

Section 3. *Epidemiology of silica, silicosis and cancer*

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Silicosis surveillance in Ontario from 1979 to 1992

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This paper reports the detection rates of silicosis among silica-exposed persons first exposed to dust in 1950 or later and still employed in 1979 or later in the province of Ontario. The rate varied strongly with latency, being less than two new cases per 10 000 examinations during the first two decades from first exposure, reaching two new cases per 1000 examinations at 27 years from first exposure, and averaging between two and four new cases per 1000 examinations thereafter. A Poisson regression analysis found that the silicosis rate in the interval after 30 years from first exposure was more than 16 times higher than the rate prior to 20 years from first exposure. There was no significant difference in the diagnosis rates among the workers in the mining, primary metal, and nonmetallic mineral industries sectors. The rate of silicosis was higher among smokers than among never smokers (rate ratio 1.54).

Key terms foundry workers, medical surveillance, miners, occupational diseases, screening, silica, smoking.

Exposure to crystalline silica occurs in a variety of industries, including the mining of metal ores, minerals, and coal; the manufacture of stone, clay, and glass products; and iron, steel, and nonferrous foundries. Medical programs to assist in the control of silicosis frequently include periodic chest radiographs and lung function testing. The National Institute for Occupational Safety and Health in the United States, for example, recommends that chest X-rays and pulmonary function testing be carried out prior to employee placement and at least once every three years thereafter (1).

The Province of Ontario, Canada, is one of a few jurisdictions operating a governmental surveillance program for workers in dusty industries. The program has operated for almost 70 years, utilizing both fixed examining stations in the major centers and a mobile service to remote industrial sites and mines. Chest radiographs were the primary screening modality for workers exposed to silica. In the 1960s, pulmonary function testing and a short respiratory questionnaire were added. The frequency of surveillance for silicosis has been determined largely by traditional practice. For many years examinations were carried out in a one- to two-year cycle. The Ontario silica regulation of 1983 specified radiographic examinations at least once every two years. It is the aim of this paper to report on the detection rates of silicosis in the Ontario surveillance program and to discuss the influence of such factors as time from first exposure, industrial sector, and smoking.

Subjects and methods

The Ontario surveillance program has included both miners and workers in dusty surface industries. Some miners attended clinics in the larger mining communities, while others from remote sites were examined by surveillance teams using mobile vans. Surface industry workers were generally surveyed by staff using the vans.

Full-sized 14 × 17 inch radiographs have been used in the clinics since 1970. Miniature radiographs were used in the vans until 1980 when they were replaced by full-sized films. Full-sized radiographs were obtained prior to 1980 for workers whose prior radiographs suggested abnormalities. Staff radiologists interpreted radiographs according to the 1930 Johannesburg Conference Report (2). This procedure is a diagnostic, rather than descriptive, coding scheme for pneumoconiosis. The suspicion of possible radiographic pneumoconiosis is recorded as Ontario code 4, sometimes called "dust effects." The definite radiographic diagnosis of silicosis is marked code 5. In the last decade, these ratings have been supplemented by the current codes of the International Labour Organisation (ILO) (3). For the purposes of this report, only the older pneumoconiosis codings were used. Although the radiographs were not reinterpreted for this analysis, a sample of films was reread by two experienced readers. A comparison of their interpretations with those made by the original readers is shown in table 1. Over 98% of the 1584 films not coded as silicosis by the original coders were read as ≤ 0/1 by both readers, and 78% of the films coded originally as silicosis were read as ≥ 1/1 by one or both of the readers. Seven of 46 (15%) films originally coded as silicosis were read as ≤ 0/1 by both readers. This result would suggest that cases of silicosis were unlikely to have been missed by the original coders, but that some opacity codings would not have been so coded according to the ILO scale.

The results of the examinations were traditionally recorded in a card file. In 1979, current results for workers in surface industries began to be entered into a computer data base, followed in 1983 by the results for miners. In 1992, this data base contained information on 68 701 silica-exposed persons who were first exposed to dust in 1950 or later and were still employed in 1979 or later. There were 211 workers diagnosed with silicosis.

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Table 1. Codings of the International Labour Organisation for a sample of study films.

