Original article
Scand J Work Environ Health 1991;17(5):356-359
doi:10.5271/sjweh.1692

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This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/1947921
Cancer incidence among pulp and paper workers exposed to organic chlorinated compounds formed during chlorine pulp bleaching

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JÄPPINEN P, PUKKALA E. Cancer incidence among pulp and paper workers exposed to organic chlorinated compounds formed during chlorine pulp bleaching. *Scand J Work Environ Health* 1991;17:356-9.

Numerous chlorinated organic compounds are formed during the chlorine bleaching of wood pulp (1-4), and they have been found both in bleached pulp mill effluents and in end products. Among them are polychlorinated dibenzo-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). Many of these chlorinated compounds are toxic, mutagenic, teratogenic, and also carcinogenic in experimental animals. One of the major PCDD compounds formed during chlorine pulp bleaching and found in many paper products, 2,3,7,8-tetrachlorodibenzodioxin, is the most potent animal carcinogen that has been tested (5).

Recently, many volatile organohalogen compounds with a low molecular weight have been identified in liquors from different bleaching stages (6) and also in workplace air of the bleaching departments (Rosenberg et al, unpublished data). It is also possible that PCDD and PCDF can spread from washing drums of the bleaching department to workplace air with water vapor.

There are some reports of an increased cancer risk among pulp and paper workers. Among the cancers with a reported increased risk are lymphomas (7-9), leukemias (8-10), gastrointestinal cancers (7-11), oral and pharyngeal cancers (9, 12, 13), and lung cancer (9, 13-16). A significant excess of lung cancer was reported for male board-mill workers in a Finnish study (16) (40 observed, 18.1 expected, standardized incidence ratio (SIR) 222, 95 % confidence interval (95 % CI) 158-302], and the risk increased as the latency since first employment and the duration of employment increased.

Since pulp and paper workers are exposed to potentially carcinogenic compounds formed during chlorine pulp bleaching, a study was performed to assess the cancer risk of workers undoubtedly exposed to these compounds in the bleaching and board manufacturing departments of a large pulp and paper mill.

**Subjects and methods**

The study population consisted of 152 male workers in a large pulp and paper mill in the province of Kymi in southeastern Finland with the following job categories: bleaching plant operators, stock preparation workers, board machine workers, and slitter-rewinder operators (table 1). They were all included in the original cohort of a previously reported Finnish study (16) in which a significantly increased risk of lung cancer was found among pulp and paper workers in general, and especially among board mill workers. In addition to a longer follow-up time than in the original study, the job categories in this study were chosen so that the workers were exposed to chlorinated organic compounds via either the respiratory system or the skin. In the bleaching department and, especially, the stock preparation department, with partially open vats, the workers were exposed to vapors, spent liquor, and pulp splashes. At the board machines the workers were exposed to process water and pulp splashes and to a smaller amount of board dust. The latter was the main source of exposure at the slitter-rewinders.

A worker was included in the cohort if he had worked continuously in his job for at least one year.
between 1 January 1945 and 31 December 1961. Therefore, the shortest latency time since first employment was one year, and the calculation of the person-years and cancer cases started one year after the first employment. The cohort was followed for incident cancers from 1 January 1953 until 31 December 1987 with the use of the data of the Finnish Cancer Registry. The registry has virtually complete data on all primary cancers notified in Finland since 1953.

The person-years (4095 for the whole cohort) (table 1) were calculated until death (according to the data of the National Population Register) or the general closing date (31 December 1987), whichever came first. The expected numbers of primary cancers were calculated for three calendar periods (1953—1965, 1966—1976, and 1977—1987) and for four follow-up times (1—4 years, 5—9 years, 10—14 years, and ≤ 15 years) since first employment and for three age groups (≤ 29 years, 30—59 years, and ≥ 60 years). We estimated the expected numbers of cases by multiplying the age- and calendar-period-specific numbers of person-years at risk with the corresponding cancer incidence rates of the local central hospital district with a population of approximately 135 000. There were small differences in the age-standardized cancer incidence rates between the whole country and the local central hospital district, with site-specific variations. For instance, the incidence rate for all primary cancers among the men in the whole country was 267.1 per 100 000 inhabitants during 1977 to 1987, while the corresponding rate in the local hospital district was 242.4. For lung cancer, the corresponding figures were 69.5 and 62.7, respectively. SIR values were obtained as ratios between the observed and expected numbers of cases. The 95 % CI values were estimated on the assumption of a Poisson distribution for the observed numbers of cases.

**Results**

There were 12 cancers against 8.1 expected in the whole study population (SIR 1.5, 95 % CI 0.8—2.6) (table 2), 11 of which occurred after a latency of at least 15 years (6.4 expected). Seven of the 12 primary cancers were in the age group 30—59 years (4.7 expected), and five occurred in the group of ≥ 60 years (3.3 expected).

There were seven lung cancers against 2.3 expected (SIR 3.0, 95 % CI 1.2—6.2), two cancers of the digestive organs against 2.1 expected (one stomach and one pancreas cancer), one cancer of the genital organs, one bladder cancer, and one brain cancer.

Among the bleaching plant operators, two cancers had been diagnosed against 1.1 expected, one pancreas and one brain cancer. Both workers had started to work in the bleaching plant in 1955, and both cases were diagnosed when the worker was over 60 years of age, in 1982 and 1987.

