A proportionate mortality ratio analysis of pulp and paper mill workers in New Hampshire

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ABSTRACT A proportionate mortality ratio (PMR) analysis of 1071 deaths in pulp and paper mill workers in New Hampshire during 1975-85 showed an increase in cancers of the digestive tract and lymphopoietic tissues. A similar analysis of deaths for 452 timber cutters and loggers failed to show excess PMRs for cancers of these sites. Despite methodological constraints, these results suggest that one or more of the exposures experienced by pulp and paper mill workers may pose a significant carcinogenic risk. More definitive epidemiological studies are required to determine particular high risk processes or specific aetiological agents.

More than 120m tons of pulp, paper, and paperboard are produced annually in the United States by an estimated 156 000 production workers.¹ The first American woodpulp manufacturing facilities were built in the 1870s, mostly in New England because of the abundant supply of spruce. By 1910, New Hampshire mills were producing more than 10% of the national supply of woodpulp, ranking fourth in national production.² New Hampshire plants have primarily used two chemical pulping processes, the acid based process and the Kraft or sulphate process.

Several reports suggest that pulp and paper mill workers experience increased mortality due to cancers of the gastrointestinal tract and lymphopoietic issues.³⁻⁸ A recently completed state wide population based mortality analysis provided an opportunity to examine the patterns of mortality of pulp and paper mill workers in New Hampshire.⁹

Materials and methods

A proportionate mortality ratio (PMR) analysis was performed for all deaths between 1975 and 1985 among white male residents (age 20 years or older) in New Hampshire (n = 37 426). Occupation, industry, age, and date and cause of death information were abstracted from death records. The underlying cause of death was categorised according to the eighth revision of the International Classification of Diseases (ICD-8) and coded by a trained nosologist at the New Hampshire Bureau of Vital and Health Statistics.¹⁰

Occupation and industry data were classified into one of 503 occupational and 231 industrial categories according to the Industry and Occupation Classification devised by the United States Bureau of the Census.¹¹ The analysis was performed by using a computer program developed by Monson that calculates cause specific expected numbers of deaths based on the mortality experience of the United States general population.¹² In this analysis the proportion of deaths in specific cause of death categories is compared with the corresponding proportion of deaths in the United States population. The PMRs are standardised for the potentially confounding effects of age, sex, race, and year of death.

In addition, standardised mortality odds ratios (SMORs) were derived by calculating the ratio of mortality odds for each cause of death category using deaths from cancer as "controls" and expected deaths based on the mortality experience of the United States general population as the "unexposed."^{12a} The SMOR is calculated in a manner identical to the relative odds in case-control studies and provides a better estimate of the relative risk than the PMR.¹³ Statistically significant differences between observed and expected deaths and confidence intervals were determined by using a summary Mantel-Haenszel chi-squared test with one degree of freedom.

Results

Among the total population of decedents were 1071 pulp, paper, and paperboard mill workers (industrial code 160) and 452 timber cutters and loggers (occupational code 496). The distributions of statis-

Table 1 Statistically significant PMRs and observed and expected deaths† in pulp, paper and paperboard mill workers: New Hampshire 1975–85

Total No of deaths = 1071				Industrial code 160 90% CI			
ICD‡	Cause of death	Obs	Exp	PMR§	LL	UL	χ²
140–149	Cancer of buccal cavity & pharynx	10	5.7	175	105	293	3.21*
150–159	Cancer of digestive organs	79	61.2	129	108	154	5.50*
151	Cancer of stomach	15	8.9	168	110	255	4.17**
154	Cancer of rectum	11	5.7	194	119	316	5.00**
161	Cancer of larynx	6	2.9	209	108	403	3.42*
204–207	Leukaemia and aleukaemia	12	7.5	160	100	256	2.74*
250	Diabetes mellitus	22	15.1	146	103	207	3.23*
290–317	Mental & psychoneurotic disorders	12	6.0	201	126	320	6.17**

*p < 0.10; **p < 0.05.

†Complete tables are available upon request.

