

Influence of smoking habits and place of residence on the risk of lung cancer among workers in one rock-wool producing plant in Denmark

by Jørgen H Olsen, MD,¹ Ole M Jensen, MD,¹ O Kampstrup, MD²

OLSEN JH, JENSEN OM, KAMPSTRUP O. Influence of smoking habits and place of residence on the risk of lung cancer among workers in one rock-wool producing plant in Denmark. *Scand J Work Environ Health* 12 (1986): suppl 1, 48–52. Cancer incidence was studied among 5 317 employees in one rock-wool production plant in Denmark. During the period 1943–1982 a marginally significant excess of 240 cancer cases was observed versus 211.0 cases expected. Among the subgroup of male workers an increasing risk with time since first employment was observed for cancer of the buccal cavity and pharynx, cancer of the respiratory system, and cancer of the bladder, of which only the excess of the first-mentioned reached significance. The increased risk of lung cancer among male workers with 20 or more years since first employment, which was not significantly in excess of 1.0, although still compatible with a two- to threefold increase according to conventional 95 % confidence limits, could not be explained by deviations in local lung cancer incidence, place of residence among the rock-wool male workers, or smoking habits prevailing among unskilled workers in the eastern part of Denmark. The number of cases, however, was too small to exclude the effect of chance in this single investigation.

Key terms: cancer incidence, man-made mineral fibers, retrospective follow-up study.

Cancer incidence was studied among employees in one rock-wool production plant in Denmark. The factory started producing mineral wool in 1937, initially in small amounts and without binders or oils added. The workforce at that time was modest (table 1), and most of the production was carried out manually (batch production). Since 1942 cases of cancer in the total population of Denmark have been notified to the Danish Cancer Registry, including cases detected among employees at the plant under study. The results of the cancer incidence analysis for the follow-up period 1943–1977 have been reported previously (8).

The present analysis was made for the period 1943–1982, ie, an additional five-year follow-up. The use of alternative reference populations reflecting the places of residence of the plant's workforce are now presented in order to emphasize the importance of a reliable determination of expected number. In addition, new information on lung-cancer risk associated with smoking habits among unskilled workers in Denmark has been applied to the data to compensate for the lack of information on smoking habits among the cohort members in this study.

Material and methods

From the manual files still preserved at the plant, identification data on all persons employed during 1937–1977 were extracted in addition to start of employment(s), end of employment(s), and staff position. Follow-up was carried out through linkage with national and municipal population registries, the name and date of birth (when deceased before April 1968) and the national personal identification number (when alive in April 1968) being used as identifiers for the employees. A total of 173 persons, corresponding to 3.4 % of the cohort, could not be traced by this procedure, as many of them were foreign workers, and they were excluded from this study. Moreover 52 individuals were deleted from the cohort because, although they appeared in the personnel records, they did not in fact start work at the factory. After

Table 1. Number of employees according to date of first employment at the factory and the cumulative percentage of persons ever employed.

Date of first employment	Manual workers		Office workers	
	Number	Cumulative percentage	Number	Cumulative percentage
1937–1942	72	1.6	6	0.8
1943–1947	90	3.5	6	1.6
1948–1952	96	5.6	15	3.7
1953–1957	214	10.3	19	6.3
1958–1962	840	28.6	68	15.6
1963–1967	903	48.3	129	33.2
1968–1972	975	69.6	194	59.6
1973–1977	1 393	100.0	296	100.0

¹ The Danish Cancer Registry, Institute of Cancer Epidemiology under the Danish Cancer Society, Copenhagen, Denmark.

² Rockwool International AIS, Hedeusene, Denmark.

Reprint requests to: Dr JH Olsen, The Danish Cancer Registry, Institute of Cancer Epidemiology under the Danish Cancer Society, Landskronagade 66, DK-2100 Copenhagen Ø, Denmark.

these deletions the cohort under study then consisted of 5 317 employees (4 880 males and 437 females). Table 1 shows the cumulative number of male and female employees ever employed at the factory in the period 1937–1977.

As 1943 was the year when the Danish Cancer Registry started reporting incidence data and 1982 is the year of the latest compilation available, the analysis of cancer morbidity was restricted to the period 1943–1982. Members of the cohort were searched for in the files of the Cancer Registry, and, if registered, the site of cancer and time of diagnosis were obtained directly from the files.

