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Historical total and respirable silica dust exposure levels in mines and pottery factories in China

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Historical exposure estimates of total dust and respirable silica were made in a recent nested case-referent study of lung cancer among mine and pottery workers in China. Exposure to total dust and respirable silica was assessed in 20 mines and 9 pottery factories. The average total dust concentration was 7.26 mg · m^{-3}, with a range from 17.68 mg · m^{-3} in the 1950s to 3.85 mg · m^{-3} in the 1980s, while the average respirable silica dust was 1.22 mg · m^{-3}, with a range from 3.89 mg · m^{-3} in the 1950s to 0.43 mg · m^{-3} in the 1980s. The highest respirable silica dust occurred in the underground mining operations (1.43 mg · m^{-3}), particularly for manual drillers (9.03 mg · m^{-3}). Among all facility types, tungsten mines had the highest respirable silica dust exposure (1.75 mg · m^{-3}), while the lowest exposure occurred in copper-iron mines (0.32 mg · m^{-3}).

Key terms Chinese mines and potteries, exposure assessment, industrial hygiene measurements, occupational exposure, retrospective assessment, silica.

Occupational silica exposure is common worldwide (1). The National Institute for Occupational Safety and Health in the United States estimates that approximately 3.2 million workers in 238 000 plants are potentially exposed to crystalline silica (2).

A recent nested case-referent study evaluated the association between lung cancer risk and silica exposure experienced among employees in mines and pottery factories in China (3). The description of the retrospective assessment of exposure to silica carried out in 20 mines (10 tungsten, 6 iron-copper, and 4 tin), and 9 pottery factories has been reported elsewhere (4).

In this report, we present the results of the retrospective assessment of exposure to total and respirable silica dust by operation type (underground mining, surface mining, ore dressing, and pottery making), job title (in 64 mining and 15 pottery making jobs), and facility type (tungsten mines, iron-copper mines, tin mines, and pottery factories) for four decades from the 1950s to the 1980s.

Subjects and methods

The exposure assessment method used in the nested case-referent study has been described in detail elsewhere (4). Briefly, a job-title dictionary specific for the mine and pottery industries (79 specific job titles) was developed and used in both the collection of historical exposure information and work histories of 1668 subjects. A retrospective exposure matrix was developed on the basis of facility, job title, and calendar-year combinations using available historical exposure information and current exposure profiles. The current exposure levels based on the recent measurements carried out in iron and copper mines have been reported elsewhere (5). Information on the amount of respirable and free silica content in total dust was used in estimating exposure to silica. Starting from 1950, 6805 historical estimates were developed for 14 calendar-year periods, using 2.1 million industrial hygiene monitoring data points and other historical exposure information. Exposure indices such as cumulative dust, average dust, cumulative respirable (< 5 µm in particle size) and thoracic (< 10 µm in particle size) silica dust, average respirable and thoracic silica dust, exposure-weighted duration, and the highest or longest exposure were calculated for individuals by merging work histories and the historical exposure matrix for each study subject. In this report, we present the exposure data (for total and respirable silica dust) by four decades starting from 1950, showing the arithmetic mean, the number of estimates at each facility or job title, and the arithmetic standard deviation over time.

Results

Table 1 presents the total dust exposure levels by operation and facility in the mining and pottery industries. The levels of ex-

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Table 1. Historical total dust exposure levels and the number of workers by operation and facility in the mines and potteries.

