Pergamon

Ann. occup. Hyg., Vol. 38, No. 4, pp. 539–546, 1994
Elsevier Science Ltd

0003–4878/94 $7.00 + 0.00

0003–4878(94)E0010–W

MORTALITY AND CANCER INCIDENCE OF WORKERS EXPOSED TO CHRYSOTILE ASBESTOS IN THE FRICTION-PRODUCTS INDUSTRY

G. BERRY

(*Received* 23 *November* 1993)

Paper read at the Workshop on Health Risks Associated with Chrysotile Asbestos, held in Jersey, Channel Island, 14–17 November 1993

Abstract—see p. 413.

INTRODUCTION

A LITERATURE search was carried out in Medline to identify studies relating to the mortality and cancer incidence of employees working in the friction-products industry with chrysotile asbestos. Four studies were identified: a factory in the U.K. (NEWHOUSE *et al.*, 1982), a plant in Connecticut, U.S.A. (MCDONALD *et al.*, 1984), two automotive parts factories in Ontario, Canada (FINKELSTEIN, 1989) and a factory in Tianjin, China (CHENG and KONG, 1992). In all these studies the design was a historical cohort study in which a group of workers was identified from records and the vital status of each employee established at the time of study. Analysis consisted of comparisons of observed mortality with the mortality expected using national or regional rates and allowing for age and period using the subject-years method (DOLL, 1952; BERRY, 1983). The comparative measure of mortality is the ratio of observed to expected deaths expressed as a percentage, the standardized mortality ratio (SMR). In this review 95% confidence intervals are given for the SMRs based on the Poisson distribution using the tables given by BAILAR and EDERER (1964). In addition internal comparisons were used in some of the studies based on a case-control study within the cohort (MANTEL, 1973; LIDDELL *et al.*, 1977).

THE STUDIES

Factory producing friction materials in the U.K.

The mortality experience of 9104 men and 4346 women employed in 1941 or later at the Ferodo factory in the north of England in the U.K. has been studied with follow-up until the end of 1986. Follow-up to the end of 1979 was reported by NEWHOUSE *et al.* (1982) and BERRY and NEWHOUSE (1983), and was extended to the end of 1986 by NEWHOUSE and SULLIVAN (1989).

The factory produced friction materials, mainly brake blocks, brake and clutch linings and stair treads, and woven asbestos was an essential constituent from 1920. Non-woven asbestos was introduced later and in 1960 the processes using woven

asbestos were transferred to another factory. The main processes were the coating of fibre in resin, and the forming, shaping and machining of the friction materials. Except during 1929–1933 and 1939–1944, when crocidolite was used for a special contract involving only a minority of the workforce, only chrysotile asbestos was used.

The environmental conditions were described by SKIDMORE and DUFFICY (1983). Before 1931 exposures were generally high, greater than 20 f ml^{-1} longer than 5 μm. The introduction of the 1931 Asbestos Regulations resulted in a reduction in concentrations, which exceeded 5 f ml^{-1} only in the grinding and preparation processes. There were more improvements after 1950 with concentrations of 2–5 f ml^{-1} in storage and distribution, preparation and grinding, and lower concentrations elsewhere. Finally, after 1970 concentrations were reduced to less than 2 f ml^{-1} with most processes below 1 f ml^{-1}.

There was a turn-over of short-term workers in the factory and the median duration of service was between 2 and 3 years both for men and for women. Twenty-seven per cent of men and 14% of women worked at the factory for more than 10 years.

American chrysotile asbestos friction plant

MCDONALD *et al.* (1984) reported on a mortality study at a plant in Connecticut manufacturing friction products (clutch facings, brake linings and automatic transmission materials such as friction discs and pads) and packings. The principal form of asbestos used was chrysotile, mainly from Canada, but some anthophyllite was introduced in 1957 and a small amount of crocidolite was used experimentally on a few occasions between 1964 and 1972. The cohort consisted of 3641 men and 905 women employed for 1 month or more between 1938 and 1958. Follow-up was until the end of 1977, and results were given only for men.

