Evaluation of SKC Inc. Dust Detective

E.E. Hall, R.P, Vinson, and J.C. Volkwein

U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory, Pittsburgh, PA, USA

ABSTRACT: Assessment of workplace exposures is an important tool for helping to minimize dust-related occupational illness and diseases. Real-time particulate monitoring can effectively locate areas where dust controls are needed and determine how well they are working. An affordable, person-wearable, real-time dust monitor is needed. The SKC Inc. Dust Detective (SKCDD) fulfills those requirements (Disclaimer: Mention of any company or product does not imply endorsement by NIOSH). The SKCDD consists of a disposable sampling tube (DST) connected to a small hand-held sampling pump. The SKCDD was developed through a Cooperative Research and Development Agreement (CRADA) between the National Institute of Occupational Safety and Health (NIOSH) and SKC Inc. The relationship of dust concentrations measured by personal gravimetric samplers to those measured by the SKCDD was determined in a laboratory aerosol chamber. A comparison of the means and the relative standard deviation of triplicate measurements of each type of sampling device demonstrated the SKCDD to be a viable alternative means for measuring dust. While it provides accurate measurements for specific coal types, it requires correction factors (those correction factors still need to be calculated) for other coal types.

1 INTRODUCTION

Medical studies have shown that prolonged inhalation of excessive levels of respirable coal mine dust can lead to coal workers' pneumoconiosis, a disease that is irreversible and can be progressive, disabling, and ultimately fatal. Thousands of underground and surface mine workers who are potentially at risk of developing adverse health effects from breathing respirable coal and silica dusts. The Coal Mine Health and Safety Act of 1969 included a Black Lung Benefits Program. Over 104,000 beneficiaries received benefits in 2004. The Black Lung Disability Trust Fund provided over $292 million in monthly benefits to beneficiaries while the Division of Coal Mine Worker's Compensation administered another $380 million in monthly benefits (Office of Workers' Compensation Programs 2004). Research and development in the measurement and control of mine dust will help reduce the number of pneumoconiosis cases as well as minimize worker compensation expenses.

The assessment and sampling of dust levels can be challenging because of the variable composition of the dusts and the constantly moving work area (Hearl & Hewett 1993). Currently, dust levels in mining are either measured gravimetrically (Raymond et. al. 1987), using filters and the accumulated dust mass in a given quantity of air, or through the use of instantaneous electronic or direct-reading dust monitors (Cantrell et. al. 1993). The filter method can take several weeks to process before results are reported to the mine, which creates a delay in identifying and correcting the problem. Current available instantaneous or direct-reading monitors are not practical for routine personal monitoring because of their complexity, size and expense (Volkwein et. al. 2000).

The U.S. Department of Labor's Advisory Committee on the Elimination of Pneumoconiosis Among Coal Mine Workers recommended the development of both fixed site and portable continuous respirable dust monitors that could be used to enhance their compliance monitoring program. In response to this request, NIOSH examined several approaches. A personal dust monitor (PDM) has been designed, built and at present is proving to be an accurate and reliable dust monitor (Volkwein et. al. 2000). However, when the PDM becomes available to industry, it will cost several thousand dollars (present estimates range from $7,000 to $15,000). A more affordable, person-wearable, real-time dust monitor is now available that will provide the coal miner with a good estimate of his/her exposure to dust. The monitor is called the SKC Inc. Dust Detective (SKCDD) and will be less than $1,000 to purchase. The SKCDD empowers miners to self-assess their exposure to respirable dust in real time.

The PDM is a quantitative instrument while the SKCDD is a qualitative tool. The PDM is a more expensive instrument yielding greater accuracy and more user options, while the SKCDD provides fewer options and still maintains accuracy at a lower cost. Both instruments will be very useful in providing mine operators the information they need to make control technology and administrative changes to reduce miner exposure when needed.

2 DESCRIPTION OF INSTRUMENTS

2.1 *Personal gravimetric samplers*

Flow-controlled coal mine dust personal sampler units (CMDPSU) are currently used in mines; they are mandated by 30CFR part 74. A CMDPSU consists of a Mine Safety Appliances (MSA) Escort Elf pump operated at 2 lpm, connected to a sampling head by a section of ¼-in inside diameter (ID) flexible tubing. The sampling head consists of a 37-mm diameter MSA filter cassette connected to a 10-mm diameter Dorr-Oliver cyclone size preselector. The CMDPSU were used to sample coal dust aerosols from the Marple chamber, a laboratory dust exposure chamber designed to evenly disburse dust throughout the chamber (Marple & Rubow 1983). Filters were pre- and post-weighed at the Pittsburgh Research Laboratory (PRL) in a controlled atmosphere. NIOSH receives filters unassembled; therefore the filters were prepared without the tamper-resistant backflow valve or the inner stainless steel support wheel since they were not necessary for laboratory testing. Pump flows were checked weekly with a Gilian Bubble Flow Meter, a primary standard flow measurement device. Twelve personal samplers were arranged for each test in groups of three, so that each grouping was evenly spaced about the central portion of the chamber at about the same elevation.