Operation or facility type	Calender period 1950—1959			1960—1968			1969—1980			1981—1987		
	Mean ($mg \cdot m^{-3}$)	Number of samples	Number of subjects	Mean ($mg \cdot m^{-3}$)	Number of samples	Number of subjects	Mean ($mg \cdot m^{-3}$)	Number of samples	Number of subjects	Mean ($mg \cdot m^{-3}$)	Number of samples	Number of subjects
Underground mining	21.06	505	636	4.46	530	665	3.21	852	485	2.52	619	173
Surface mining	11.45	63	149	9.34	82	211	6.62	142	175	5.59	108	77
Ore dressing	14.31	228	246	6.19	256	275	4.18	388	219	2.45	296	92
Others	11.24	85	699	10.01	192	1167	10.19	280	1352	8.78	213	672
Pottery factories	11.82	91	200	11.28	206	277	11.64	300	317	10.44	231	174
Tungsten mines	18.09	533	460	3.49	502	518	2.10	651	549	1.65	486	221
Iron and copper mines	13.61	75	324	7.61	169	430	4.68	418	454	3.11	317	278
Tin mines	21.19	167	375	6.02	165	499	4.22	269	514	2.61	184	257
All facilities combined	17.6	888	1377	6.26	1060	1743	4.91	1662	1853	3.85	1236	940

Table 2. Historical respirable silica dust exposure levels by operation or facility type in the mines and potteries.

Operation or facility type	Calender period 1950—1959			1960—1968			1969—1980			1981—1987			All periods		
	Number of samples	Mean ($mg \cdot m^{-3}$)	SD	Number of samples	Mean ($mg \cdot m^{-3}$)	SD	Number of samples	Mean ($mg \cdot m^{-3}$)	SD	Number of samples	Mean ($mg \cdot m^{-3}$)	SD	Number of samples	Mean ($mg \cdot m^{-3}$)	SD
Underground mining	505	4.89	5.3	530	0.84	1.7	852	0.51	0.5	619	0.39	0.4	2506	1.43	3.1
Surface mining	63	1.75	2.3	82	0.83	0.8	142	0.39	0.3	108	0.27	0.3	395	0.67	1.2
Ore dressing	228	3.45	3.4	256	1.19	1.5	388	0.69	0.9	296	0.42	0.5	1168	1.27	2.1
Pottery making	85	0.77	0.7	192	0.70	0.8	280	0.76	0.9	213	0.64	0.9	770	0.71	0.9
Pottery factories	91	0.75	0.7	206	0.69	0.8	300	0.75	1.0	231	0.65	0.9	828	0.71	0.9
Tungsten mines	533	4.99	5.3	502	1.01	1.7	651	0.61	0.7	486	0.46	0.5	2172	1.75	3.3
Iron and copper mines	75	0.75	0.9	169	0.45	0.8	418	0.28	0.3	317	0.20	0.3	979	0.32	0.5
Tin mines	167	3.49	3.2	165	1.03	1.6	269	0.73	0.7	184	0.45	0.3	785	1.31	2.0
All facilities combined	881	3.89	4.7	1060	0.90	1.5	1662	0.56	0.7	1236	0.43	0.5	4839	1.22	2.5

posure to total dust showed a notable decrease over time from 17.68 $mg \cdot m^{-3}$ in the 1950s to 3.85 $mg \cdot m^{-3}$ in the 1980s with an overall average of 7.26 $mg \cdot m^{-3}$. By operation type, the highest average total dust level over all the years (9.87 $mg \cdot m^{-3}$) was observed for the pottery making operations. In the 1950s, the maximum mean dust level (21.06 $mg \cdot m^{-3}$) was determined for underground mining operations. With effective control measures, the total dust level was decreased to 2.52 $mg \cdot m^{-3}$ in the 1980s. By facility type, the highest total dust level was observed in the pottery factories. Among the mining facilities, tin mining showed the overall highest total dust level, 7.83 $mg \cdot m^{-3}$.