There were some measurements by impinger from which estimates of dust conditions in terms of millions of particle per cubic feet (mpcf) were derived. During the 1930s most processes involved exposures of 1–5 mpcf but work in the sheet-packings fibre room and with dry mould mix of brake finish/hot press involved concentrations of more than 10 mpcf. Dust concentrations gradually declined over the next 30 years so that in the 1960s most were less than 0.5 mpcf; the two situations mentioned above remained the most dusty parts of the plant at 5 mpcf.

Thirty-six per cent of the men worked at the plant for less than 1 year, 38% for 5 years or more, and 21% for 20 years or more.

Canadian automotive parts factories

FINKELSTEIN (1989) reported on a mortality study at two factories in Ontario which manufactured friction materials containing chrysotile asbestos. A range of automotive component parts were manufactured and friction materials were used only in the brake assembly areas. In 1976 only 11% of the employees worked directly with friction materials, although others may have been exposed indirectly. The study population consisted of 1314 men and 343 women employed for at least 12 months after 1 January 1950. Follow-up was until the end of 1985. There is little information about dust concentrations; between 1975 and 1980 they were less than 2 f ml^{-1}. Sixty per cent of the men and 34% of the women worked at the factories for at least 5 years.

Chrysotile asbestos products workers in Tianjin

This factory was formed in 1955 by merging several small asbestos plants. There were five workshops covering asbestos textiles and asbestos cement as well as friction materials. Results were given for the factory as a whole with no results specific to the employees working with friction materials (CHENG and KONG, 1992), so this study has not been considered further.

RESULTS

Factory producing friction materials in the U.K.

The mortality of the whole workforce 10 or more years after first employment is given in Table 1 both up to the end of 1979 (BERRY and NEWHOUSE, 1983) and to the end of 1986 (NEWHOUSE and SULLIVAN, 1989). The reference death rates were the sex-, age- and period-specific rates for England and Wales. There was no evidence of excess mortality due to all causes, and in particular there was no suggestion of any excess due to cancer of the lung, cancer of the gastrointestinal tract, or to cancer at other sites, except that there were 13 mesotheliomas. The analysis was repeated including only those workers with at least 10 years' employment at the factory and after 20 or more years' follow-up since first employment (NEWHOUSE and SULLIVAN, 1989). The results are shown in Table 2 and there was still no evidence of excess mortality except for 10 mesotheliomas.

BERRY and NEWHOUSE (1983) reported the results of a case-control study of the 10 mesotheliomas reported to the end of 1979. For eight of these workers there was definite exposure to crocidolite asbestos working on the special contract, and another one had worked in the same shed as the crocidolite contract work although not directly with crocidolite. Of 40 controls only three had worked on the crocidolite contract and

TABLE 1. OVERALL MORTALITY OF WORKERS EMPLOYED AT A FACTORY PRODUCING FRICTION MATERIALS IN ENGLAND AFTER 10 OR MORE YEARS SINCE FIRST EMPLOYMENT

	Follow-up to 1979			Follow-up to 1986		
	Observed	SMR	(95% CI)	Observed	SMR	(95% CI)
Men						
All causes	1339	98	(93–104)	2055	99	(95–104)
Lung cancer (ICD 162)	143	103	(86–121)	229	103	(90–118)
Pleural mesothelioma (ICD 163)	8			11		
Gastrointestinal cancer (ICD 150–159)	103	96	(78–117)	156	93	(79–109)
Cancer of larynx (ICD 161)	2	56	(7–201)	6	64	(23–139)
Other cancers	75	89	(70–112)	128	93	(78–111)
Other causes	1008	98	(92–104)	1525	99	(94–105)
Women						
All causes	299	91	(81–102)	522	90	(83–98)
Lung cancer (ICD 162)	6	53	(19–116)	12	57	(29–99)
Pleural mesothelioma (ICD 163)	2			2		
Gastrointestinal cancer (ICD 150–159)	29	106	(71–152)	46	98	(72–131)
Cancer of breast (ICD 174)	22	90	(56–137)	40	92	(66–126)
Cancer of ovary (ICD 183)	8	99	(43–194)	11	109	(54–195)
Other cancers	21	76	(47–117)	37	75	(53–103)
Other causes	211	92	(80–105)	374	92	(83–101)