2.2 *SKC Dust Detectives*

One of the main components of the SKCDD is the dust detector tube. The dust detector tube was developed to provide inexpensive, short-term measurement of the cumulative personal dust exposure of a worker during a shift. The dust detector tube models itself after the concept of a radiation dosimeter or, more precisely, after sorbent detector tubes used to measure exposure to various gases. The SKCDD software converts differential pressure to cumulative respirable dust exposure and short term exposure.

The SKCDD consists of a disposable sampling tube (DST) connected to a small hand-held sampling pump. Flow-controlled sampling pumps manufactured by SKC Inc. (Dust Detective) were operated at a flow rate of 0.250 lpm to draw coal dust aerosols into the dust detector tubes. The sampling pump consists of programmable microprocessor, flow sensor, pressure sensor, air pump, control switches, and a digital display. The DST dimensions are ½-in in ID by 4 inches in length. The tube contains two cylinders of porous foam that are particle size pre-separators at the inlet end and a glass fiber filter at the outlet end. The outlet end of the DST is connected to a sampling pump/monitor with a section of ¼-in ID flexible tubing. The disposable single-use tube contains a respirable size classifier and the pressure drop filter media and can be assembled for a few dollars per tube (Volkwein et. al. 2000).

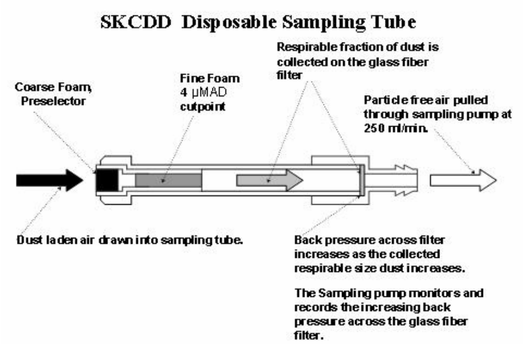

Figure 1. SKC Dust Detective disposable sampling tube

As the respirable dust collects on the glass fiber filter there is a corresponding increase in pressure drop across the filter. The pressure drop and air flow through the pump are continuously monitored and used by the pump's programmable microprocessor to calculate the dust concentration. The back pressure increases linearly with dust particle buildup on the filter. The instruments are equipped with only three buttons, which allow for simplicity in programming the units, entering a calibration factor, and test parameters (Fig. 2).

Figure 2. SKC Dust Detective

3 METHODS AND MATERIALS

Dust concentrations were measured by personal gravimetric samplers and by SKC Dust Detective (SKCDD) in a laboratory aerosol chamber. By comparing the means and the relative standard deviation of triplicate measurements of each type of sampling device, a correlation could be determined. A regression analysis was done to obtain the relative standard deviation (RSD), slope, and regression coefficient (R^2) values.

3.1 *Test aerosols*

Tests for this study were conducted in the Marple Chamber. They were comprised of three separate trials of five different coal types for a total of fifteen coal dust samplings, where MMD is the mass median diameter and GSD is the gravimetric standard deviation. The coal types were:

- Keystone Black, 4.66 MMD, 3.04 GSD
- Illinois #6, 5.72 MMD, 3.15 GSD
- Pittsburgh Coal 18 µm, 11.01 MMD, 2.79 GSD
- Pittsburgh Coal 10 µm, 4.05 MMD, 1.98 GSD
- Pittsburgh Coal 5.77 µm, 3.68 MMD, 2.59 GSD

The size distribution measurements were made in the Marple Aerosol Chamber using Marple Personal Cascade Impactors 290 Series.

3.2 *Test procedure*

The guidelines for each set of three tests are as follows:

Test 1: The Marple Aerosol Chamber was brought to an MRE equivalent (MRE is a multiplier of 1.38 required to meet federal standards (30CFR)) concentration of 2.0 mg/m^3. Three SKCDDs and 12 CMDPSUs were started at the beginning of the test. The SKCDDs ran for 8 hours. Three CMDPSUs were turned off at each of the MRE equivalent concentrations of 0.3, 0.5, 1.0, and 2.0 mg/m^3 to compare concentrations at different mass loadings.