Table 2 presents the respirable silica dust exposure levels by operation and facility type in the mining and pottery making industries. Levels of exposure to respirable silica dust showed almost a tenfold decrease over the four decades from 3.89 $mg \cdot m^{-3}$ in the 1950s to 0.43 $mg \cdot m^{-3}$ in the 1980s with an overall average of 1.22 $mg \cdot m^{-3}$ for the 40 years. By operation type, the highest overall respirable silica dust level (1.43 $mg \cdot m^{-3}$) was observed for underground mining operations. In the 1950s, the maximum dust levels were 4.89 $mg \cdot m^{-3}$ and 3.45 $mg \cdot m^{-3}$ for underground mining and ore dressing operations, respectively. For the same operations in the 1980s, the exposure levels were 0.39 $mg \cdot m^{-3}$ and 0.42 $mg \cdot m^{-3}$, respectively, indicating that exposure levels declined in these operations. Among the mining facilities, the maximum exposure to respirable silica occurred in the tungsten mining facilities (1.75 $mg \cdot m^{-3}$).

Table 3 presents respirable silica dust exposure levels by job titles and number of workers in underground mine operations. The maximum exposure to respirable silica was observed among the manual drillers (9.03 $mg \cdot m^{-3}$). This underground job was dominant in the 1950s and 1960s, and its exposure level was dramatically reduced to 0.37 $mg \cdot m^{-3}$ in the 1970s and 1980s. Similarly, among service workers, timber workers had the highest exposure to respirable silica with exposure levels of 7.91 $mg \cdot m^{-3}$ in the 1950s and 0.56 $mg \cdot m^{-3}$ in the 1980s with an average of 2.43 $mg \cdot m^{-3}$ over the four decades. Respirable silica dust showed diverse exposure levels across job titles in the underground mining operations, ranging from 0.04 $mg \cdot m^{-3}$ for water pump workers to 9.03 $mg \cdot m^{-3}$ for manual drillers.

Table 4 presents respirable silica dust exposure levels by the number of workers and occupations in surface mine (open cast) operations. Manual miners (0.92 $mg \cdot m^{-3}$), general transport workers (1.69 $mg \cdot m^{-3}$), road repair workers (1.02 $mg \cdot m^{-3}$), and general service workers (1.26 $mg \cdot m^{-3}$) had higher exposure levels than the other surface jobs. Note that, although samples were collected, there were few or no workers in the manual miner jobs. In the surface mining operations, transport and service occupations generally had higher exposure levels than the mine production occupations, in contrast to the opposite pattern in underground mining operations.

Table 5 presents respirable silica dust exposure levels by job title in ore dressing operations. Higher exposures were observed

Table 3. Historical mean respirable silica dust exposure levels and the number of workers by underground mine job titles.

