Mortality among pulp and paper workers in Berlin, New Hampshire

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ABSTRACT Cause specific mortality was analysed among 883 white male workers from a paper company in Berlin, New Hampshire. Subjects were assigned to different exposure groups on the basis of their having worked in the pulp mill, the paper mill, or elsewhere in the paper company. A standardised mortality ratio (SMR) analysis was used to compare death rates for each of the exposure groups with United States national rates. For all the subjects, deaths due to all causes, all malignant neoplasms, and lung cancer were close to the number expected and excesses were noted for cancers of the digestive system and leukaemia. Among pulp mill workers, the number of cancers of the digestive system was raised and the SMR for pancreatic cancer was especially high (SMR = 305, 95% CI = 98-712). Among paper mill workers, more deaths were due to leukaemia and cancers of the digestive system than expected. These results are consistent with the findings from other studies that employment in pulp and paper mills is associated with excess mortality due to digestive and lymphopietic cancers.

Results from several studies have suggested an association between employment in the paper industry and excess mortality due to cancers of the digestive system, lymphopietic tissues, and the respiratory tract.¹⁻¹⁶ Excesses in mortality have also been observed by several researchers for circulatory system diseases.^{10 11 17} In most mortality studies that consider employment in a paper company data on the occupational histories of the subjects are limited and the whole industry, rather than particular processes within the industry, are implicated. For example, the determination of exposure may be based on residency in counties with paper manufacturing facilities^{1 2} or on usual or last occupation as indicated in death registries, cancer registries, or hospital records.^{3-7 9 10 12 14-16} In a few analytical studies work histories were detailed enough to determine with which processes in a paper company each subject had worked.^{8 11 13 17} With more detailed employment data, researchers have noted differences in cause specific mortality between pulp and paper mill workers and among the workers from the different types of pulping operations.

The following study was initiated to investigate the mortality of workers from different operations within a pulp and paper manufacturing company. The subjects for this study were participants in a prospective study of respiratory health begun in Berlin, New

Hampshire, in 1961. Occupational histories were gathered from the subjects during interviews and provided the exposure information needed to investigate workers from different locations within the company and to examine the effect of latency and duration of employment on mortality. With respect to outcomes, attention was focused on those causes of death found to be raised in other studies of paper workers. Of particular interest were circulatory diseases and cancers of the digestive system, lymphopietic tissues, and the respiratory tract.

Methods

WORK ENVIRONMENT

The manufacturing of paper has two general stages: pulp production and paper making. In chemical pulp production wood chips are "cooked" in an alkaline or acidic solution under increased temperature and pressure. During paper making, the soft pulp is suspended in water and chemicals are added to impart the desired characteristics to the final product. Then the pulp mixture is distributed on to a moving screen and the material is pressed and dried in order to yield paper.

The two major approaches to chemical pulping are the sulphite and sulphate processes. These methods differ not only in process chemicals but also in the type of wood used. The acidic sulphite process uses spruce and other trees that have low resin contents, whereas

the alkaline sulphate process works best with the higher resin trees such as pine. Both chemical pulping operations release several different airborne contaminants, including sulphur dioxide, hydrogen sulphide, and methyl mercaptan. The sulphite and sulphate processes differ in the levels of gaseous byproducts yielded. For example, measurements at the paper company in Berlin, New Hampshire, indicated that the levels of sulphur dioxide were usually higher in the sulphite mill compared with the sulphate mill.¹⁸ Pulp mill workers may also be exposed to chlorine and chlorine dioxide, which are commonly used to bleach the pulp. Findings from mutagenicity studies indicate that effluents from the chlorination process are mutagenic and possibly carcinogenic.¹⁹

The pulp mill contains more irritant gases, such as sulphur dioxide, than are found in the paper mill. The practice of putting additives and fillers into the pulp before the actual making of the paper, however, introduces various substances (and mixtures of substances) into the air of the paper mill that are not found in the pulp mill environment. An example of such a compound is formaldehyde, a known animal carcinogen, that is added to pulp to increase the wet strength of the paper.²⁰

Paper making has been a major industry in Berlin, New Hampshire, since the 1890s. Over the years, the company has produced newsprint, paper towels, bathroom tissue, and various other paper products intended for agricultural, industrial, and commercial use. For the production of pulp, the sulphite process was used from 1892 to 1963. The sulphate process was introduced in 1948 and after 1963 it was the only process used to produce pulp. This pattern of moving away from the sulphite process to the sulphate process has occurred throughout the paper industry in the United States.²¹ One advantage of the sulphate method is that the process chemicals are more readily recovered than with the sulphite method. The recovery process is technically not necessary for producing pulp but it is important for economic and environmental reasons.