Reader 2	Reader 1		
	≤ 0/1	1/0	≥ 1/1
<i>Subjects not coded as silicotic by original readers (N = 1584)^a</i>			
≤ 0/1	1560	10	1
1/0	5	3	1
≥ 1/1	1	2	1
<i>Subjects coded as silicotic by original readers^b (N = 46)^b</i>			
≤ 0/1	7	0	2
1/0	1	2	8
≥ 1/1	1	1	24

^a 1560 of the 1584 (98%) coded ≤ 0/1 by both readers.

^b 36 of the 46 (78%) coded 1/1 or more by both readers; 7 of the 46 (15%) coded 0/1 or less by both readers.

Table 2. Distribution of the subjects and cases by industrial classification (latency ≥ 14 years)

Industrial classification ^a	Subjects under surveillance (N)	Number with silicosis diagnosis	Crude rate (per 1000)
Mines and quarries			
Placer gold (051)	304	—	0.0
Gold quartz (052)	3 493	22	6.3
Copper-gold-silver (053)	208	3	14.4
Nickel-copper (054)	1 665	3	1.8
Silver-cobalt (055)	115	—	0.0
Uranium (057)	2 296	40	17.4
Iron (058)	480	1	2.1
Other metal (059)	469	2	4.3
Stone quarries (083)	165	1	6.1
Sand pits or quarries (087)	413	3	7.3
Contract drilling (098)	541	3	5.5
Miscellaneous (099)	416	1	2.4
Total	10 565	79	7.5
Food and beverage (101—147)	96	—	0.0
Rubber industries (161—169)	246	1	4.1
Primary metal industries			
Iron and steel mills (291)	3 581	19	5.3
Iron foundries (294)	1 692	17	10.0
Smelting and refining (295)	11	—	0.0
Aluminum rolling, casting, extruding (296)	949	1	1.1
Copper and alloy rolling, casting (297)	429	2	4.7
Metal rolling NES (298)	325	1	3.1
Total	6 987	40	5.7
Metal fabricating industries (301—309)	489	4	8.2
Machinery industries (311—318)	742	2	2.7
Transportation equipment (321—329)	1 319	1	0.8
Electrical products (331—339)	239	—	0.0
Nonmetallic mineral products			
Cement manufacture (341)	678	1	1.5
Lime manufacture (343)	86	—	0.0
Gypsum products (345)	239	1	4.2
Concrete products (347)	378	3	7.9
Ready-mix concrete (348)	25	—	0.0
Clay products (351)	922	6	6.5
Refractories manufacture (352)	246	1	4.1
Stone products (353)	226	1	4.4
Mineral wool (354)	15	—	0.0
Glass and products (356)	418	—	0.0
Abrasives (357)	365	1	2.7
Other nonmetallic minerals (359)	34	—	0.0
Total	3 632	14	3.9
Refineries and chemicals (365—379)	798	1	1.3
All industries	25 113	142	5.6

^a Code of the Standard Industrial Classification in parentheses.

The diagnosis rate varied strongly with the length of time since first exposure; only three workers were diagnosed with < 14 years from the start of exposure. The subjects for this analysis included 26 403 workers with ≥ 14 years from first exposure while still under surveillance.

For each subject, the date of birth, the year of first dust exposure, the date of first diagnosis of silicosis (or the date of last examination if silicosis was not diagnosed), industrial sector, and smoking habits (ever or never cigarette smoker) were abstracted. Life-table methods (4) were used to calculate silicosis detection rates during each year from first exposure. Each person entered the calculation in 1979 (surface sector), in 1983 (mining sector), or in his year of first exposure, whichever came later. We did not determine whether each subject had an examination in any given year. Rather, it was assumed that an examination in any year prior to the one in which silicosis was found would not have been diagnosed as silicosis and included the subject in the denominator of that year. Subjects were withdrawn from the denominator in the year after they were diagnosed with silicosis or the year after their last examination. The cut-off date for follow-up was July 1992.

Poisson regression analysis was used to model silicosis rates while adjusting simultaneously for latency, industrial sector, and smoking (4).

Results

Silicosis rate by sector. Table 2 shows the distribution of the study population and the number with silicosis for the major industrial sectors. The crude rate (unadjusted for latency or smoking) is also listed in table 2.