Underground mine job titles	Calender period													
	1950–1959			1960–1968			1969–1980			1981–1987			All periods	
	Mean (mg · m-3)	Number of samples	Number of subjects	Mean (mg · m-3)	Number of samples	Number of subjects	Mean (mg · m-3)	Number of samples	Number of subjects	Mean (mg · m-3)	Number of samples	Number of subjects	Mean (mg · m-3)	Number of samples
Face workers														
Machine driller	7.81	41	80	1.10	49	97	0.73	84	67	0.53	61	12	0.19	235
Blaster	6.58	46	100	0.79	46	63	0.56	76	32	0.45	55	8	1.82	223
Excavator operator	0.50	1	3	0.49	4	3	0.43	8	5	0.37	6	4	0.43	19
Ore sampler	7.12	25	14	1.50	34	18	0.73	60	11	0.56	43	4	1.93	165
Hand shovel worker	6.03	17	11	0.85	14	11	0.27	16	3	0.23	12	1	2.06	59
Roof control worker	5.08	29	13	0.98	26	17	0.56	36	8	0.38	25	1	1.75	116
Manual driller	11.47	37	164	5.70	9	17	0.37	4	1	0.37	3	1	9.03	53
Transport workers														
General transport worker	3.78	7	12	1.65	6	16	0.96	8	15	0.50	6	3	1.74	27
Loader	4.19	29	148	0.53	31	160	0.42	56	84	0.39	40	17	1.13	156
Unloader	3.08	14	3	0.56	16	4	0.28	24	10	0.26	18	3	0.88	72
Railway car driver	2.94	31	129	0.32	41	105	0.28	68	83	0.25	49	16	0.72	189
Pipeline worker	1.75	30	12	0.42	31	19	0.39	52	16	0.32	39	7	0.65	152
Service workers														
Drill rod supplier	5.11	20	8	0.56	16	4	0.37	24	3	0.34	18	1	1.62	78
Timber worker	7.91	46	68	1.36	46	69	0.81	68	35	0.56	49	13	2.43	209
Cement sprayer	0.25	1	0	0.29	4	—	0.25	8	2	0.20	6	2	0.24	19
Maintenance worker	1.18	33	35	0.46	40	58	0.45	68	50	0.32	49	20	0.55	190
Ventilation worker	1.28	25	8	0.51	34	31	0.43	60	25	0.35	43	13	0.56	162
Dust sampler worker	2.32	6	2	0.77	11	3	0.77	16	2	0.65	12	—	0.94	45
Gunpowder mixer	0.95	4	—	0.28	6	7	0.17	8	5	0.17	6	1	0.33	24
Analyst	1.35	4	1	0.54	3	4	0.68	4	2	0.25	3	—	0.75	14
Engineer/technician	1.41	41	45	0.52	45	66	0.48	72	54	0.37	52	26	0.66	215
Signal worker	0.46	4	6	0.34	6	7	0.27	8	6	0.26	6	5	0.32	24
Service worker	0.09	1	14	0.07	3	37	0.22	8	40	0.12	6	16	0.15	18
Water pump worker	0.03	1	11	0.03	3	40	0.03	4	49	0.07	3	31	0.04	11
Elevator worker	0.58	1	7	0.46	3	11	0.13	8	9	0.14	6	3	0.21	18

Table 4. Historical respirable silica dust exposure levels and the number of workers by surface mine job titles.

Surface mine job titles	Calender period													
	1950–1959			1960–1968			1969–1980			1981–1987			All periods	
	Mean (mg · m-3)	Number of samples	Number of subjects	Mean (mg · m-3)	Number of samples	Number of subjects	Mean (mg · m-3)	Number of samples	Number of subjects	Mean (mg · m-3)	Number of samples	Number of subjects	Mean (mg · m-3)	Number of samples
Mine workers														
Machine driller	0.73	3	27	0.66	8	23	0.33	19	14	0.24	12	5	0.39	42
Blaster	0.74	2	4	0.50	6	5	0.37	12	5	0.29	9	2	0.40	29
Excavator operator	0.28	4	8	0.28	6	12	0.24	12	10	0.20	9	5	0.25	31
Manual miner	1.91	4	5	0.80	4	2	0.42	4	0	0.42	3	0	0.92	15
Transport workers														
General transport worker	5.11	6	6	1.22	8	9	0.73	11	6	0.65	6	1	1.69	31
Forklift operator	0.47	3	7	0.59	4	5	0.40	8	3	0.21	6	1	0.39	21
Truck driver	0.15	2	15	0.28	4	17	0.31	12	15	0.28	15	7	0.28	33
Service workers														
Road repair worker	1.97	15	38	1.35	18	45	0.47	20	33	0.25	12	15	1.02	65
Maintenance worker	1.26	6	10	0.69	6	16	0.25	12	19	0.08	9	8	0.47	33
Analyst	0.68	2	10	0.52	3	13	0.43	4	14	0.13	3	5	0.42	21
Signal worker	0.15	3	9	0.15	3	12	0.12	8	11	0.09	6	8	0.12	20
Engineer/technician	0.15	3	4	0.15	3	6	0.17	8	7	0.19	9	4	0.17	23
General service worker	2.62	10	2	1.17	9	13	0.75	12	16	0.51	6	6	1.26	40

for the course crusher (2.01 mg · m^{-3}), ore unloader (1.05 mg · m^{-3}), mesher (1.81 mg · m^{-3}), fine crusher (1.31 mg · m^{-3}), ball mill worker (1.05 mg · m^{-3}), grinding worker (1.17 mg · m^{-3}), manual separation worker (1.80 mg · m^{-3}), transport worker (1.79 mg · m^{-3}), package worker (2.12 mg · m^{-3}), sand baker (3.39 mg · m^{-3}), cast cleaning worker (1.56 mg · m^{-3}), and smelter (1.20 mg · m^{-3}) occupations than for other occupations. The majority of these heavier exposures were in the ore pre-

