

Silica, silicosis and cancer in Finland

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Approximately 100 000 Finnish workers are currently employed in jobs and tasks that may involve exposure to airborne silica dust. The major industries involved are mining and quarrying; production of glass, ceramics, bricks and other building materials; metal industry, particularly iron and steel founding; and construction. Over 1500 cases of silicosis have occurred in Finland since 1935. Tuberculosis has been a frequent complication of silicosis. Results of studies from several countries strongly suggest that silica dust also causes lung cancer. The results of the relevant Finnish epidemiologic and industrial hygiene studies addressing cancer risk and exposure to quartz dust are summarized.

Key terms ceramics, construction, dust, excavation, glass, iron founding, lung cancer, mining, steel casting, stone industry.

In Finland, heavy occupational exposures to quartz dust trace back to mining operations in the 16th century. From 1910 to the late 1980s a large copper mine represented a prominent source of extensive silica exposure. Iron foundries, steel casting, stone quarries, ceramic factories, and the construction industry constitute trades associated with health hazards from quartz dust. The earliest workplace measurements of dust concentrations were made in 1944, continuing on a sporadic basis. Legislation concerning the work environment, the medical follow-up of Finnish workers in dusty trades, and compensation of silicosis have been operative for decades (1).

Öhman (2) and Noro & Päätilä (3) conducted pioneering Finnish studies of silicosis in 1927 and 1954. Since the 1970s, epidemiologic and industrial hygiene studies have been conducted on silica dust exposures (4—6), silicosis (1, 7), silicosis and cancer (8, 9), mortality in various silica-related occupations (10, 11), granite workers (12—15), foundry workers (16), copper miners (17), and the work environment and health status of granite workers (18). This communication reviews the results of these studies, with special emphasis on cancer risk.

Occupational exposure to silica dust

About 100 000 Finnish workers are currently employed in jobs and tasks that may involve hazardous exposure to airborne silica dust. In 1980—1989 the Finnish Institute of Occupational Health conducted dust measurements at 146 worksites. The hygienic limit, 0.2 mg · m⁻³, for respirable quartz was exceeded in 45% of the 802 samples taken from various industries (table 1). The estimated number of exposed workers was about 1000 in the stone industry; about 5000 in mining and quarrying; about 10 000 in the production of glass, ceramics, bricks, and other building materials; about 3000 in iron and steel founding; and about 50 000 in construction

and excavating occupations. High silica exposures were also common during sandblasting and grinding in numerous metal industries (6).

Silicosis

The first diagnosis of silicosis in Finland was made in 1914. As a result of a comprehensive search, Ahlman (1) identified 878 cases diagnosed from 1935 to 1964. A total of 667 additional cases was reported from 1964 to 1992 to the Finnish national register of occupational diseases. Thus approximately 1500 cases have occurred since 1935 in a total Finnish labor force that varied between one and two million. In the past, tuberculosis was a frequent complication of silicosis. On the average, the workers with early cases of silicosis had been exposed to mineral dusts with higher silica contents than the workers with more recent cases, particularly in the mining and stone industry. Recently diagnosed cases represent a higher proportion of mixed dust fibrosis. The distribution of cases from 1964 to 1992 is shown in table 1 by industry.

Epidemiology of silica, silicosis and cancer

The results of the Finnish epidemiologic studies of lung cancer risk among workers exposed to silica dust and among silicotics are summarized in table 1.

A follow-up study (14) from 1940 to 1985 of 1026 granite workers exposed to "pure" silica revealed a significant excess mortality [standardized mortality ratio (SMR) 1.6, 95% confidence interval (95% CI) 1.1—2.2] from lung cancer. Confounding by tobacco smoking or concomitant occupational exposures did not explain the risk increment. There were 15 deaths from gastrointestinal cancer (7.4 expected, SMR 2.0, 95% CI 1.1—3.8) for workers employed for at least three months and followed until 1975 (15). From 1970 to 1972 the mean concentration of respira-

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Table 1. Summary of quartz dust levels, numbers of silicotics, and lung cancer risk by industry. (N = number of worksites, n = number of measurements, SMR = standardized mortality ratio, SIR = standardized incidence ratio, 95% CI = 95% confidence interval)