TABLE 2. MORTALITY OF WORKERS EMPLOYED FOR 10 YEARS OR MORE AT A FACTORY PRODUCING FRICTION MATERIALS IN ENGLAND AFTER 20 OR MORE YEARS SINCE FIRST EMPLOYMENT

	Men			Women		
	Observed	SMR	(95% CI)	Observed	SMR	(95% CI)
All causes	743	94	(87–101)	126	99	(83–119)
Lung cancer	88	107	(86–132)	4	89	(24–227)
Pleural mesothelioma	9			1		
Gastrointestinal cancer	56	89	(67–116)	13	124	(66–212)
Other cancers	47	87	(64–116)	25	120	(77–176)
Other causes	543	92	(84–100)	83	92	(73–114)

seven in the same shed. At *post mortem* an analysis of lung contents (POOLEY and CLARK, 1979) of seven of the mesotheliomas confirmed the crocidolite exposure of all five of those who had worked on the crocidolite contract and of the woman who had worked in the same shed. The seventh case had the lowest crocidolite content, which fitted with the job history that involved no contact with crocidolite at the factory. This man did not join the factory workforce until age 50 and had worked for over 20 years in an asbestos-cement factory. Of the three later mesotheliomas reported by NEWHOUSE and SULLIVAN (1989) one had worked in the factory for 46 years, including work on the crocidolite contract. A second man had worked in the factory for only 2 weeks 20 years before his death, and the third man had worked in the factory for 19 years when only chrysotile was processed. This mesothelioma had not been confirmed by histopathology. Thus of the total 13 mesotheliomas there were 10 who had either worked directly or near to the crocidolite contract, and one who had worked previously in an asbestos-cement factory. For the other two there was no exposure to crocidolite in the factory; for one of these diagnosis was unconfirmed and the other worked in the factory for only 2 weeks.

NEWHOUSE and BERRY (1983) also carried out case-control studies for lung cancer and gastrointestinal cancer. Controls were matched with cases with respect to the year that they first started work at the factory, survival to the time of death of the lung cancer case, and year of birth. A detailed assessment was made of the job history of each case and each control, and these histories were interpreted in terms of the corresponding levels of exposure to chrysotile (SKIDMORE and DUFFICY, 1983). There was no evidence of a dose–response relationship with cumulative exposure (fibre-years ml^{-1}) for either site of cancer. A linear relationship between lung cancer relative risk and cumulative exposure gave a regression coefficient of 0.0006 per fibre-year ml^{-1}, corresponding to a relative risk of 1.06 for a cumulative exposure of 100 fibre-years ml^{-1}; the 95% confidence interval of this relative risk was from 0.6 to 2.0.

American chrysotile asbestos friction plant

The mortality experience of the men was reported by MCDONALD *et al.* (1984). The reference death rates were the race-, age- and period-specific rates for Connecticut, U.S.A. The overall mortality is shown in Table 3. There was a significant excess of deaths due to respiratory cancer (ICD 160–164), but this was unrelated with duration of employment and the highest excess was in the group with less than 1 year's service at the factory. The excess was also unrelated wth cumulative dust exposure (Table 4). No mesotheliomas were observed.

TABLE 3. OVERALL MORTALITY OF WORKERS EMPLOYED AT A FACTORY PRODUCING FRICTION MATERIALS IN CONNECTICUT AFTER 20 OR MORE YEARS SINCE FIRST EMPLOYMENT

	Observed	SMR	(95% CI)
All causes	803	109	(101–116)
Respiratory cancer (ICD 160–164)	73	149	(117–187)
Pleural mesothelioma	0		
Digestive cancer (ICD 150–159)	59	114	(87–148)
Other cancers	70	116	(91–147)
Other causes	601	104	(96–112)

TABLE 4. MORTALITY OF WORKERS EMPLOYED AT A FACTORY PRODUCING FRICTION MATERIALS IN CONNECTICUT AFTER 20 OR MORE YEARS SINCE FIRST EMPLOYMENT ACCORDING TO COMULATIVE DUST EXPOSURE

Accumulated dust exposure (mpcf-years)	Respiratory cancer		Digestive cancer		Other cancer	
	Observed	SMR	Observed	SMR	Observed	SMR
< 10	55	167	34	103	45	114
10–<20	6	102	9	135	7	90
20–<40	5	105	8	153	6	101
40–<80	6	163	5	120	8	177
≥80	1	55	3	127	4	150

A dose–response relationship was fitted of the relative risk due to respiratory cancer against cumulative dust exposure. The slope of this line was 0.0016 per mpcf-year. This was not statistically significant, and about one-fiftieth of the slope found for workers employed in a textile plant in South Carolina, U.S.A., where chrysotile asbestos was the only type of asbestos used (MCDONALD *et al.*, 1983).