Table 5. Historical respirable silica dust exposure levels and the number of workers by ore dressing job titles.

Ore dressing job titles	Calender period 1950–1959 Mean (mg · m^{-3})	1950–1959 Number of samples	1950–1959 Number of subjects	1960–1968 Mean (mg · m^{-3})	1960–1968 Number of samples	1960–1968 Number of subjects	1969–1980 Mean (mg · m^{-3})	1969–1980 Number of samples	1969–1980 Number of subjects	1981–1987 Mean (mg · m^{-3})	1981–1987 Number of samples	1981–1987 Number of subjects	All periods Mean (mg · m^{-3})	All periods Number of samples
Ore preparation workers														
Ore washer	1.81	3	49	0.51	3	33	0.25	4	5	0.28	3	2	0.68	13
Course crusher	2.47	3	3	2.47	3	17	2.25	4	12	0.79	3	2	2.01	13
Ore unloader	2.57	35	27	1.08	35	22	0.48	48	16	0.33	36	5	1.05	154
Mesher	4.31	26	9	1.35	24	8	1.04	32	5	0.61	14	3	1.81	106
Fine crusher	4.40	44	62	1.05	48	59	0.49	77	47	0.30	60	16	1.31	229
Ball mill worker	3.14	114	4	1.03	12	7	0.52	20	7	0.26	15	3	1.05	58
Grinding worker	3.27	18	4	0.78	21	6	0.66	28	7	0.45	21	3	1.17	88
Ball mill repair worker	1.36	4	1	0.52	6	2	0.32	8	1	0.23	6	—	0.52	24
Ore separation workers														
Flotation worker	·	—	13	·	—	10	·	—	11	0.06	2	2	0.06	2
Magnetic worker	2.25	8	5	0.54	9	3	0.32	16	2	0.17	12	1	0.67	45
Manual separation worker	3.29	8	1	2.44	6	3	0.73	8	3	0.61	6	2	1.80	28
Wet crusher	1.20	1	—	0.55	3	1	0.23	4	1	0.23	3	—	0.40	11
Conveyor operator	0.75	4	7	0.28	6	11	0.22	16	7	0.16	4	4	0.27	38
Service workers														
Maintenance worker	0.43	2	9	0.22	3	21	0.32	8	25	0.15	6	14	0.26	19
Crane operator	·	—	6	·	—	13	0.07	4	17	0.04	3	8	0.06	7
Dust prevention worker	2.05	2	—	0.99	3	1	0.53	4	2	0.37	3	2	0.86	12
Sampling worker	·	—	—	0.15	2	—	0.26	4	1	0.09	3	1	0.18	9
Transport worker	1.88	3	13	2.17	3	12	1.58	4	6	1.58	3	6	1.79	13
Engineer/technician	0.33	2	9	0.13	6	18	0.26	12	14	0.12	9	11	0.19	29
Package worker	4.48	13	11	1.90	12	6	1.55	16	3	0.55	12	—	2.12	53
Sand baker	7.71	18	3	3.28	15	3	1.46	19	2	0.76	15	2	3.39	67
Foundry worker	1.03	12	8	0.88	15	3	0.61	24	4	0.60	18	1	0.74	69
Molder	0.74	1	1	0.74	3	1	0.87	4	1	0.06	3	1	0.60	11
Caster	1.11	5	4	0.75	6	3	0.50	8	2	0.16	6	1	0.60	25
Cast cleaning worker	0.47	1	4	1.63	9	4	1.61	12	4	1.53	9	3	1.56	31
Smelter	0.68	4	2	0.68	3	2	2.52	4	3	0.68	3	2	1.20	14

Table 6. Historical respirable silica dust exposure levels and the number of workers by pottery making job title.