Cohort definition and testing

The subjects for this study were all white men and were included in the study cohort if they met the following criteria.

(1) Participation in the study of respiratory health initiated in 1961 in Berlin, New Hampshire, by B G Ferris Jr and colleagues.

(2) At least one year of work in the paper company in Berlin, New Hampshire.

(3) Less than five years of work in pulp or paper production in other paper companies.

Subjects for the study of respiratory health in Berlin were enrolled in 1961, 1963, or 1967. All were white. In 1961 residents of Berlin were selected by means of an age stratified random sample of the general population and then invited to take part in a field survey. Details of the sampling process are published elsewhere.²² A total of 522 men were tested at that first field survey. A similar process was used to enrol an additional 305 men in 1967.²³ The 271 subjects enrolled in 1963 were employees at the paper company in Berlin.¹⁸ Thus a total of 1098 white men took part in the study of respiratory health.

The subjects enrolled in 1961 and 1967 were invited to be tested again every six years, with the most recent field survey having been conducted in 1985. Those first enrolled from the paper company in 1963 were invited, along with the other subjects, to be retested in 1973, 1979, and 1985. At each field survey subjects were tested by means of an interviewer administered questionnaire and pulmonary function testing. Items on the questionnaire inquired about respiratory symptoms, smoking habits, and occupation. The occupational history sections of the questionnaires provided spaces for the interviewer to record the dates of employment, industry, actual job, and materials to which the subject was exposed.

Lifetime work histories were abstracted and coded for each subject and covered the years 1900–85. Each job within the Berlin paper company was assigned to one of the following categories: pulp mill operations (in particular, sulphite mill, sulphate mill, chlorine production and use), paper mill operations, and other jobs within the paper company. The interpretation of job histories was done by two of the authors (PH and BF), without knowledge of the vital status or cause of death of the subjects. Current and former employees from the paper company in Berlin who were familiar with the different operations of the plant helped.

The occupational histories from the survey questionnaires were used to determine whether a candidate for the study met the second criterion of having worked at least one year in the paper company in Berlin. Review of the work histories determined that 621 of the 827 men who were first examined in 1961 or 1967 had worked in the paper company in Berlin for at least one year. With the additional 271 subjects who were enrolled directly from the paper company in 1963, 892 subjects met this second criterion.

Work histories were also used to evaluate potential subjects for the third criterion—that is, whether the person had worked less than five years in a pulp or paper mill outside the paper company in Berlin, New Hampshire. Of the 892 men who had met the first two criteria, nine failed to meet this third criterion. Thus the final study cohort comprised 883 white male subjects.

Exposure categories

The work histories were used again to determine where in the paper company each subject had worked and how many years he had worked in each location. Subjects were assigned to three occupational exposure groups within the paper company.

(1) Pulp mill work: at least one year of work in the pulp mill.

(2) Paper mill work: at least one year of work in the paper mill.

(3) Other paper company work: no work in either the pulp or paper mill, and at least one year of work elsewhere in the paper company.

It was possible that a subject could be included in both the pulp and paper exposure groups, but the subjects in the other paper company work category were distinct from the pulp and paper mill workers. Of the 883 subjects, 396 were in the pulp mill category, 376 in the paper mill category, and 267 in the other paper company work category. There were 156 subjects with work experience in both the pulp and paper mills who were included in both categories.

The subjects in the pulp mill category were further divided according to work experience in the three major areas of that operation: the sulphite mill, the sulphate mill, and chlorine production and use. More subjects had worked in the sulphite mill than the sulphate mill. Of the 396 subjects with some experience in the pulp operation, 259 had worked in the sulphite but not the sulphate mill, 38 in both mills, 45 in the sulphate but not the sulphite mill, and 54 exclusively in the chlorine operation. Another 50 subjects with experience in the sulphite or sulphate mill also worked in the chlorine operation. The 297 subjects with sulphite mill experience were analysed separately. Because limited numbers of men had worked in the sulphate process and chlorine departments, these groups were not analysed separately.

