is in millimeter of mercury (mm Hg) and sample mass in gram (g).

* This reading is suspect because the hose was found to be disconnected during the experiment.

** In these two cases, the dosimeter pressure readings could not be obtained.

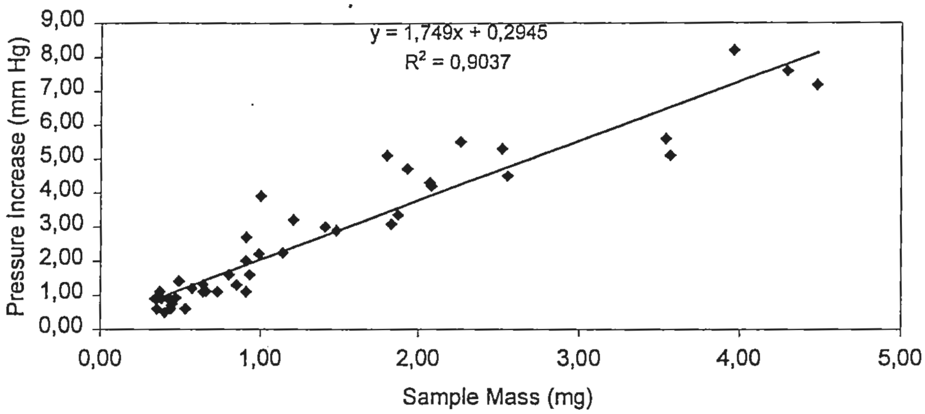

Figure 5. Scatter Plot of the One to One Sample GRD Mass and RDD Pressure Increase data, and the Associated Least Square Linear Regression Equation for Mine B Data

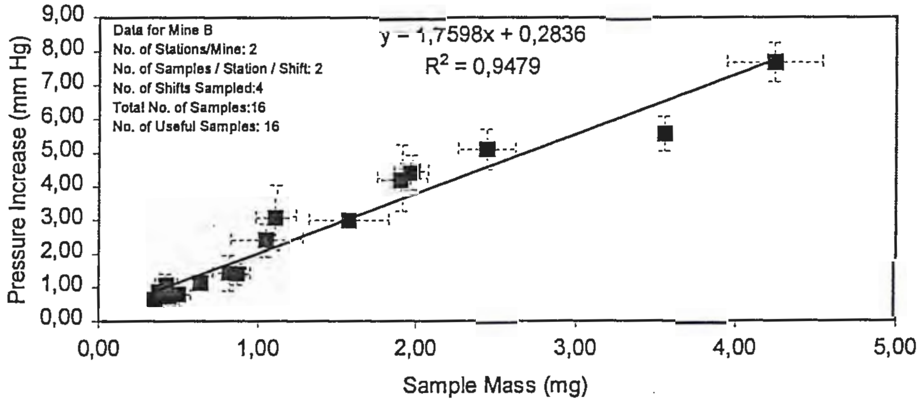

Figure 6. Scatter Plot of the Averages of the Sample Masses and Pressure Increases, and the Associated 95% Error Bars, and the Least Square Linear Regression Equation for Mine B Data

Conclusions

The results from Mine B confirm that the dosimeter (RDD) readings have a higher variability than the gravimetric readings. The side-by-side comparison of the individual readings from the two instruments through regression analysis shows a much higher R^2 value (90%) compared to that from the Mine A reading (59%). It is likely that, when subjected to a wider range of dust loadings, the problem with the low co-efficient of correlation between the RDD and GRD is decreased.

The comparison of the averages of the readings of the two instruments also confirms the existence of a high degree of predictability of the average of the mass loadings on gravimetric filters from the average of the pressure increases in corresponding dosimeters. The linear and non-linear relationship derived from Mine B readings also have high R^2 values (95%), as compared to those (R^2=90%) from Mine A readings.

The comparison of the side-by-side, one-to-one measurements, and that of the averages of the combined data set of Mine A and Mine B data reveal that the predictive linear relationship between the RDD and the GRD data is quite strong. The value of the coefficient of variation (R^2) for the regression equation is 93%, which is higher than those for Mine B (90%) and Mine A (56%). Caution must be exercised in extrapolation of this finding to different coals. Firstly, the amount and the range of mass loadings in Mine A were rather small (0.05 mg to 0.55 mg) as compared to that for Mine B (0.35 mg to 4.50 mg). Secondly, the in-mine variations in Mine A may be higher on the factors that influence the RDD and GRD performances than the mine-to-mine variations between Mine A and Mine B. The controlled experiments in the laboratory may provide more reliable information on the impact of different coal dusts on the RDD and GRD performances.