Person-years at risk were computed by means of the program developed by Monson (5) from the date of employment until death, emigration, or 31 December 1982, whichever occurred first. Based on the number of person-years at risk, the number of expected malignancies in the cohort was estimated. In the calculation of the expected numbers the cancer incidence rates, specific for age (five-year groups), sex, and calendar time (quinquennia) for the total Danish population were used. The expected number of cases (E) was compared with that observed (O), yielding the $O : E$ ratio, or estimated relative risk. The 95 % confidence limits (95 % CL) were calculated on the assumption of a Poisson distribution of the observed frequency, and the calculations were performed using the programs developed by Rothman & Boice (9). When the lower of the 95 % confidence limits was equal to or above 1.0, the relative risk was considered significantly increased.

Adjustment for place of residence

The following three alternative methods for the calculation of expected lung cancer cases among male workers at the factory were applied: one using the aforementioned national rates for lung cancer, another using the age-specific local rates for lung cancer (Roskilde County), and a third using weighted reference rates, according to the fraction of male workers with place of residence in rural and urban areas, respectively, using reference rates specific for geographic regions (Copenhagen, Copenhagen suburbs, provincial towns, and rural areas) available at the Cancer Registry (1, 2).

However, the rates of lung cancer, both local and categorized according to residential area, have not been applied directly to the person-years at risk in the calculation of expected numbers. Instead adjustment factors have been derived as (i) the proportion between the age-standardized local lung cancer rate and the corresponding national rate (table 4 in the Results section) and (ii) the proportion between the age-standardized weighted lung cancer rate according to place of residence and the national rate (table 6 in the Results section). These adjustment factors were subsequently multiplied by the expected number of lung cancer cases based on national lung cancer rates

to yield the adjusted number of lung cancer cases (table 7 in the Results section), ie, with the use of the local population or the population with equivalent place of residence as reference populations. The years 1968–1977 were chosen for the calculation of the adjustment factors, because local cancer rates were available for this period and because this is the essential period due to the long latency time for lung cancer. Place of residence among a random sample of workers was categorized according to the address held by the worker at the time of first employment at the factory. Only workers employed prior to 1968 were included, as the place of residence among this subgroup of workers was judged to be the most informative in relation to later cancer development.

Adjustment for smoking habits

A survey of smoking habits in relation to staff position, industry of employment, and degree of urbanization among inhabitants of the eastern part of Denmark — which includes the county where the factory is situated — has been conducted recently (7). Smoking-associated cancer risk among unskilled workers aged 30–59 years has been calculated accordingly, using the information on smoking habits in relation to position, in addition to earlier reports on the relative risk of lung cancer associated with tobacco use (cigarettes, pipes, and cigars) (4). Thus an adjustment factor has been derived, as the lung cancer risk among unskilled workers aged 30–59 years, which could be explained by their tobacco consumption relative to the lung cancer risk among all males aged 30–59 years. This adjustment factor, which is equivalent to 1.07, has subsequently been applied in the calculation of the expected number of lung cancer cases among the rock-wool workers to take account of the effect of tobacco consumption on the assumption that it is similar to that of unskilled workers in general.

Because age-specific smoking-induced lung cancer risks were available for men aged 30–59 years only, the calculation of an adjustment factor was restricted to this age group. It is unlikely that the adjustment factor would change substantially if younger or older age groups were included.

Results

During the period 1943–1982 a total of 240 cancer cases were observed among all employees, whereas 211.0 cases were expected on the basis of national incidence rates ($O : E = 1.14$, 95 % CL = 1.00–1.29). From table 2 it appears that the excess risk was restricted to the largest of the subgroups, ie, male workers with 213 observed cancer cases versus 182.0 expected ($O : E = 1.17$, 95 % CL = 1.02–1.34).

Table 3 gives the risk estimates for selected cancer sites among *male workers* according to time between

Table 2. Total number of observed (O) and expected (E) cancer cases, 1943–1982.

	Males			Females			Both sexes		
	Observed	Expected	O:E	Observed	Expected	O:E	Observed	Expected	O:E
Manual workers	213	182.0	1.17*	9	9.9	0.91	222	191.9	1.16*
Office workers	11	12.5	0.88	7	6.6	1.06	18	19.1	0.94*
All employees	224	194.5	1.15	16	16.5	0.97	240	211.0	1.14

* $p < 0.05$.**Table 3.** Observed (O) and expected (E) number of cases of cancers of selected sites among male workers according to time between first employment and date of diagnosis.