Canadian automotive parts factories

The overall mortality was reported by FINKELSTEIN (1992) in terms of the sex-, age- and period-specific death rates in the general population of Ontario. The overall mortality is shown in Table 5 for deaths occurring more than 20 years after first employment. The most striking feature in the men is the excess of deaths due to cancer of the larynx. For women there was a significant excess mortality but this excess was not specific to any particular causes. The mortality in men due to cancer more than 10 years since first employment and according to duration of employment is shown in Table 6. The only significant excess mortality was that due to cancer of the larynx in men with more than 10 years of employment. There were two deaths in men which were recorded as lung cancer but where pleural mesothelioma was suspected. In one case the pathologist had diagnosed pleural mesothelioma but the slides were lost so that confirmation was impossible. In the second case the pathologists could not exclude the possibility of a metastatic carcinoma.

Case-control studies were carried out for lung cancer, cancer of the larynx and gastrointestinal cancer to assess the association of these cancers with occupational exposure to asbestos. There were 18 deaths certified as due to lung cancer. Only two

TABLE 5. OVERALL MORTALITY OF WORKERS EMPLOYED AT TWO AUTOMOTIVE PARTS FACTORIES IN ONTARIO AFTER 20 OR MORE YEARS SINCE FIRST EMPLOYMENT

	Observed	SMR	(95% CI)
Men			
All causes	104	109	(89–132)
Lung cancer (ICD 162–163)	11	140	(70–250)
Gastrointestinal cancer (ICD 150–159)	6	81	(30–176)
Cancer of larynx (ICD 161)	3	854	(176–2500)
Other cancers	9	116	(53–220)
Other causes	75	104	(82–130)
Women			
All causes	20	181	(110–280)
Lung cancer (ICD 162–163)	1	193	(5–1070)
Other cancers	5	139	(45–325)
Other causes	14	202	(110–339)

TABLE 6. MORTALITY OF MEN EMPLOYED AT TWO AUTOMOTIVE PARTS FACTORIES IN ONTARIO BY DURATION OF EMPLOYMENT AFTER 10 OR MORE YEARS SINCE FIRST EMPLOYMENT

	Duration of employment			
	< 10 years		≥ 10 years	
	Observed	SMR	Observed	SMR
Lung cancer	5	185	10	101
Gastrointestinal cancer	2	118	6	98
Cancer of larynx	0	0	4	1000
Other cancers	1	28	14	136

(11%) of these subjects had worked in a department where asbestos was used compared with 12 (23%) out of 52 controls. None of the four men who died due to cancer of the larynx had worked in the departments where asbestos was used, although it was noted that some of them may have visited these departments. For gastrointestinal cancer there were no significant differences between cases and controls in exposure factors.

DISCUSSION

If working with chrysotile asbestos in the friction-products industry results in any excess mortality, the two most likely causes would be lung cancer and pleural mesothelioma, with other cancers particularly gastrointestinal cancer and laryngeal cancer as possibilities. There was no appreciable excess of deaths due to lung cancer at the factory in the U.K. and the total number of deaths due to this cause, 229, was sufficient to provide a sensitive test. An internal analysis failed to find an association with aspects of exposure to asbestos in the factory. In the Connecticut plant the SMR due to lung cancer was 1.5, based on 73 deaths, and was statistically significant. There was no association between deaths due to this cause and features of exposure to asbestos. The majority of the excess occurred in the least exposed group and

McDONALD *et al.* (1984) suggested that this may be due to selective factors. In the Ontario study there were only 18 deaths certified as due to lung cancer and the majority of the workforce did not work with asbestos so that this study does not provide a great deal of additional data. But within these limitations there was no suggestion of an exposure-related effect.