Vital status

Vital status was determined for each subject as of 1 August 1985. Each subject was classified in one of three categories: alive, dead, or lost to follow up. The research staff for the study of respiratory health maintained contact with subjects during the study by field surveys, postal inquiries, and telephone calls. With subjects who could not be contacted directly, inquiries were made to known or suspected relatives, friends, and neighbours. The effort to locate subjects and secondary sources was aided by using the local telephone book, the telephone company's directory assistance, and the Berlin city directory. In addition, information on subjects was requested from the Social Security Administration and the National Death Index.

With each report of a dead subject, a copy of the death certificate was requested from the appropriate state or provincial governmental agency. An independent certified nosologist was employed to code the death certificates. The nosologist coded the major underlying cause of death using the eighth revision of the International Classification of Diseases (ICD). Precautions were taken to avoid any biased interpretations of the death certificate data. In particular, the nosologist was never informed about the nature or intent of the study. Also, usual occupation and industry as indicated on the death certificates were visually blocked before sending the certificates to be coded.

If a death certificate was not located a subject was still considered dead, with cause unknown, if the notice of death had come from a reliable source and at least the year of death was known. With no date of death and no death certificate, a subject was classified as lost, regardless of the source of information.

Statistical analysis

A standardised mortality ratio (SMR) was computed for each of several causes of death using a computer program developed by Monson.²⁵ The program was run for all subjects and for each of the occupational exposure groups. The ratios are indirectly standardised rate ratios, using death rates from the United States vital statistics that were specific for sex and colour and available for each five year age and time period. Expected numbers of deaths were calculated by multiplying the age time specific death rates from the United States vital statistics by the corresponding age time specific person-years of follow up as observed among the study subjects. The age time specific expected numbers were then added to arrive at an expected number for all age and time periods. The SMRs were computed by dividing the observed number of deaths by the expected number and multiplying by 100. As part of the computer program, the Mantel-Haenszel χ^2 statistic was computed to test for statistical significance.²⁶ The Poisson approximation was used to calculate the variance of the expected number of deaths.

The date of entering follow up was either one year after the date of first employment or the date when first tested, whichever was later. The date of leaving follow up was 1 August 1985 for those still alive at that time, the date of death, or the date of last contact for those lost to follow up.

The SMRs control for age, sex, race, and calendar time. The effect of duration of employment and latency on the SMRs for selected causes of death were examined for the sulphite pulp mill workers and the paper mill workers. The term "latency" is used here to

Table 1 Standardised mortality ratios of selected causes of death for all 883 subjects

Cause of death (8th ICD)	Obs	Exp	SMR	95% CI
All causes (001-998)	414	426.3	97	88-107
All malignant neoplasms (140-209):	97	87.9	110	89-135
Buccal cavity & pharynx (140-149)	2	2.4	84	9-302
Digestive organs (150-159):	33	24.7	134	92-188
Stomach (151)	5	4.2	120	39-280
Large intestine (153)	9	8.7	103	47-196
Rectum (154)	1	2.6	38	0-212
Pancreas (157)	9	4.8	187	85-355
Larynx (161)	2	1.2	166	19-599
Lung (162)	25	28.0	89	58-132
Prostate (185)	9	8.8	102	47-194
Bladder (188)	4	3.2	124	33-318
Kidney (189)	3	2.0	149	30-435
Brain (191-192)	2	1.7	115	13-417
Lympho- & reticulosarcoma (200)	1	1.5	68	1-380
Hodgkin's disease (201)	0	0.5	0	—
Leukaemia & aleukaemia (204-207)	6	3.3	180	66-392
Other lymphatic (202, 203, 208)	3	2.3	130	26-380
Diabetes mellitus (250)	9	6.3	143	65-271
Circulatory system diseases (390-458):	220	240.5	91	80-104
Ischaemic heart disease (410-414)	145	162.3	89	75-105
Respiratory system diseases (460-519)	29	32.1	90	60-130
Digestive system diseases (520-577):	14	16.5	85	46-142
Liver cirrhosis (571)	8	7.2	112	48-220
All external causes (800-998)	18	19.6	92	54-145
Other causes	17	22.5	76	44-121
Cause unknown	10	0.7	—	—

mean the number of years from first employment to death.