Pottery making job titles	Calender period 1950–1959 Mean (mg · m^{-3})	1950–1959 Number of samples	1950–1959 Number of subjects	1960–1968 Mean (mg · m^{-3})	1960–1968 Number of samples	1960–1968 Number of subjects	1969–1980 Mean (mg · m^{-3})	1969–1980 Number of samples	1969–1980 Number of subjects	1981–1987 Mean (mg · m^{-3})	1981–1987 Number of samples	1981–1987 Number of subjects	All periods Mean (mg · m^{-3})	All periods Number of samples
Mud preparation workers														
Ore crusher	1.55	8	3	1.15	12	5	1.79	16	5	1.30	12	3	1.47	48
Mesher	2.34	4	3	0.54	5	4	0.59	8	4	0.49	6	1	0.86	23
Ore mixer	·	—	11	3.48	5	14	5.14	8	11	5.14	6	5	4.70	19
Other preparation worker	0.76	3	2	0.41	4	4	0.42	16	4	0.42	12	1	0.45	41
Mud forming worker														
Press forming worker	0.05	3	4	0.39	5	9	0.76	8	7	0.55	6	3	0.52	22
Molding worker	0.68	11	44	0.74	22	41	0.64	32	34	0.50	12	3	0.63	89
Fine material worker	0.62	4	5	0.69	6	9	0.39	8	8	0.22	6	4	0.46	24
Finishing workers														
Glazed material worker	0.96	5	4	0.78	19	9	0.76	28	10	0.45	3	12	0.69	73
Furnace loading worker	0.78	11	16	0.72	22	28	0.69	32	33	0.64	24	16	0.69	89
Furnace unloading worker	0.39	5	3	0.39	16	4	0.38	20	8	0.34	15	5	0.37	56
Greenware inspector	0.59	7	2	0.65	17	2	0.67	24	7	0.61	18	6	0.64	66
Fire watcher	0.63	11	19	0.67	22	34	0.55	32	41	0.46	24	25	0.57	89
Boiler worker	0.69	1	1	0.44	4	2	0.37	8	1	0.44	9	—	0.42	22
Service workers														
Maintenance worker	0.30	6	—	0.32	11	3	0.32	16	3	0.32	1	1	0.32	45
Other service worker	0.39	6	11	0.39	16	15	0.38	24	18	0.38	8	8	0.38	64

paration unit or in foundry occupations in the nonmining production unit.

Table 6 presents respirable silica dust exposure levels by occupations in the pottery making operations. High-level exposures were observed for the ore crusher (1.47 mg · m^{-3}) and ore mixer (4.70 mg · m^{-3}). In the pottery making operations, the major source of high exposure to respirable silica dust was found in the mud preparation unit, where the dry raw materials are crushed and mixed for forming pottery mud.

Discussion

We have presented historical exposure levels for total dust and respirable silica dust found in the mines and pottery factories of China. These exposures were estimated using a detailed historical exposure assessment method (4) and were employed in the epidemiologic analysis of a nested case-referent study of lung cancer in China (3).

Although there were 2.1 million monitoring results for total dust exposure, very few (14%) direct measurements were available for the percentage of silica and the respirable or thoracic fraction of the total dust. The quality and quantity of historical measurements of total dust allowed us to employ a detailed job-title specific exposure assessment for total dust concentration. The information on the silica content of total dust and the percentage of respirable dust was, however, limited to recent years and to a few jobs, so that the average percentage of silica and percentage of respirable dust for each facility was used. Mean silica was 32.7%, ranging from 10.6% for the iron-copper mines to 47.6% for the tungsten mines. The respirable portion of the total dust also showed some variation with the mean value of 48.0%, ranging from 25.7% for the pottery factories to 65.1% for the iron-copper mines. These differences in the percentage of silica and the respirable portion have created different rank orders for total dust and respirable silica dust. For example, the highest average total dust exposure was found in pottery factories, while the highest average respirable silica dust exposure occurred in the tungsten mines.