Silicosis rate by time from first dust exposure. The detection rate of new cases of silicosis was strongly dependent upon the time from first exposure. The detection rate was less than two new cases per 10 000 examinations during the first two decades from first exposure, reached 20 new cases per 10 000 examinations at 27 years from first exposure, and averaged between 20 and 40 new cases per 10 000 examinations thereafter. Figure 1 shows how the cumulative probability of silicosis varied in the mining and primary metal industries according to time from first dust exposure.

Poisson regression analysis of silicosis rates. Poisson regression analysis was used to compare the silicosis rates of the major sectors (mining, primary metal industries, and nonmetallic mineral products) controlling for latency and smoking. The results are shown in table 3. The analysis confirmed that rates were strongly dependent upon the interval from first exposure. The silicosis rate in the interval after 30 years from first exposure was more than 16 times higher than the rate in the period prior to 20 years from first exposure. The silicosis rates were similar in the mining and primary metal sectors. The rate of silicosis was higher among the smokers than among the never smokers (rate ratio 1.54), but the difference was not statistically significant.

Discussion

Some 69 000 silica-exposed Ontario workers have had at least one screening examination since 1979, and between 11 and 26 new cases of silicosis have been diagnosed annually. As would be expected, the detection rate varied strongly with latency. The detection rate was less than two new cases per 10 000 examinations during the first two decades from first exposure, reached about 20

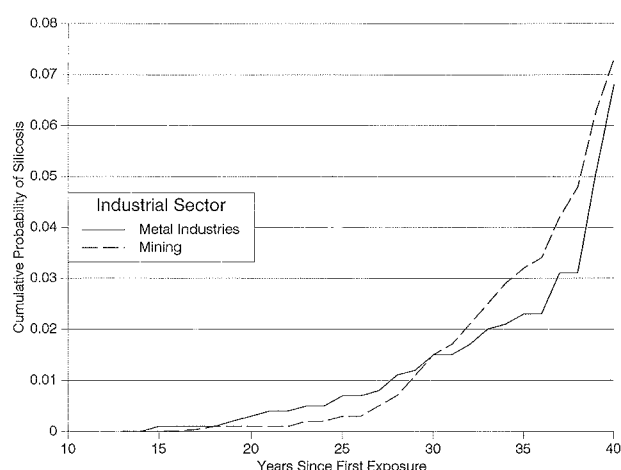


Figure 1. Cumulative probability of silicosis diagnosis versus time from first dust exposure among workers in the mining and primary metal industries under surveillance in Ontario.

new cases per 10 000 examinations at 27 years from first exposure, and thereafter averaged between 20 and 40 new cases per 10 000 examinations.

There were no substantial differences between the major industrial sectors. Figure 1 shows the cumulative probability, among miners and primary metal industry workers, of developing silicosis up to 40 years from first exposure. The cumulative probability was 1.5% for miners and 1.6% for workers in primary metal industries at 30 years from first exposure and was 3.2% for miners and 2.7% for workers in the metal sector at 35 years from first exposure.

It has been shown that asbestos workers who smoke are more likely to develop radiographic asbestosis (5). Since smoking information was available for 98% of the subjects in the study, it was possible to examine whether smokers were more likely to develop silicosis than nonsmokers. The rate of silicosis was 54% higher among the smokers, and the difference was almost statistically significant. It is plausible that a true difference exists but that, because of the small number of nonsmoking silicotics, this study may not have had the power to detect a difference. If smoking is a risk factor for the diagnosis of silicosis, it would explain, in part,

Table 3. Poisson regression analysis of the silicosis rates.

Variable ^a	Rate ratio	95% confidence interval
Time from first exposure		
14—19 years	1.0	
20—24 years	2.7	1.4—5.5
25—29 years	8.5	4.5—15.9
30—34 years	16.2	8.7—30.3
35—39 years	28.7	14.2—57.9
Industrial sector		
Mining	1.0	
Primary metal industries	1.2	0.8—1.8
Nonmetallic mineral industries	0.7	0.4—1.2
Smoking		
Ever smokers versus never smokers	1.54	0.9—2.6

^a All variables included in the model simultaneously.

the increased risk of lung cancer observed among workers in silicosis registers.

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