Table 2 SMRs of selected causes of death for the 297 subjects who worked at least one year in the sulphite pulp mill at the paper company in Berlin, New Hampshire

Cause of death (8th ICD)	Obs	Exp	SMR	95% CI
All causes (001-998)	145	142.5	102	86-120
All malignant neoplasms (140-209):	36	30.0	120	84-166
Digestive organs (150-159):	12	8.4	144	74-251
Stomach (151)	1	1.4	72	1-399
Large intestine (153)	3	3.0	102	20-297
Pancreas (157)	5	1.6	305	98-712
Lung (162)	11	9.7	113	56-202
Prostate (185)	3	2.9	104	21-304
Kidney (189)	2	0.7	289	33-104
Leukaemia & aleukaemia (204-207)	1	1.1	90	1-499
Diabetes mellitus (250)	3	2.1	142	29-416
Circulatory system diseases (390-458)	73	80.0	91	72-115
Respiratory system diseases (460-519)	9	10.7	84	38-160
Other causes	23	19.6	117	74-176
Cause unknown	1	0.2	—	—

Results

Of the 883 white male subjects, 460 were still alive, 414 were dead, and nine were lost to follow up as of 1 August 1985. Death certificates were obtained for 404 and the remaining 10 were considered dead with cause unknown. For all subjects, the mean age at entry into follow up was 51, the mean number of years followed up was 17, and the mean age at death was 71. With each of these three measures the specific values for the different occupational groups differed by only a few years from the summary value for all subjects. Subjects with work experience in the pulp mill or the paper mill

Table 3 SMRs by duration of employment and latency for sulphite pulp mill workers

Duration of employment (y)	Latency					
	< 20 years			≥ 20 years		
	Obs	Exp	SMR	Obs	Exp	SMR
All causes:						
< 20	6	10.6	57	77	74.9	103
≥ 20	—	—	—	62	57.4	108
All cancers:						
< 20	2	2.3	86	16	15.9	100
≥ 20	—	—	—	18	11.8	153
Digestive cancer:						
< 20	1	0.6	169	7	4.4	158
≥ 20	—	—	—	4	3.4	119
Pancreatic cancer:						
< 20	0	0.1	0	4	0.9	459*
≥ 20	—	—	—	1	0.7	155
Lung cancer:						
< 20	0	0.8	0	4	5.2	76
≥ 20	—	—	—	7	3.8	186

*p < 0.05.

Table 4 *SMRs of selected causes of death for the 376 subjects who worked at least one year in the paper mill at the paper company in Berlin, New Hampshire*

<i>Cause of death (8th ICD)</i>	<i>Obs</i>	<i>Exp</i>	<i>SMR</i>	<i>95% CI</i>
All causes (001–998)	147	157.8	93	79–109
All malignant neoplasms (140–209):	32	33.6	95	65–135
Digestive organs (150–159):	14	9.2	152	83–256
Stomach (151)	3	1.5	198	40–579
Large intestine (153)	5	3.2	154	50–360
Pancreas (157)	2	1.8	110	12–396
Lung (162)	9	11.1	81	37–154
Prostate (185)	0	3.0	0	—
Kidney (189)	1	0.8	126	2–702
Leukaemia & aleukaemia (204–207)	3	1.2	241	48–705
Diabetes mellitus (250)	0	2.3	0	—
Circulatory system diseases (390–458)	89	86.9	102	82–126
Respiratory system diseases (460–519)	5	11.5	43	14–102
Other causes	16	23.3	69	39–112
Cause unknown	5	0.3	—	—

had spent a mean of 19 years in their respective part of the company.

The SMRs for selected causes of death for all subjects are presented in table 1. The SMRs for all causes (SMR = 97), all malignant neoplasms (SMR = 110), lung cancer (SMR = 89), circulatory system diseases (SMR = 91), and respiratory system diseases (SMR = 90) were close to unity. No deaths due to Hodgkin's disease were observed in this study. Excess mortality was evident for all digestive cancers (SMR = 134), pancreatic cancer (SMR = 187), kidney cancer (SMR = 149), and leukaemia and aleukaemia (SMR = 180). None of the raised SMRs was significantly greater than 100 based on statistical testing.