Any conclusions on lung cancer have to be against the background that the smoking habits of the workforces are unknown. It is possible that the excess rates in the Connecticut and Ontario studies are associated with a higher smoking rate. It is also possible that the close overall agreement between observed and expected mortality in the English factory is a combination of a lower than average smoking rate and an asbestos effect. SKIDMORE and DUFFICY (1983) reported that smoking was banned in the production areas until 1950. However, the absence of any dose–response relationship for asbestos exposure, including in the case-control study where there was matching with respect to year of starting work in the factory, suggests that this cannot have resulted in more than a slight possible bias.

For mesothelioma most of the cases in the factory in the north of England, U.K., had been exposed to crocidolite and there were only two possibly associated with exposure to chrysotile. One of these had worked for only 2 weeks in the factory and the other had an unconfirmed diagnosis. One of the two unconfirmed cases in Ontario had worked in the brake component assembly plant. In summary, no confirmed cases of mesothelioma could be attributed to exposure to chrysotile, but, on the other hand, there are two or three cases for which this cannot be definitely excluded.

For gastrointestinal and laryngeal cancer no association with exposure to chrysotile asbestos was found, and the large excess of cases of cancer of the larynx at the Ontario factories was unassociated with working in the departments where asbestos was used.

If there are any effects on mortality due to working in the manufacture of friction materials using chrysotile asbestos, these effects are small and much less than the risks due to working in the chrysotile asbestos textile industry.

[For the discussion of the issues raised in this and the other allied papers see pp. 413–415.]

REFERENCES

BAILAR, J. C. and EDERER, F. (1964) Significance factors for the ratio of a Poisson variable to its expectation. *Biometrics* **20**, 639–643.

BERRY, G. (1983) The analysis of mortality by the subject-years methods. *Biometrics* **39**, 173–184.

BERRY, G. and NEWHOUSE, M. L. (1983) Mortality of workers manufacturing friction materials using asbestos. *Br. J. ind. Med.* **40**, 1–7.

CHENG, W.-N. and KONG, J. (1992) A retrospective mortality cohort study of chrysotile asbestos product workers in Tianjin 1972–1987. *Environ. Res.* **59**, 271–278.

DOLL, R. (1952) The causes of death among gas-workers with special reference to cancer of the lung. *Br. J. ind. Med.* **9**, 180–185.

FINKELSTEIN, M. M. (1989) Mortality rates among employees potentially exposed to chrysotile asbestos at two automotive parts factories. *Can. Med. Ass. J.* **141**, 125–130.

GELL, F. D. K., McDONALD, J. C. and THOMAS, D. C. (1977) Methods of cohort analysis: appraisal by application to asbestos mining (with Discussion). *J. R. Stat. Soc. A* **140**, 469–491.

MANTEL, N. (1973) Synthetic retrospective studies and related topics. *Biometrics* **29**, 479–486.

McDONALD, A. D., FRY, J. S., WOOLLEY, A. J. and McDONALD, J. C. (1983) Dust exposure and mortality in an American chrysotile textile plant. *Br. J. ind. Med.* **40**, 361–367.

McDONALD, A. D., FRY, J. S., WOOLLEY, A. J. and McDONALD, J. C. (1984) Dust exposure and mortality in an American chrysotile asbestos friction products plant. *Br. J. ind. Med.* **41**, 151–157.

NEWHOUSE, M. L., BERRY, G. and SKIDMORE, J. W. (1982) A mortality study of workers manufacturing friction materials with chrysotile asbestos. *Ann. occup. Hyg.* **26**, 899–909.

NEWHOUSE, M. L. and SULLIVAN, K. R. (1989) A mortality study of workers manufacturing friction materials: 1941–86. *Br. J. ind. Med.* **46**, 176–179.

POOLEY, F. D. and CLARK, N. J. (1979) Quantitative assessment of inorganic fibrous particulates in dust samples with an analytical transmission electron microscope. *Ann. occup. Hyg.* **22**, 253–271.

SKIDMORE, J. W. and DUFFICY, B. L. (1983) Environmental history of a factory producing friction material. *Br. J. ind. Med.* **40**, 8–12.