Site ^a	Years since first employment											
	0–9			10–19			≥20			Total		
	O	E	O:E	O	E	O:E	O	E	O:E	O	E	O:E
Buccal cavity and pharynx (140–148)	5	2.6	2.0	5	2.5	2.0	3	1.2	2.5	13	6.3	2.1*
Digestive organs (150–159)	27	15.9	1.7	26	18.0	1.4	11	10.1	1.1	64	43.9	1.5*
Respiratory system (160–164)	15	14.4	1.0	20	16.5	1.2	13	9.2	1.4	48	40.0	1.2
Larynx (161)	3	1.2	2.4	—	1.4	0.0	2	0.7	2.9	5	3.3	1.5
Lung, primary (162.0–1)	12	12.4	1.0	18	14.4	1.3	11	8.1	1.4	41	34.8	1.2
Male genital organs (177–179)	7	7.8	0.9	4	7.8	0.5	5	4.1	1.2	16	19.7	0.8
Urinary system (180–181)	9	7.3	1.2	8	8.5	0.9	7	4.7	1.5	24	20.4	1.2
Bladder (181)	6	5.0	1.2	6	6.0	1.0	6	3.4	1.8	18	14.4	1.2
Skin (190–191)	9	9.0	1.0	10	10.1	1.0	6	5.3	1.1	25	24.3	1.0
Melanoma (190)	3	1.9	1.6	2	1.6	1.2	1	0.6	1.7	6	4.1	1.5
Lymphatic and hematopoietic tissue (200–205)	5	6.2	0.8	7	5.1	1.4	3	2.4	1.3	15	13.6	1.1
Non-Hodgkins lymphoma (200, 202)	2	1.7	1.2	3	1.5	1.9	1	1.7	0.6	6	4.0	1.5
Morbus Hodgkin (201)	1	1.5	0.6	2	0.7	2.8	1	0.2	6.0	4	2.5	1.6

^a Code number of the International Classification of Diseases, seventh revision, in parentheses.* $p < 0.05$.**Table 4.** Age-standardized incidence of lung cancer per 100 000 male inhabitants of Roskilde County and Denmark, 1968–1977, with corresponding adjustment factors for local lung cancer risk.

Incidence of lung cancer	1968–1972 ^a	1973–1977 ^b	1968–1977
Roskilde County	74.8	70.9	75.5
Denmark	74.0	76.9	72.9
Adjustment factor	1.01	0.92	0.97

^a Age-standardized using national standard.^b Age-standardized using European standard.

first employment and date of diagnosis. Significantly more cases than expected appeared in the buccal cavity and pharynx (O : E = 2.1, 95 % CL = 1.1–3.4) and in the digestive organs (O : E = 1.5, 95 % CL = 1.1–1.9). A nonsignificant excess risk was observed for cancers of the respiratory system (O : E = 1.2, 95 % CL = 0.9–1.6) and the bladder (O : E = 1.2, 95 % CL = 0.7–2.0), for melanoma of the skin (O : E = 1.5, 95 % CL = 0.6–3.0) and lymphomas (O : E = 1.5, 95 % CL = 0.8–2.7). However, increasing risk with time since first employment was observed for cancers of the buccal cavity and pharynx, the respiratory system, and bladder only. A reverse risk gradient was detected for cancers of the digestive organs.

Place of residence and smoking habits

Table 4 gives the standardized incidence rates for primary lung cancer for males in Denmark and for males living in Roskilde County, where the rock-wool producing factory is situated. It appears that the lung cancer risk among males in Roskilde County is 0.97 in relation to that of Denmark for the 10-year period 1968–1977. When this adjustment factor is used for the county-specific lung cancer incidence in the calculation of the expected number of lung cancer cases among male workers employed at the factory, the figures presented in table 7 appear. The adjustment for local rates did not change the risk estimates significantly.

The urban-rural distribution of residence among a random sample of 522 rock-wool male workers with first employment in the period 1937–1967 is given in table 5. Even though the factory is placed just 25 km out of Copenhagen, it appears clearly from the table that most of the workers engaged originate from provincial towns (mainly Roskilde) and rural areas, only some 2 % being left with place of residence in Copenhagen and Copenhagen suburbs. Based on the incidence rates specific for geographic regions (1, 2), a set of incidence rates was derived for the period 1968–1977. It reflects the particular urban-rural distribution among rock-wool male workers (table 6), and a lung cancer risk relative to that of males in

Table 5. Place of residence among a random sample of rock-wool male workers with first employment in the period 1937–1967 (%).