Among men with experience in the sulphite pulp mill, the SMRs for all causes (SMR = 102), lung cancer (SMR = 113), circulatory system diseases (SMR = 91), and respiratory system diseases (SMR = 84) were close to unity (table 2). Raised SMRs were observed for all malignant neoplasms (SMR = 120), cancer of all digestive organs (SMR = 144), pancreatic cancer (SMR = 305), and kidney cancer (SMR = 289). As with the analysis of all subjects, none of the SMRs was significantly greater than 100. The lower confidence limit for pancreatic cancer, however, was 98. When the analysis was repeated for all 396 subjects with any pulp mill experience, similar results were noted.

Table 3 shows the SMRs for selected causes of death by latency and duration of employment in the sulphite mill. For the categories all causes, all cancers, and lung cancer, the SMRs increased with increasing latency and duration. With all digestive cancers, the SMR decreased slightly with longer duration of employment. All deaths due to pancreatic cancer occurred after at least 20 years of latency and the mean latency was 51 years.

As seen in table 4, several SMRs for the paper mill workers were close to or less than 100: all causes (SMR = 93), all malignant neoplasms (SMR = 95), lung cancer (SMR = 81), circulatory system diseases (SMR = 102), and diseases of the respiratory system (SMR = 43). Raised SMRs were observed for all digestive cancers (SMR = 152), stomach cancer (SMR = 198), cancer of the large intestine (SMR = 154), and leukaemia and aleukaemia (SMR = 241). None of the raised values was statistically significant.

Table 5 shows the latency and duration of employment for selected causes of death among the

Table 5 *SMRs by duration of employment and latency for paper mill workers*

<i>Duration of employment (y)</i>	<i>Latency</i>					
	<i>< 20 years</i>			<i>≥ 20 years</i>		
	<i>Obs</i>	<i>Exp</i>	<i>SMR</i>	<i>Obs</i>	<i>Exp</i>	<i>SMR</i>
All causes:						
< 20	20	23.0	87	64	62.4	102
≥ 20	—	—	—	63	72.6	87
All cancers:						
< 20	6	5.0	120	13	12.9	101
≥ 20	—	—	—	13	15.7	83
Digestive cancer:						
< 20	3	1.3	236	5	3.6	138
≥ 20	—	—	—	6	4.3	139
Lung cancer:						
< 20	3	1.8	168	3	4.1	73
≥ 20	—	—	—	3	5.2	57
Leukaemia:						
< 20	0	0.2	0	2	0.5	414
≥ 20	—	—	—	1	0.6	175

Table 6 SMRs of selected causes of death for the 267 subjects who worked at least one year in the paper company in Berlin, New Hampshire, but never worked in the pulp or paper mill

Cause of death (8th ICD)	Obs	Exp	SMR	95% CI
All causes (001-998)	136	142.2	96	80-113
All malignant neoplasms (140-209):	29	28.0	104	69-149
Digestive organs (150-159):	10	8.1	124	59-228
Stomach (151)	2	1.4	143	16-517
Large intestine (153)	1	2.9	35	0-194
Pancreas (157)	2	1.5	130	15-470
Lung (162)	5	8.4	59	19-138
Prostate (185)	5	3.1	160	51-373
Kidney (189)	0	0.6	0	—
Leukaemia & aleukaemia (204-207)	2	1.1	182	20-658
Diabetes mellitus (250)	6	2.1	285	104-620
Circulatory system diseases (390-458)	65	82.1	79	61-101
Respiratory system diseases (460-519)	16	11.0	145	83-236
Other causes	16	18.7	86	49-139
Cause unknown	4	0.2	—	—

paper mill workers. With the categories of all causes, all cancers, cancers of the digestive system, and lung cancer, the SMRs remained about the same or even decreased with longer periods of employment and latency. Among the three paper mill workers who died from leukaemia, each had a latency of at least 20 years, and the mean was 41 years. One of the three cases had no particular type of leukaemia indicated on the death certificate. The other two cases had "acute" and "chronic myelogenous", respectively, indicated for type.

Among those subjects who worked in other parts of the paper company, the number of deaths observed for all causes (SMR = 96), all malignant neoplasms (SMR = 104), lung cancer (SMR = 59), and circulatory system diseases (SMR = 79) were close to or less than the number expected (table 6). Raised SMRs were observed for several malignant neoplasms, including all digestive cancers (SMR = 124), stomach cancer (SMR = 143), pancreatic cancer (SMR = 130), prostate cancer (SMR = 160), and leukaemia and aleukaemia (SMR = 182). Excess mortality was evident for diabetes mellitus (SMR = 285, 95% CI 104-620) and diseases of the respiratory system (SMR = 145).

