

TABLE V-2.—RESPIRABLE COAL MINE DUST EPIDEMIOLOGICAL STUDIES, BY REPORTED OUTCOMES FROM 1986 TO PRESENT—Continued

Studies	Reported outcomes
Hansen, <i>et al.</i> , Weiss, <i>et al.</i> , 1995	1999 LLF

COPD: Chronic obstructive pulmonary disease.

SCWP: Simple coal workers' pneumoconiosis.

LLF: Loss of lung function.

PMF: Progressive massive fibrosis.

RS: Respiratory symptoms.

* Studies of U.S. Miners Who Participated in the National Study of Coal Workers' Pneumoconiosis (NSCWP).

a. Simple Coal Workers' Pneumoconiosis (Simple CWP) and Progressive Massive Fibrosis (PMF)

Studies following Cochrane (1962) and McLintock *et al.* (1971) have confirmed that the risk of PMF increases with increasing category of simple CWP (Hurley and Jacobsen, 1986; Hurley, *et al.*, 1987; Hurley and Maclaren, 1988; Hodous and Attfield, 1990). However, the risk of PMF was greater than previously predicted among miners with simple CWP category 1 or without simple CWP (*i.e.*, category 0) (Hurley, *et al.*, 1987). The risk of PMF increased with increasing cumulative exposure, regardless of the initial category of simple CWP (Hurley, *et al.*, 1987), indicating that reducing dust exposures is a more effective means of reducing the risk of PMF than reliance on detection of simple CWP.

Attfield and Seixas (1995) have demonstrated a relationship between cumulative exposure to respirable coal mine dust and predicted prevalence of pneumoconiosis (*i.e.*, simple CWP, PMF). Two strengths of this study include the quantitative description of exposure-response among both miners and ex-miners (who had worked approximately 13–40 years in mining) and the fact that these data represent recent conditions experienced by miners in the U.S. They studied a group of approximately 3,194 men who worked in underground bituminous coal mines. The U.S. miners and ex-miners had participated in Round 1 (1970–1972) or Round 2 (1972–1975) of the NSCWP and were examined again in Round 4 (1985–1988). The study population excludes 86 miners for whom there was missing exposure data or unreadable x-rays. Chest x-rays were read to determine the number of cases of simple CWP and PMF. Attfield and Seixas (1995) used two or three B readers to identify the profusion of radiographic opacities based on the ILO classification scheme. The most inclusive category defined in their paper was CPW 1+ which includes simple CWP categories 1, 2, and 3, as well as

PMF. Dust exposure estimates were generated from measurements of dust concentrations as well as from work history. A logistic (or logit) regression model was used to estimate prevalence of simple CWP and PMF. In this statistical analysis, proportions are transformed to natural logarithmic values, *i.e.*, $y = \ln [p/(1-p)]$, before a linear model is fit to the data (Armitage, 1977). The logistic model assumes that the data have a binomial distribution (*e.g.*, presence or absence of PMF) for a given set of covariate values (*e.g.*, age, coal rank, dust exposure, pack-years of smoking). Using logistic modeling, relationships were developed between cumulative dust exposure and prevalence of simple CWP (category 1+, category 2+) and PMF. These relationships were the key strengths of the Attfield and Seixas study and serve as the basis for the quantitative risk assessment (QRA) of this rule.

The recent paper of Kuempel, *et al.* (1997) has provided a detailed discussion and quantitative presentation of excess risks associated with respirable coal dust exposures. Their study was based upon results from previous studies of some 9,000 underground coal miners who participated in the NSCWP (Attfield and Morring, 1992b; Attfield and Seixas, 1995). Kuempel, *et al.* estimated excess (exposure-attributable) prevalence of simple CWP and PMF (*i.e.*, number of cases of disease present in a population at a specified time, divided by the number of persons in the population at that specified time). Point estimates of excess risk of PMF ranged from 1/1000 to 167/1000 among miners exposed at the current MSHA standard for respirable coal mine dust. These estimates were based upon dust exposure that occurred over a miner's working lifetime (*e.g.*, 8 hours per day, 5 days a week, 50 weeks per year, over a period of 45 years). Actual occupational lifetime exposure may be more, due to extended work shifts and work weeks. The point estimates of PMF presented by Kuempel, *et al.* (1997)

were related to coal rank, where higher estimates (*e.g.*, 167/1000) were obtained for high-rank coal (anthracite coal) and somewhat lower estimates were obtained for medium/low rank bituminous coal (*e.g.*, 21/1000). Within each coal rank, the estimates of simple CWP cases were at least twice as high as those for PMF (*e.g.*, 167/1000 PMF vs. 380/1000 simple CWP \geq 1).

The data of Attfield and Seixas (1995) and Kuempel, *et al.* (1995; 1997) were consistent with previous data of Attfield and Morring (1992b) who reported relationships between estimated dust exposure and predicted prevalence of simple CWP or PMF. They also noted that exposure-response relationships were steeper for higher ranks of coal such as anthracite, and concluded that the risks for anthracite miners appeared to be greater than for miners exposed to lower rank coal dust. Attfield and Morring (1992b) used similar methods as described above (*i.e.*, logistic modeling), but included miners from Round 1 of the NSCWP (1969–1971); thus representing an earlier time point in the NSCWP when the respirable coal mine dust concentrations were much higher than they are today.

Recently, Goodwin and Attfield (1998) reported that there were concerns regarding methodological inconsistencies across surveys given during the four rounds of the NSCWP. In particular, they noted the discordance in classification of simple CWP and PMF among readers of chest films. Despite potential discordance, Goodwin and Attfield (1998) have confirmed previous findings of a decline in simple CWP prevalence from 1969 to 1988. Yet, these analyses also demonstrated that simple CWP has not been eliminated. The Round 4 prevalence rates were 3.9 percent for simple CWP category 1 and higher, and 0.9 percent for category 2 and higher. This illustrates the need for continued efforts to reduce dust exposures.

Given the current system for monitoring exposures and identifying overexposures in the U.S., miners are at increased risk of developing simple