Although several previous reports (6—16) have presented the level of exposure to silica dust in similar or other occupational settings, only four of them (6, 10, 11, 13) were employed in epidemiologic studies. We believe that the results of the exposure levels presented in this report will be helpful for other investigators who assess exposure to silica in epidemiologic studies.

References

1. International Agency for Research on Cancer (IARC). Silica and some silicates. Lyon: IARC, 1987. IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans, vol 42.
2. National Institute for Occupational Safety and Health (NIOSH). Review of the literature on crystalline silica. Cincinnati, OH: NIOSH, 1983. PB 83—238733.
3. McLaughlin J, Chen J, Dosemeci M, Chen RA, Rexing SH, Wu Z, et al. A nested case-control study of lung cancer among silica-exposed workers in China. Br J Ind Med 1992;49:167—71.
4. Dosemeci M, Chen J-Q, Hearl F, Chen R-G, McCawley M, Wu Z, et al. Estimating historical exposure to silica in a retrospective occupational study in People's Republic of China. Am J Ind Med 1993;24:55—66.
5. Wu Z, Hearl F, Peng KL, McCawley M, Chen AL, Palassis J, et al. Current exposure levels in Chinese iron and copper mines. Appl Occup Environ Hyg 1992;7:735—43.
6. Theriault GP, Burgess WA, DiBerardinis LJ, Peters JM. Dust exposures in the Vermont granite sheds. Arch Environ Health 1974;28:12—7.
7. Kolton R, Richter ED, Israeli R. Occupational exposure to dust containing free silica in a ceramics factory. Isr J Med Sci 1981;17:277—82.
8. Ayalp A, Myroniuk D. Evaluation of occupational exposure to free silica in Alberta foundries. Am Ind Hyg Assoc J 1982;43:825—31.
9. Oudiz J, Brown JW, Ayer HE, Samuels S. A report on silica exposure levels in United States foundries. Am Ind Hyg Assoc J 1983;44:374—6.
10. Rice C, Harris RL Jr, Lumsden JC, Symons MJ. Reconstruction of silica exposure in the North Carolina dusty trades. Am Ind Hyg Assoc J 1984;45: 689—96.
11. Eisen EA, Smith TJ, Wegman DH, Louis TA, Froines J. Estimation of long term dust exposure in the Vermont granite sheds. Am Ind Hyg Assoc J 1984;45:89—94.
12. Guenel P, Breum NO, Lynge E. Exposure to silica dust in the Danish stone industry. Scand J Work Environ Health 1989;15:147—53.
13. Verma DK, Sebestyen A, Julian JA, Muir DC, Schmidt H, Bernholz CD, et al. Silica exposure and silicosis among Ontario hardrock miners: II. exposure estimates. Am J Ind Med 1989;16:13—8.
14. Que-Hee SS. Respirable/total dust and silica content in personal air samples in a nonferrous foundry. Appl Ind Hyg 1989;4:57—60.
15. Hosey AD, Ashe HB, Trasko VM. Control of silicosis in Vermont granite industry. Washington (DC): US Department of Health Education and Welfare, Public Health Service (USPHS), 1957. USPHS publication, no 557.
16. Flinn RH, Brinton HP, Doyle HN, Cralley LJ, Harris RL Jr, Westfield J, et al. Silicosis in the metal mining industry. Washington (DC): US Department of Health Education and Welfare, Public Health Service (USPHS) and Department of Interior, Bureau of Mines, 1963. USPHS publication, no 1076.