Test 2: The Marple Aerosol Chamber was brought to an MRE equivalent concentration of 2.5 mg/m^3. Three SKCDDs and 12 CMDPSUs were started at the beginning of the test. The SKCDDs ran for 8 hours. Three CMDPSUs were turned off at each of the MRE equivalent concentrations of 0.6, 1.2, 1.8, and 2.5 mg/m^3 to compare concentrations at different mass loadings.

Test 3: The Marple Aerosol Chamber was brought to an MRE equivalent concentration of 4.0 mg/m^3. Three SKCDDs and 12 CMDPSUs were started at the beginning of the test. The SKCDDs ran for 8 hours. Three CMDPSUs were turned off at each of the MRE equivalent concentrations of 1.0, 2.0, 3.0, and 4.0 mg/m^3 to compare concentrations at different mass loadings.

The sampling inlets for both the SKCDD and CMDPSUs were positioned so that they were all facing the center of the chamber. The dust concentrations in the aerosol chamber were monitored with a TEOM1400a operated at 2.0L/min. The inlet of the TEOM was connected to a 10-mm cyclone with a 5-ft section of ¼-in diameter tubing.

4 RESULTS AND DISCUSSION

Tests were run using concentrations as a guide for comparison with federal standards however for simplicity in data analysis dust mass was used. Data was analyzed and the standard deviation and relative standard deviation for both the CMDPSUs and the SKCDDs were calculated and are shown in Table 1.

Table 1. Summary of laboratory correlation data

Coal Type	Power Function y =	R2	CMDPSU STD	SKCDD STD	CMDPSU RSD	SKCDD RSD
Keystone Black	1.1x + 0.25	0.98	0.02	0.14	0.02	0.13
Illinois #6	0.72x + 0.06	0.96	0.02	0.10	0.02	0.11
Pittsburgh 10um	0.35x + 0.03	0.89	0.03	0.06	0.03	0.06
Pittsburgh 18um	0.39x + 0.03	0.94	0.03	0.17	0.03	0.14
Pittsburgh 5.77um	0.72x + 0.12	0.99	0.03	0.19	0.03	0.16