Branch of industry	Respirable quartz dust in 1980—1989 ^a					Number of notified cases of silicosis 1964— 1992	Lung cancer risk							
	% exceed- ing 0.2 mg · m ⁻³	Mean (mg · m ⁻³)	Maximum (mg · m ⁻³)	N	n		Census linkage ^b 1971—1980		Cohort studies ^c		Silicotics, mortality ^d 1935—1982		Silicotics, incidence ^e 1953—1991	
							SMR	95% CI	SMR	95% CI	SMR	95% CI	SIR	95% CI
Mining and quarrying	11	0.10	0.7	6	19	92	4.3	2.8—6.5	2.3	1.1—4.3	4.4	2.6—6.7	3.7	2.6—5.0
Stone industry	88	1.29	6.8	12	33	80	1.8	1.0—2.9	1.6	1.1—2.2	2.7	1.1—5.5	2.9	1.6—5.0
Casting and founding						182	1.6	1.3—1.9					1.7	1.1—2.6
Steel	37	0.27	2.6	4	128						1.8	0.5—4.5	1.7	0.8—3.3
Iron	30	0.23	4.9	15	169				1.4 ^f	1.1—1.9 ^f	2.3	0.9—4.7	1.6	0.9—2.9
Glass, ceramics and building materials production	49	0.90	26.7	43	177	103	1.3	0.8—1.9					3.3	1.6—6.1
Construction	58	1.64	28.9	21	72	25	.	.	.	.	.	.	10.4	1.3—37
Excavation	94	1.58	15.4	10	36	71	2.0	1.3—2.8	.	.	.	.	5.8	2.7—11
Other	41	0.68	8.6	47	145	114								
All	45	0.69	28.9	146	802	667	.	.	.	.	3.1	2.3—4.1	2.9	2.4—3.5

^a From reference 7.^b From references 10 and 11.^c From references 15, 16, and 17.^d From reference 4.^e From reference 12.^f Proportional mortality ratio.

ble silica dust was about 1 mg · m⁻³. The workplace standard was exceeded on the average by a factor of ten in drilling and stone cutting operations (14, 15).

An excess proportional mortality ratio (PMR) from lung cancer (PMR 1.4, 95% CI 1.1—1.9) was reported for iron foundry workers (16). Tossavainen (19) estimated that in iron foundries the probabilities for polyaromatic compounds, silica, and metal fumes as causes of lung cancer would be 0.20, 0.15, and 0.05, respectively.

Lyne and her colleagues (10, 11) followed Nordic cohorts exposed to silica dust for cancer mortality and incidence. The Finnish component was defined as of 1970 and followed-up for lung cancer mortality from 1971 to 1980. Significant excesses were observed for miners (SMR 4.3, 95% CI 2.8—6.5) and workers in the stone industry (SMR 1.8, 95% CI 1.0—2.9), foundries (SMR 1.6, 95% CI 1.3—1.9), and excavation and related industries (SMR 2.0, 95% CI 1.3—2.8). A follow-up study from 1954 to 1986 of 597 copper miners (17) found 10 deaths from lung cancer against 4.3 expected (SMR 2.3, 95% CI 1.1—4.3).

In a mortality follow-up study (8) extending to 1982, 80 deaths from lung cancer occurred among 961 male silicotics diagnosed from 1935 to 1977, against 25.6 expected (SMR 3.1, 99% CI 2.3—4.1). The excess persisted over various branches of industry and over time. A sevenfold increase for deaths from all pulmonary diseases, including an "infinite" excess for pneumoconiosis and fibrosis, a 4.5-fold increase for chronic bronchitis, emphysema, and asthma, and a 7.4-fold increase for respiratory tuberculosis were observed. The authors noted that tobacco smoking was unlikely to explain the observed lung cancer excess completely (8).

In a subsequent study by Partanen et al (9) the lung cancer excess was confirmed when 811 silicotics diagnosed from 1953 to 1991 were followed for cancer incidence. Excesses were observed for all cancers [standardized incidence ratio (SIR) 1.7, 95% CI 1.4—1.9], all lung cancers (SIR 2.9, 95% CI 2.4—3.5), squamous-cell lung cancers (SIR 3.3, 95% CI 2.3—4.5), and skin

cancers (melanoma: SIR 3.0, 95% CI 0.8—7.6; nonmelanoma: SIR 2.9, 95% CI 1.2—6.1). Neither confounding by tobacco smoking nor detection bias explained the elevated lung cancer risk. The skin cancer excess, a novel finding, may be explained either by other carcinogens in foundries or a silica-induced lowering of immunocompetence, which could lead to a more pronounced effect of solar ultraviolet radiation (9).

Concluding remarks

Silica dust has posed and still constitutes an occupational health hazard for 100 000 potentially exposed workers in Finland. The severity of the risk is characterized by the resulting health risks, including silicosis, silicotuberculosis, and reduced life span. Results of recent Finnish research strongly support the findings of numerous studies from other countries in suggesting that silica dust also causes lung cancer.

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