

exposures. Inhalation was generally the route of exposure, although several studies have also employed instillation techniques (*i.e.*, a method which places a known quantity of dust into the trachea or bronchi).

Most recent toxicological studies have been short-term studies, largely focusing on "lung overload" (Sipes, 1996; Oberdorster, 1995; Morrow, 1988, 1992; Witschi, 1990), species-dependent lung responses (Nikula, *et al.*, 1997a,b; Mauderly, 1996; Lewis, *et al.*, 1989; Moorman, *et al.*, 1975), and particle size-dependent lung inflammation (Soutar, *et al.*, 1997). The data have shown that pulmonary clearance of particles may become impaired, potentially leading to inflammatory and other cellular responses in the lung. Although overloading has not been demonstrated in humans, the finding of reduced lung clearance among retired U.S. coal miners (Freedman and Robinson, 1988) is consistent with this possibility.

The data from Moorman, *et al.* (1975), Lewis, *et al.* (1989), and Nikula, *et al.* (1997a,b) are noteworthy for several reasons. First, these groups of investigators conducted chronic inhalation toxicity studies (*i.e.*, chronic

bioassays). This is important since miners' exposures also occur via inhalation, and over a working lifetime. Secondly, the investigators used an exposure concentration of 2.0 mg/m<sup>3</sup> in their bioassays. As noted above, this is the current MSHA standard for respirable coal mine dust. Thirdly, the exposures involved nonhuman primates, whose responses are thought to closely mimic those of man. Some of the key findings of these studies included: deposition of coal dust in the animals' lungs, retention of coal dust in alveolar tissue, altered lung defense mechanisms, reduced pulmonary airflows, and hyperinflation of the lungs. One of the shortcomings of these studies is that complete dose-response relationships were not developed. However, at higher exposure concentrations, greater effects may be expected which is a basic tenet of toxicology. Thus, at exposure concentrations above 2.0 mg/m<sup>3</sup>, MSHA and NIOSH believe that more severe obstructive lung disease may occur (65 FR 42078).

### 3. Epidemiological Literature

Epidemiological studies have consistently demonstrated the serious health effects of exposure to high levels

of respirable coal mine dust (*i.e.*, above 2.0 mg/m<sup>3</sup>) over a working lifetime. Table V-2 lists epidemiological studies since 1986 whose results will be discussed on the basis of the type of observed health effect. Studies completed even earlier including the early work of Cochrane (1962), McLintock, *et al.* (1971), and Jacobsen, *et al.* (1971) demonstrated the adverse health effects (*e.g.*, simple CWP, PMF) of respirable coal mine dust in British coal miners.

Both early and recent studies have shown that the lung is the major target organ (*i.e.*, organ in which toxic effects occur) when exposure to respirable coal mine dust occurs. As seen in Table V-2, numerous studies of miners have been conducted. Recent U.S. studies were conducted using data from one or more of the first four rounds of the National Study of Coal Workers' Pneumoconiosis (NSCWP), and have provided extensive data on miners' health. Many of these studies demonstrated that miners are at increased risk of multiple, concurrent respiratory ailments (Attfield and Seixas, 1995; Kuempel, *et al.*, 1997; Meijers, *et al.*, 1997; Seixas, *et al.*, 1992).

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

Studies	Reported outcomes
Meijers, <i>et al.</i> , 1997 .....	PMF, SCWP, COPD, LLF
Bourgard, <i>et al.</i> , 1998 .....	PMF, SCWP, LLF, RS
Kuempel, <i>et al.</i> , 1997* .....	
Maclaren, <i>et al.</i> , 1989 .....	
Kuempel, <i>et al.</i> , 1995* .....	PMF, SCWP, COPD
Love, <i>et al.</i> , 1997 .....	PMF, SCWP, LLF
Love, <i>et al.</i> , 1992 .....	
Althouse, <i>et al.</i> , 1998* .....	PMF, SCWP
Attfield and Moring, 1992b* .....	
Attfield and Seixas, 1995* .....	
Goodwin and Attfield, 1998* .....	
Hodous and Attfield, 1990* .....	
Hurley and Jacobsen, 1986 .....	
Hurley and Maclaren, 1987; 1988 .....	
Hurley, <i>et al.</i> , 1987 .....	
Morfeld, <i>et al.</i> , 1997 .....	
Starzynski, <i>et al.</i> , 1996 .....	
Yi and Zhang, 1996 .....	
Collins, <i>et al.</i> , 1988 .....	SCWP, COPD, LLF, RS
Morfeld, <i>et al.</i> , 1997 .....	SCWP
Cockcroft and Andersson, 1987 .....	SCWP, COPD, LLF
Wang, <i>et al.</i> , 1997 .....	
Leigh, <i>et al.</i> , 1994 .....	COPD, LLF, RS
Marine, <i>et al.</i> , 1988 .....	
Seixas, <i>et al.</i> , 1993 .....	
Soutar and Hurley, 1986 .....	
Attfield and Hodous, 1992* .....	LLF, RS
Carta, <i>et al.</i> , 1996 .....	
Henneberger and Attfield, 1997* .....	
Henneberger and Attfield, 1996* .....	
Lewis, <i>et al.</i> , 1996 .....	
Seixas, <i>et al.</i> , 1992* .....	