Among the stock preparation workers, there were nine cancers against 3.1 expected (SIR 2.9, 95 % CI 1.3—5.4) (table 3). Six of them were lung cancers (1.0 expected, SIR 6.3, 95 % CI 2.3—14). Five of the lung cancers occurred after a latency of at least 15 years (0.8 expected). The risk was the most prominent in the age group of 30—59 years (4 observed, 0.5 expected, SIR 7.8, 95 % CI 2.1—20). According to the records of the company health unit, all lung cancer patients among the stock preparation workers were smokers. In addition to the lung cancers, there was one stomach cancer, one cancer of the genital organs, and one bladder cancer among the stock preparation workers.

Among the board machine and slitter-rewinder workers there was one cancer against 3.9 expected (SIR 0.3, 95 % CI 0.01—1.4). The only cancer was a lung cancer that occurred after a latency of at least 15 years.

**Discussion**

Only 152 subjects were included in this study. It was not possible to form a larger cohort with definite exposure to organic chlorinated compounds formed during pulp bleaching. Subjects with other job categories

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**Table 1. Study population and person-years by job category.**

| Job category                        | Number of workers | Person-years |
|-------------------------------------|-------------------|--------------|
| Bleaching plant operators           | 13                | 377          |
| Stock preparation workers           | 53                | 1395         |
| Board machine and slitter-rewinder workers | 86                | 2323         |
| Total                               | 152              | 4095         |

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**Table 2. The observed (O) numbers of all primary cancers and lung cancer among the men exposed to organic chlorinated compounds in the bleaching and stock preparation departments, at the board machines and slitter-rewinders, and the corresponding standardized incidence ratios (SIR) with 95 % confidence intervals (95 % CI), by latency (time since first employment). The incidence rates of the local central hospital district have been used as reference.**

| Site                               | Latency       | O   | SIR 95 % CI | O   | SIR 95 % CI | O   | SIR 95 % CI | O   | SIR 95 % CI | O   | SIR 95 % CI |
|------------------------------------|---------------|-----|-------------|-----|-------------|-----|-------------|-----|-------------|-----|-------------|
|                                    | 1—4 years     |     |             | 5—14 years |     |             | ≥ 15 years |     |             | Total |             |
| All cancers (140—209)              |               |     |             |       |             |       |             |       |             |       |             |
| Trachea, bronchi, and lungs (162)  |               |     |             |       |             |       |             |       |             |       |             |

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*a Code of the International Classification of Diseases, eighth revision, in parentheses.
Even the workers in this study had been exposed to organic chlorinated compounds formed during chlorine pulp bleaching. The excess risk for lung cancer was the most prominent after a latency of at least 15 years and at the age of 35—59 years, which is not the typical age for smoking-related lung cancers. Our conclusion on the basis of this small cohort study is that the increased risk of lung cancer found among stock preparation workers may be connected with workplace exposure to organic chlorinated compounds formed during chlorine pulp bleaching.

The number of all cancers combined was slightly more than expected, which is not a common finding among industrial populations. The excess was due to lung cancer among the stock preparation workers. All of the stock preparation workers with lung cancer were smokers, but there are no data about the amount of tobacco consumption. Pukkala et al (17) have reported a close positive correlation between the SIR of lung cancer and the occupational category-specific prevalence of smoking in Finland, but Axelsson (18) has, on the other hand, postulated that only rarely does the confounding effect of smoking distort the risk ratios of lung cancer outside the range of 0.5—1.5 in industrial populations. The lower 95 % confidence limit of the SIR found in our study was 2.3. Therefore, it is probable that smoking alone does not explain the excess risk of lung cancer found.

Stock preparation workers are the first subjects along the paper and board manufacturing process to be exposed to compounds formed during chlorine pulp bleaching. The excess risk for lung cancer was the most prominent after a latency of at least 15 years and at the age of 35—59 years, which is not the typical age for smoking-related lung cancers. Our conclusion on the basis of this small cohort study is that the increased risk of lung cancer found among stock preparation workers may be connected with workplace exposure to organic chlorinated compounds formed during chlorine pulp bleaching.

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### Table 3. The observed (O) numbers of all primary cancers and lung cancer among the men exposed to organic chlorinated compounds in the stock preparation and the corresponding standardized incidence ratios (SIR) with 95 % confidence intervals (95 % CI), by latency (time since first employment). The incidence rates of the local central hospital district have been used as reference.

| Site*                              | 1—4 years | 5—14 years | ≥ 15 years | Total     |
|------------------------------------|-----------|------------|------------|-----------|
|                                    | O SIR 95 % CI | O SIR 95 % CI | O SIR 95 % CI | O SIR 95 % CI |
| All cancers (140—209)              | 1 8.6 0.2—48 | — — 0—26 | 8 3.3 1.4—6.6 | 9 2.9 1.3—5.4 |
| Trachea, bronchi, and lungs (162)  | 1 60 1.5—336 | — — 0—115 | 5 6.4 2.1—15 | 6 6.3 2.3—14 |

* Code of the International Classification of Diseases, eighth revision, in parentheses.
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Received for publication: 24 January 1991