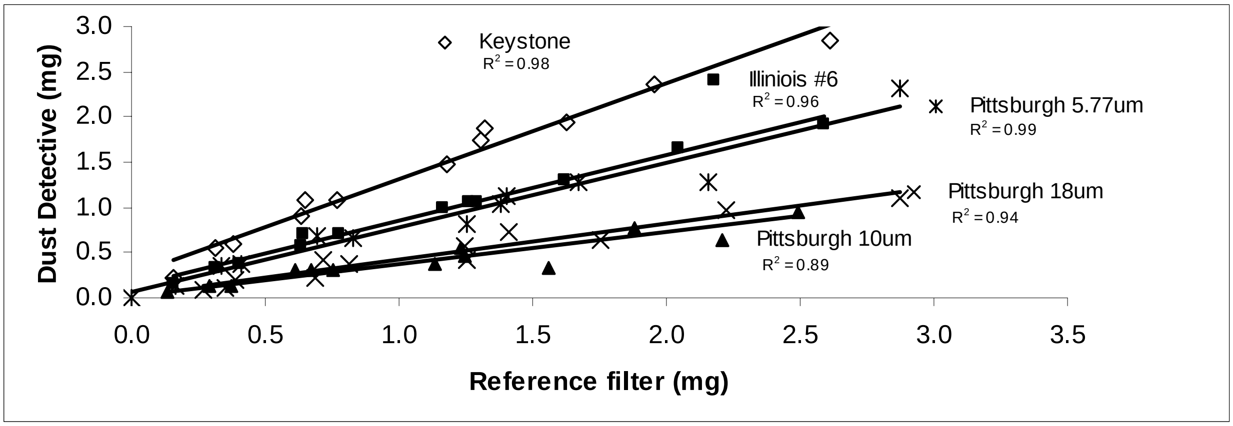

Figure 3. Dust Detective responses to coal types

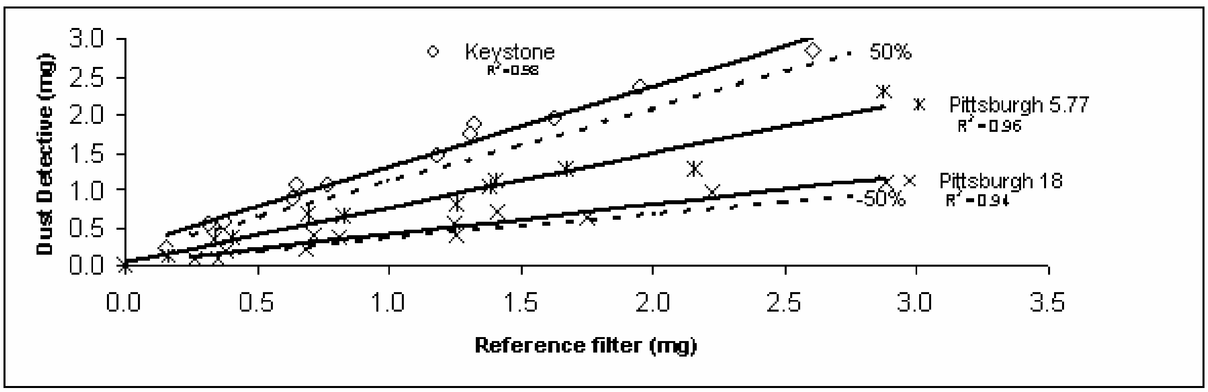

Figure 4. Dust Detective responses optimized for calibration factor

The RSD for the CMDPSU for all coal types, except Pittsburgh 18 µm, was lower than that of the SKCDD, but the differences were generally minimal. The regression coefficient was 0.86 or greater for all coal types.

The averages of the three SKC Dust Detective instruments were compared with the CMDPSU data. The SKCDD dust masses were plotted against the CMDPSU dust masses. Linear regression was used to find the RSD, slope and R^2 values. As shown above in Figure 3, the Dust Detective response for each coal type was linear. The slopes for the coal types varied. The Illinois #6 and Pittsburgh 5.77µm had similar slopes as did Pittsburgh 18 µm and Pittsburgh 10 µm. This is attributed to the differences in how each coal type loads the filter and changes the pressure drop.

A regression analysis was performed for the data for all coal types. Based on the slope of the line that was derived from the data from all coal types, a range of ±50% is shown above in figure 4. The ±50% is the European Standard criteria for survey instruments (EN 1994). Four of the five coal types fall within the parameters, therefore suggesting that one calibration factor would adequately represent those coal types. Keystone Black was the only coal type whose slope was out of the range. This could be due to that it is a manufactured product and not naturally occurring; it is a more finely ground coal material with size distribution less than naturally occurring coal. Based on the R^2 values, the SKCDDs can be programmed for coal seams specific to mine operations.

5 CONCLUSIONS

Initial work indicates that the SKC Dust Detective will be a reliable instrument that will provide a low cost alternate means for estimating dust concentrations. The instrument can be calibrated for specific coal types and is easy to program. Laboratory comparisons to CMDPSUs show good correlation for individual coal types. These instruments will be most applicable when big differences in size distribution are not expected. Future work will include water spray response (for longwall operations), determining correction factors, and conducting underground mine studies. The instantaneous feedback on dust level exposures that the SKC Dust Detective provides will help empower the worker and mine management to improve the mining conditions and protect the worker's respiratory health.

6 DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

REFERENCES

Cantrell, B.K.; Williams, K.L.; Watts, W.F. Jr.; et al.: Mine Aerosol Measurement, Aerosol Measurement: Principles, Techniques and Application, Chap. 26, pp.591-611. K. Willeke and B.A. Baron, Eds. Van Nostrand, New York (1993).

European Standard. EN 482 (1994).

Hearl, F.J.; Hewett, P.: Problems in Monitoring: Dust Levels Within Mines. Occupational Medicine: State of the Art Reviews 8(1):93-109 (January-March 1993).

Marple, V.A.; Rubow, E.L.: An Aerosol Chamber for Instrument Evaluation and Calibration. American Industrial Hygiene Association Journal 44(5):361-367 (1983).

Office of Workers' Compensation Programs: Black Lung Benefits Act 1996. DOL, Washington, D.C. (1997).

Raymond, L.D.; Tomb, T.F.; Parobeck, P.S.: Respirable Coal Mine Dust Sample Processsing. MSHA IR 1156 (1987).

U.S. Department of Labor: Report of the Secretary of Labor's Advisory Committee on the Elimination of Pneumoconiosis Among Coal Mine Workers, recommendations 8 and 17. DOL, Washington, D.C. (October 1996).

Volkwein, J.C.; Schoeneman, A.L.; Page, S.J.: Laboratory Evaluation of Pressure Differential Based Respirable Dust Detector Tube. Applied Occupational and Environmental Hygiene 15(1):158-164 (2000).