Table 3. Ranges of the Relative Standard Deviations of the Personal Gravimetric Sampler (GRD) and the Respirable Dust Dosimeter (RDD) from Mine A, Mine B and Mine A andMine B Combined Data.

Instrument	Mine A Data			Mine B Data			Mine A and Mine B Data		
	Min	Max	Average	Min	Max	Average	Min	Max	Average
Personal Gravimetric Sampler, (GRD)	0.021	0.299	0.100	0.006	0.184		0.006	0.299	0.100
Respirable Dust Dosimeter (RDD)	0.0670	0.433	0.214	0.033	0.386	0.214	0.033	0.433	0.214

Table 4. List of the Linear and Non-linear Equations from Mine A and Mine B Data

Data From	Analysis	Number of Data Pairs	Linear Equation	Non-Linear Equation
Mine A	One-to-One	39	$y=1.90x+0.30$ $R^2=0.59$	$y_1=1.70x^{0.57}$ $R^2=0.57$
	Average	14	$y_1=2.23x_1+0.22$ $R^2=0.91$	$y_1=1.92x_1^{0.64}$ $R^2=0.89$
Mine B	One-to-One	45	$y=1.75x+0.29$ $R^2=0.90$	$y=1.96x^{0.99}$ $R^2=0.90$
	Average	16	$y_1=1.76x_1+0.28$ $R^2=0.95$	$y_1=1.98x_1^{0.99}$ $R^2=0.95$
Mine A and Mine B	One-to-One	84	$y=1.74x+0.33$ $R^2=0.93$	$y=2.09x^{0.76}$ $R^2=0.86$
	Average	30	$y_1=1.74x_1+0.32$ $R^2=0.96$	$y_1=2.14x_1^{0.77}$ $R^2=0.93$

SUMMARY

In underground mine experiments, the performance of a total of 96 respirable dust dosimeters (RDD) was evaluated by comparing the pressure increase across each dosimeter filter to the mass of dust collected on the filter of a matching personal gravimetric sampler (GRD). The dosimeters were equally split between two mines, Mine A and Mine B. The samplers were exposed to additional temporal and spatial variability of airborne dust concentrations as sampling was conducted at each mine for four different days at two distinct locations with at least six hours of sampling per day. At each location, there were three dosimeters and six gravimetric samplers.

Some of the limitations of the data must be recognized. The data for the study came from only two mines. Further, the dust loadings in Mine A were rather small, and varied only over a small range. Even with the most careful experimental design and execution, some data collected during the experiments were found to be questionable. However, sufficient data were available for the analyses needed by the study. Therefore, the conclusions drawn from these analyses are valid.

From the three RDD and GRD readings at a location, the coefficients of variation [or the relative standard deviation (RSD)] of the RDD and GRD were calculated. The range of the individual RSD values calculated from the Mine A, Mine B, and the combined Mine A and Mine B data are shown in Table 3. The RSDs for both the GRD and the RDD vary over a wide range. The average of the calculated RSDs for GRD is 0.0999 (nearly 10%), and that for the RDD is 0.2136 (over 21%). Clearly, on the average, a respirable dust dosimeter reading is associated with greater uncertainty.

The linear and non-linear regression equations and associated coefficients of determination (R^2) of the side-by-side, one-to-one, comparison of the RDD (y) and GRD (x) readings as well as of the average RDD (y_1) and GRD (x_1) readings obtained from Mine A, Mine B, and combined Mine A and Mine B data are shown in Table 4. As already indicated, the data from Mine A encompassed not only very small mass loading but also a very narrow range of mass loadings. Even then, the linear equation based on the averages has a R^2 of 91%, indicating that a very high degree of linear association between the GRD and RDD averages. The representation of the relationship between the GRD and RDD by a linear equation appears to be appropriate since the values of R^2 for the non-linear relationship are loweror at most equal, and in several cases, the exponent values are close to unity. On the basis of this experimental study, it is concluded that the pressure increase across the respirable dust dosimeter filter is strongly related to the mass of dust on the corresponding personal gravimetric sampler filter.Further, it is concluded that this relationship is strongly linear in the range of mass loadings experienced in the two mines. Therefore, the dosimeter reading is a good surrogate of the mass of dust on a personal gravimetric filter, and can be used to approximate the cumulative dust exposure, calculated either as a mass or a time-weighted concentration. The development of an appropriate calibration curve for use in the field with the dosimeters must take into account the several influencing factors discussed here.Controlled experiments in the laboratory should provide additional insights to this challenging but very rewarding task.

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