

# 5 Conclusions

The following conclusions about the health effects caused by exposure to respirable crystalline silica are derived from studies in humans and animals published since the 1974 criteria document [NIOSH 1974]. These studies support the risk of silicosis, lung cancer, and several other debilitating and fatal diseases from occupational exposure to crystalline silica. The onset of silicosis and lung cancer is thought to be related to the biological activity and the lack of solubility of crystalline silica particles in body fluids and tissues.

## 5.1 Lung Cancer

In 1988 testimony to the U.S. Department of Labor, NIOSH recommended that respirable crystalline silica be considered a potential occupational carcinogen [54 Fed. Reg. 2521 (1989)]. Since then, additional studies have supported a lung cancer risk from exposure to crystalline silica:

- Lung cancer is associated with occupational exposures to crystalline silica [ATS 1997], specifically quartz and cristobalite [IARC 1997].
- An exposure-response relationship has been reported in studies of miners, diatomaceous earth workers, granite workers, pottery workers, refractory brick workers, and other workers (see Section 3.4.2).
- Meta-analyses of the epidemiologic studies of silica exposure and lung cancer reported a moderate summary relative risk of 1.3 for silica-exposed

workers [Steenland and Stayner 1997] and higher summary relative risks of 2.2 to 2.8 for silicotic workers [Steenland and Stayner 1997; Tsuda et al. 1997; Smith et al. 1995]. Some of the studies of silica-exposed workers controlled for the effects of smoking and others did not. The available data also support the conclusion that silicosis produces an increased risk for bronchogenic carcinoma, but the data are “less clear” as to whether silica exposure is associated with lung cancer in the absence of silicosis [ATS 1997].

## 5.2 Noncarcinogenic Health Effects

In 1974, NIOSH established an REL for respirable crystalline silica of  $0.05 \text{ mg/m}^3$  as a 10-hr TWA to prevent the risk of silicosis from occupational exposure [NIOSH 1974]. Since then, additional studies have indicated that a risk for silicosis exists at the NIOSH REL. Three recent epidemiologic studies have shown that the estimated risk of silicosis for a 45-year working lifetime is 47% to 90% for cumulative silica exposures at concentrations equal to the current OSHA and MSHA PELs, and approximately 10% to 30% at concentrations equal to the NIOSH REL (see appendix) [Kreiss and Zhen 1996; Steenland and Brown 1995a; Hnizdo and Sluis-Cremer 1993]. The results from these studies support the need for continued medical and epidemiologic surveillance of workers after they leave employment and for revision of OSHA and MSHA standards for respirable crystalline silica.

Additional studies have reported the risk for several other debilitating and fatal diseases:

- Several epidemiologic studies have reported statistically significant numbers of excess deaths or cases of immunologic disorders and autoimmune diseases in silica-exposed workers. These diseases and disorders include scleroderma [Steenland and Brown 1995b; Cowie 1987], rheumatoid arthritis [Sluis-Cremer et al. 1986; Klockars et al. 1987; Rosenman and Zhu 1995], systemic lupus erythematosus [Steenland and Brown 1995b], and sarcoidosis [Rafnsson et al. 1998].
- Recent epidemiologic studies have reported statistically significant associations of occupational exposure to crystalline silica with renal diseases and subclinical renal changes [Steenland et al. 1990, 1992; Steenland and Brown 1995b; Calvert et al. 1997; Nuyts et al. 1995; Hotz et al. 1995; Boujema et al. 1994; Ng et al. 1993].
- Crystalline silica may affect the immune system, leading to mycobacterial infections (tuberculous and nontuberculous) or fungal infections [ATS 1997; NIOSH 1992a,b, 1996b; Ziskind et al. 1976; Parkes 1982; Parker 1994], especially in workers with silicosis [Corbett et al. 1999; Kleinschmidt and Churchyard 1997; Althouse et al. 1995; Goldsmith et al. 1995; Hnizdo and Murray 1998; ATS 1997].
- Occupational exposure to respirable crystalline silica is associated with bronchitis, COPD, and emphysema (see Section 3.5). Some epidemiologic studies suggest that these health effects may be less frequent or absent in nonsmokers.

### 5.3 Exposures, Monitoring, and Controls

Published studies on workers exposed to crystalline silica indicate that exposures still occur at concentrations exceeding the OSHA and MSHA PELs and the NIOSH REL. Engineering control methods used to control silica exposures in some industrial environments may not be feasible for reducing airborne exposures in other workplaces where their implementation is hindered by the type of work being performed. In addition, sampling and analytical techniques used to measure airborne crystalline silica exposures are limited in their ability to accurately quantify exposures below the NIOSH REL. The following issues must be resolved to prevent silicosis and other debilitating and fatal diseases:

- Many occupational exposures to crystalline silica still exceed applicable Federal standards. Of the 255 industries targeted for OSHA inspection between 1980 and 1992, 48% had overall average exposures for respirable quartz that exceeded the PEL [Freeman and Grossman 1995]. Analysis of OSHA compliance data for five of the three-digit SICs (masonry and plastering, heavy construction, painting and paper hanging, iron and steel foundries, and metal services) for the period 1979–1995 indicated that an estimated number of workers were exposed to concentrations of respirable crystalline silica that were at least 10 times the NIOSH REL of  $0.05 \text{ mg/m}^3$  (10-hr TWA) [Linch et al. 1998] (see Section 2.3).
- Workers are exposed to crystalline silica in a variety of industries and occupations in which engineering controls may not be feasible for reducing exposures and may necessitate the use of other worker protection measures such as substitution

(use of a less hazardous material) or respirator use.

- Current sampling and analytical methods used to evaluate occupational exposure to crystalline silica do not meet the appropriate accuracy criterion needed to quantify exposures at concentrations below the NIOSH REL of  $0.05 \text{ mg/m}^3$  (see Section 2.4). However, the recent introduction of a new sampler that can operate at a higher flow rate and the ongoing improvements in the analysis of crystalline silica should soon make it possible to measure crystalline silica exposure accurately when it is below  $0.05 \text{ mg/m}^3$ .

Until these improved sampling and analytical methods are developed for respirable crystalline silica, NIOSH will continue to recommend an exposure limit of  $0.05 \text{ mg/m}^3$  to reduce the risk of developing silicosis, lung cancer, and other adverse health effects. NIOSH also recommends minimizing the risk of illness that remains for workers exposed at the REL by substituting less hazardous materials for crystalline silica when feasible, by using appropriate respiratory protection when source controls cannot keep exposures below the NIOSH REL, and by making medical examinations available to exposed workers.