Discussion

With an SMR of 97 for all causes for all subjects, no "healthy worker effect" was evident. This was probably due to the long period of follow up and the fact that follow up was independent of employment status. Several of the excesses in cause specific mortality noted in other studies were also observed in

the current study. Raised SMRs were observed for diseases of the digestive system among both pulp and paper mill workers and for leukaemia among paper mill workers. Also lung cancer mortality had a positive association with latency and duration of employment among sulphite pulp mill workers. By contrast, the SMRs for circulatory system diseases were not raised among production workers and no cases of Hodgkin's disease were seen.

The absence of Hodgkin's disease may be due to the relatively small amount of experience that the study cohort had with a particular pulping process. In their study of unionised paper workers in the United States and Canada Milham and Demers observed an excess in Hodgkin's disease associated with the sulphate rather than the sulphite process.¹¹ In the present study relatively few subjects worked in the sulphate mill.

A review of other analytical studies shows mixed results on the association of pancreatic cancer with work in the sulphite pulp mill. Milham and Demers found excesses of pancreatic cancer associated with both the sulphite pulp workers and paper mill workers but not with workers with the sulphate process.¹¹ In another study conducted in the United States Robinson and colleagues observed fewer deaths than expected from pancreatic cancer for both sulphite and sulphate process workers.¹³

Excesses in lymphatic and haematopoietic cancers have been observed in several studies of pulp and paper workers.^{3-6 10-15} In the present study the excess in deaths due to leukaemia and aleukaemia was most apparent among the paper mill employees. As noted above, the paper mill environment may be contaminated with additives and fillers not present in the pulp mill environment. Those additives may have a causative role in the excess cancers observed among the paper mill workers but not the pulp mill workers.

Examination of duration of employment and latency showed a positive association with lung cancer for the sulphite pulp mill workers but not for the subjects with paper mill experience. The potential confounding effect of cigarette smoking was not formally examined in the present analysis. In a study conducted in Finland Jappinen and Tola observed that smoking habits could not account for the excess number of lung cancers that they observed among pulp and paper workers.⁸ By contrast with the current findings, however, they found that paper mill workers rather than pulp mill workers were at a higher risk for lung cancer.

The reason for the raised SMR for diabetes among the subjects with no experience in the pulp and paper mills is not clear. A review of the work histories for those men did not suggest any further explanation.

Two prior studies of mortality among pulp and paper workers included subjects who were part of the

current analysis. As noted above, 271 subjects were enrolled into the study of respiratory health from the paper company in 1963. This cohort was re-examined in 1973, at which time death rates were calculated.²⁷ Ten years had elapsed since that cohort's first testing and only 33 had died. The present analysis, with more subjects and a longer follow up period, allows for the examination of cause and exposure specific mortality that was severely hampered by the few deaths available for the earlier analysis.

In a study by Schwartz death certificates for men who had died in New Hampshire between 1975 and 1985 were reviewed and usual occupation and industry were checked.¹⁴ There were 1071 certificates that indicated that the usual place of employment was a pulp, paper, or paperboard mill. Of the 414 deaths from the present study, 140 (or 34%) of the men died in New Hampshire during 1975-85 and had a reference to work in a paper company on their death certificates. Given the overlap of subjects between the two studies, it is understandable that the findings from the present study and from the study by Schwartz showed some similar excesses in cause specific mortality. For example, Schwartz observed proportionate mortality ratios (PMRs) for all causes and for all malignant neoplasms that were close to unity. Also similar to the present study, Schwartz found raised PMRs for cancers of the digestive organs (PMR = 129), the stomach (PMR = 168), the pancreas (PMR = 126), and for leukaemia (PMR = 160). The study of New Hampshire death certificates also showed excess cancers of the rectum (PMR = 194), colon (PMR = 128), buccal cavity (PMR = 175), and the larynx (PMR = 209), which were not observed in the present study.

With respect to future research, additional studies of paper company cohorts could help to refine the understanding of the risks associated with different processes in the paper industry. Ideally, future efforts would be able to identify the chemical exposures in the paper industry responsible for the raised mortality rates. This goal, however, will be difficult to attain given the complex and changeable chemical environment present in pulp and paper production facilities.

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