‡International Classification of Disease, 8th rev.

§PMR = (Obs/exp) × 100.

Obs = Observed number of deaths.

Exp = Expected number of deaths.

tically significant PMRs and observed and expected deaths are presented in tables 1 and 2.

Pulp and paper workers showed statistically significant rises in the PMR for cancers of the digestive tract, particularly for cancers of the buccal cavity (PMR = 175, 90% CI 105–293), stomach (PMR = 168, CI 110–255), and rectum (PMR = 194, 90% CI 119–316). PMRs for cancers of the colon (PMR = 128, 90% CI 95–172), pancreas (PMR = 126, 90% CI 82–192), and larynx (PMR = 209, 90% CI 108–403) were also raised. Lymphopietic tissue cancers (PMR = 119, 90% CI 85–167), particularly leukaemia (PMR = 160, 90% CI 100–256) and lymphoma/multiple myeloma (PMR = 140, 90% CI 84–234), were increased as were cirrhosis of the liver (PMR = 115, 90% CI 80–166), diabetes (PMR = 146, 90% CI 103–207), and mental and psychoneurotic disorders (PMR = 201, 90% CI 126–320). SMORs produced virtually identical results as the PMRs, confirming the finding of an excess proportion of cancers of the gastrointestinal tract and lymphopietic tissues.

Of the 24 deaths due to lymphopietic tissue cancers among pulp and paper mill workers, 12 were leukaemias, six lymphomas (unspecified), four multiple myelomas, one Hodgkin's disease, and one lymphosarcoma. Among these, one was due to gastric lymphoma. Contrary to the findings of other studies of woodworkers, an excess of Hodgkin's disease was not observed.¹⁴ Among 12 deaths due to mental and psychoneurotic disorders, six were due to acute alcoholism, four to organic brain syndrome, and two to other psychological disorders. No deaths due to nasal cancer were observed.

Timber cutters and loggers experienced a statistically significant rise in the PMR for cancer of the larynx (PMR = 458, 90% CI 234–896), pneumonia (PMR = 171, 90% CI 121–241), cirrhosis of the liver (PMR = 169, 90% CI 104–274), and injury related deaths (PMR = 132, 90% CI 101–172). Among 29 injury related deaths, eight were due to falling objects, four to falls, and two to electrocution. Among 37 cancers of the respiratory tract, one was due to

Table 2 Statistically significant PMRs and observed and expected deaths† Timber cutting and logging occupations: New Hampshire 1975–85

Total No of deaths = 452				Occupational code 496 90% CI			
ICD‡	Cause of death	Obs	Exp	PMR§	LL	UL	χ²
161	Cancer of larynx	5	1.1	458	234	896	14.02**
460–519	Non-malignant respiratory disease	56	36.6	153	124	189	11.30**
480–486	Pneumonia	22	12.9	171	121	241	6.67**
571	Cirrhosis of liver	11	6.5	169	104	274	3.23*
800–949	Accidents	29	22.0	132	101	172	3.00*

*p < 0.10; **p < 0.01.

†Complete tables are available upon request.

‡International Classification of Disease, 8th rev.

§PMR = (Obs/exp) × 100.

Obs = Observed number of deaths.

Exp = Expected number of deaths.

squamous cell carcinoma of the nasal cavity.

Because occupational histories were not available, analyses by process, job title, duration of employment, or latency were not possible.

Discussion

Pulp and paper mill workers and timber cutters and loggers both experienced rises in PMR due to laryngeal cancer and alcohol related diseases. Pulp and paper workers experienced raised PMRs for cancers of the gastrointestinal tract, leukaemia, and lymphoma/multiple myeloma, whereas the timber cutters and loggers experienced rises in PMR for injury related death and pneumonia.