Date of first employment	Capital		Capital suburbs		Provincial towns		Rural areas		Total	
	Number of workers	Percent-age of workers	Number of workers	Percent-age of workers	Number of workers	Percent-age of workers	Number of workers	Percent-age of workers	Number of workers	Percent-age of workers
1937–1947	—	0	1	1	68	50	67	49	136	100
1948–1957	—	0	—	0	98	57	73	43	171	100
1958–1967	2	1	8	4	88	41	117	54	215	100
1937–1967	2	0	9	2	254	49	257	49	522	100

Denmark was subsequently estimated (adjustment factor 0.79). Table 7 shows the influence of this adjustment, which is now measurable and which gives an O : E ratio of lung cancer for the subgroup of male workers with 20 or more years since first employment of 1.7 (95 % CL = 0.9–2.8). The risk of cancers of the entire respiratory tract for the same subgroup of employees was found to be 1.8 (95 % CL = 0.9–2.8).

Finally, table 7 shows the O : E ratios for lung cancer among rock-wool male workers after adjustment for the place of residence *and* the smoking habits prevailing among unskilled workers. This adjustment yields an O : E ratio for lung cancer of 1.6 (95 % CL = 0.9–2.8) among male workers with 20 or more years since first employment and an O : E ratio for cancers of the entire respiratory tract of 1.7 (95 % CL = 0.9–2.8).

Discussion

In the cohort of employees at one rock-wool production plant in Denmark the cancer morbidity has been examined. An overall increased risk of cancer was detected among all the employees ever employed at the plant. However, after subdivision of the cohort, the excess appeared to be restricted to the largest subgroup employed, ie, male rock-wool production workers (table 2), which is the group of persons among whom the highest risk would be expected *a priori*.

Several site-specific excesses accounted for these findings, of which cancers of the digestive organs, buccal cavity and pharynx, and respiratory system

Table 6. Age-standardized number of lung cancer cases per 100 000 inhabitants with place of residence as indicated in table 5, and in Denmark, 1968–1977, with corresponding adjustment factors for place of residence.

Reference population	1968–1972 ^a	1973–1977 ^a	1968–1977
According to place of residence			
Denmark	56.8	63.3	60.1
	74.0	77.3	75.7
Adjustment factor	0.77	0.82	0.79

^a Age-standardized using national standard.

predominated. An increasing trend with time since first employment was recognized for cancers of the buccal cavity and pharynx and the respiratory organs, while a decreasing trend was detected for cancers of the digestive organs, which, for the latter, indicates that the significant excess risk must be attributed to factors other than the rock-wool work environment.

The major objective of this study was to evaluate whether an association exists between exposure to mineral wool — especially fibers — and cancer of the respiratory tract. The increased risk of lung cancer among workers with 20 or more years since first employment, although not significantly in excess of 1.0 but still compatible with a two- to threefold increase according to conventional 95 % confidence limits, are in line with this hypothesis. However, a number of potential errors must be considered.

The group of people under investigation was formed on the basis of existing documentation in the factory

Table 7. Observed (O) and expected (E) number of lung cancer cases among rock-wool male workers according to alternative reference rates and after adjustment for smoking habits among unskilled workers.

Years since first employment	Observed lung cancer cases	Denmark		Roskilde County		Place of residence		Smoking habits and place of residence	
		E	O:E	E	O:E	E	O:E	E	O:E
≤9	12	12.4	1.0	12.0	1.0	9.8	1.2	10.5	1.1
10–19	18	14.4	1.3	13.9	1.3	11.4	1.6	12.1	1.5
≥20	11	8.1	1.4	7.8	1.4	6.4	1.7	6.8	1.6
Total	41	34.8	1.2	33.8	1.2	27.7	1.5	29.4	1.4

and without knowledge of later cancer development. The follow-up of the group was almost complete (96.6 %), and the information about incident cancer cases was obtained from an independent source — the Danish Cancer Registry — without knowledge of the person's occupation within the plant. Thus the study is unbiased with regard to registration of cancer incidence among the factory's personnel.