An unusual experience of cancer among workers in the pulp and paper industry has been reported by others. Milham, analysing the patterns of mortality among pulp and paper workers in Washington State, reported statistically significant rises in PMR for cancers of the small intestine (PMR = 335, $n = 6$), lymphatic and haematopoietic tissues (PMR = 142, $n = 99$), Hodgkin's disease (PMR = 194, $n = 17$), multiple myeloma (PMR = 182, $n = 19$), diseases of the blood (PMR = 174, $n = 17$), and machine injuries (PMR = 259, $n = 16$).³ Raised PMRs were also observed for cancers of the stomach (PMR = 108, $n = 47$), rectum (PMR = 123, $n = 28$), gallbladder (PMR = 142, $n = 8$), larynx (PMR = 121, $n = 10$), kidney (PMR = 127, $n = 22$), and for leukaemia (PMR = 126, $n = 38$).

In a PMR analysis of deaths identified from listings found in the *Pulp, Sulfite and Paper Mill Worker's Journal*, Milham and Demers reported excesses for cancers of the stomach (PMR = 176, $n = 68$), small intestine (PMR = 444, $n = 4$), rectum (PMR = 118, $n = 19$), and accidents (PMR = 122, $n = 266$).⁴ The PMR for cancers of the pancreas (PMR = 131, $n = 21$), kidney (PMR = 118, $n = 9$), brain (PMR = 124, $n = 13$), and lymphosarcoma (PMR = 164, $n = 11$) were also raised. When delineated by type of process, increases in cancers of the pancreas, rectum and kidney, and lymphosarcomas occurred primarily among sulphite process workers, whereas rises in Hodgkin's disease were limited to workers in the sulphate (Kraft) pulping process. A recent cohort study of workers employed in five pulp and paper plants in the northwestern United States also showed process specific differences in mortality.⁵ An excess risk of stomach cancer was observed among men who worked in sulphite mills, whereas an excess risk of lymphosarcomas was observed among sulphate process workers.

In a case-control analysis of deaths among Swedish pulp and paper workers, Wingren *et al* reported an excess of gastric cancer (OR = 2.7, $n = 13$).⁶ An

analysis of deaths from cancer in Massachusetts, performed by Dubrow and Wegman, showed raised PMRs for all cancers (PMR = 120, $n = 91$) and cancers of the digestive organs (PMR = 138, $n = 31$), particularly cancers of the colon and rectum (PMR = 154, $n = 15$) among pulp and paper workers.⁷ Based on small numbers of deaths, cancer of the brain (PMR = 298, $n = 4$) and cirrhosis of the liver (PMR = 170, $n = 19$) were also increased. In addition, Guralnick's national survey has shown an excess of deaths from intestinal and rectal cancer (PMR = 117, $n = 21$) among United States pulp and allied product operatives.⁸

Potential chemical exposures encountered during pulping operations depend on the particular digesting process used. In the acid based sulphite process bisulphites are used as the cooking liquid to remove lignan from wood chips. The sulphite process is generally used to digest long fibred, low resinous woods such as spruce, fir, and hemlock. The alkaline based sulphate, or Kraft process, uses sodium hydroxide and sodium sulphite to form the digesting liquid. The advantages of this method are that almost any type of wood may be used and the process chemicals may be reclaimed.²

After removal of the lignan, the remaining cellulose fibres are bleached with chlorine or a hypochlorite solution to whiten the pulp. Exposures at this stage may include hydrogen sulphate, sulphur dioxide, chlorine, chlorine dioxide, mercaptans, lime, caustics, and various organic sulphides formed during the digesting process. Additional exposures may include alcohols, aliphatic acids, herbicides, dioxins, tannins, and terpenes.

Paper making includes processes that refine, clean, press, and dry the pulp. Numerous chemical additives are combined with the fibrous pulp that affect the absorbency, strength, opacity, brightness, and printing properties of the paper.¹⁵ Pigments and dyes may be added as colourants and various coatings may be added that affect the texture of the paper. In addition, solvent exposure may arise from the use of adhesives, gums, or varnishes. (See table 3 for some commonly used additives.)