On the other hand, in a retrospective study, it is difficult to evaluate to what degree confounding factors have influenced the risk estimates. In the study of lung cancer in particular the role of tobacco smoking must be considered, as well as the possible influence of other occupational exposures. As in most retrospective cohort studies information on such factors was missing, and attempts to control or assess possible confounding could only be indirect.

Several different approaches were used to determine whether the use of rates for all Denmark as the reference could explain the increased lung cancer risk among the rock-wool workers, as it was unknown to what degree the total Danish population differed from our study population with respect to other occupational exposures and life-style factors in particular. First, an estimation of the expected number of lung cancer cases was attempted on the basis of local rates for Roskilde County. This procedure did not change the figures to any substantial degree. Second, an alternative computation of the expected number of lung cancers was undertaken with the use of cancer rates for a population composed like the cohort under study with regard to place of residence, a factor indicative of both life-style and occupation (3, 6). This adjustment for place of residence resulted in an overall 27 % decrease in the expected number of lung cancer cases, a figure corresponding to a 20 % increase in the calculated O : E ratios. Thus, applying more appropriate reference populations to adjust for the possible confounding effects of life-style factors and other occupational exposures could not explain the increased risk among rock-wool workers. This adjustment may, on the contrary, indicate that negative confounding was present.

Third, the results of a survey on smoking habits relative to staff position were implemented in the lung-cancer risk assessment among unskilled rock-wool workers. It appeared that the adjustment for smoking did not change the risk assessment of lung cancer to any substantial degree; thus it is unlikely that smoking habits among the rock-wool workers can explain the observed increased risk of cancers of the respiratory tract. Applying the effects of place of residence and smoking habits on lung cancer risk led to an 18 % increase in the O : E ratio compared to the one determined using male inhabitants of Denmark as the reference population.

In conclusion, we have observed a moderate excess risk of cancers of the respiratory tract, lung cancer in particular, and cancers of the buccal cavity and pharynx among male workers with 20 or more years since first exposure. The excess of lung cancer increases somewhat after the combined adjustment for place of residence among the workers and smoking habits prevailing among unskilled workers in general, but it remains nonsignificant. It is unlikely that the excess lung cancer risk could be ascribed to bias in cancer ascertainment or to factors such as life-style or occupational exposures unrelated to the plant under study. The number of cases, however, is too small to exclude the effect of chance in this single investigation.

Acknowledgment

The authors are grateful to the management of Rock-wool International for the cooperation received and to Mr HS Jensen of the Danish Cancer Registry for his valuable assistance. Ms Å Larsen, Ms V Clemmensen, and Mr N Christensen, of the Danish Cancer Registry, assisted with the data collection and analysis.

This study was supported by the International Agency for Research on Cancer (RA/78/020). Dr JH Olsen was supported by the Environmental Cancer Programme of the Danish Cancer Society (M 1/81).

References

1. Clemmesen J. Statistical studies in the aetiology of malignant neoplasms, trends and risks, Denmark 1943—77. Volume V. *Acta Pathol Microbiol Scand Suppl* 261 (1977).
2. Danish Cancer Registry. Incidence of cancer in Denmark. Danish Cancer Society, Copenhagen 1982.
3. Danmarks Statistik. Registerfolketællingen 1. juli 1976. Vol II. København 1979.
4. Hammond EC. Smoking in relation to the death rates of one million men and women. *Natl Cancer Inst Monogr* 19 (1966) 127—204.
5. Monson RR. Analysis of relative survival and proportional mortality. *Comput Biomed Res* 7 (1974) 325—332.
6. Komiteen til undersøgelse af den danske befolknings sundhedstilstand. Morbiditetsundersøgelsen af 1950: Sygdomsundersøgelsen i Danmark 1951—1954. Munksgaard, København 1960.
7. Olsen JH, Borch-Johansen K, Roed-Petersen B. Rygevaner og erhvervsmæssig beskæftigelse. *Ugeskr Laeg* 147 (1985) 2788—2792.
8. Olsen JH, Jensen OM. Cancer incidence among employees in one mineral wool production plant in Denmark. *Scand J Work Environ Health* 10 (1984) 17—24.
9. Rothman KJ, Boice JD. Epidemiologic analysis with a programmable calculator. Epidemiology Resources, Inc, Boston, MA 1982.