Among the multitude of potential chemicals used in the pulp and paper industry, several are known or suspected carcinogenic substances. For example, pesticide and herbicide exposure may occur from previously treated wood or from slimicides introduced during the pulping process. Numerous studies have reported excesses of lymphoma and leukaemia among agricultural workers potentially exposed to pesticides and herbicides.¹⁶ Formaldehyde exposure, although associated with cancers of the nasopharynx in animals, may also be linked with lung cancer, leukaemia, and Hodgkin's disease.¹⁷ Similarly, exposure to wood dust

Table 3 Some additives used in the pulp and paper industry^{15 18}

Alum	Polyvinyl acetates
Antifoaming agents	Rosin
Biphenyls	Slimicides
Calcium carbonate	Sodium aluminate
Clays (kaolin)	Starches
Dyes and pigments	Surface active agents
Epichlorohydrin based resins	Talc
Melamine formaldehyde	Titanium dioxide
Natural gums	Urea-formaldehyde
Polyacrylate acetates	Waxes
Polyamide resin	

has been associated with cancer of the nasopharynx and is suspected of being linked to Hodgkin's disease.¹⁸ Further, talc, used as a filler during paper making, may contain asbestiform fibres.¹⁹ At least one study has shown an association between exposure to talc and the risk of stomach cancer.²⁰

Since both pulp and paper workers and timber cutters and loggers were likely to be exposed to wood dust and herbicides, the observed excess of cancer may be associated with other agents used or formed during the pulping or paper making processes. For example, it has been suggested that the introduction of chlorine during the pulping process may result in the formation of mutagenic or carcinogenic chemicals. Consistent with this hypothesis, *Salmonella*/microsome assays of mill effluent have shown that effluents produced during the first chlorination stage from both the Kraft and sulphite mills are mutagenic.¹⁸ Further, Milham has suggested that differences in the patterns of mortality between sulphite and sulphate processes may be related to the particular species of trees processed.⁴

STUDY LIMITATIONS

PMR analyses are known to have some limitations. In particular, because the all cause mortality must equal 100%, an overrepresentation or underrepresentation of one cause may influence the PMR of other causes of death. Nevertheless, only a minor deficit in cardiovascular mortality (the major cause of mortality in the United States) was present in our data (PMR = 97), which might otherwise have tended spuriously to inflate the PMR for cancer. Further, the SMOR analysis, which focuses on odds ratio rather than cause specific proportions produced results virtually identical with those of the PMR analysis. This analysis adds confidence that the observed excess of cancer does not result from the interdependence of the data.

Other limitations could stem from use of the national mortality rates to derive the expected number of deaths. Although regional differences in cancer mortality are known to occur, the absence of an excess of cancer among timber cutters and loggers suggests

that regional differences are not responsible for the excess of cancer among pulp and paper workers. Further, the analysis failed to control for potentially confounding factors such as cigarette smoking, alcohol use, diet, and social class. For example, the observed raised PMRs for cirrhosis of the liver are strong evidence for increased chronic alcohol consumption among pulp and paper workers. Similar evidence of alcohol abuse among timber cutters and loggers was observed. These workers, however, did not show an excess of gastrointestinal tract or lymphopoietic tissue cancers. Thus alcohol abuse alone is unlikely to have accounted for the increased observed proportion of these cancers. An analysis of the role of non-occupational risk factors would require more detailed data than are available from death certificates.

The potential limitations stemming from the use of death certificate data are well known. Non-random misclassification of cause of death or occupational/industrial information may possibly have influenced the results by either raising or lowering the cancer risk observed. Finally, because many causes of death were examined and many comparisons made, some of the study findings may be due to chance.

The findings of this study are consistent with those of other studies and suggest that one or more of the exposures experienced by these workers may be carcinogenic. More definitive epidemiological studies are required to identify particular high risk processes or specific aetiological agents. In the interim additional engineering controls may be required to limit unnecessary workplace exposures. Further, workers with significant past exposure in this industry may benefit from medical surveillance designed to detect early stage colorectal cancer. The feasibility and effectiveness of such screening activities has yet to be evaluated for workers in this industry.

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