Final Report

Respiratory Disease among Sawmill Workers

(R03 OH03778-01)

Submitted to: U.S. National Institute for Occupational Safety and Health

Principle Investigator: Paul A. Demers, Ph.D.[1,2]

Co-Investigators: Hugh Davies, M.Sc.[1]
Lisa Ronald, B.Sc.[2]
Robert Hirtle, M.Sc.[1]
Kay Teschke, Ph.D.[1,2]

1. School of Occupational and Environmental Hygiene
University of British Columbia
2206 E. Mall, 3rd floor
Vancouver, B.C. V6T 1Z3
CANADA

2. Department of Health Care and Epidemiology
University of British Columbia
5804 Fairview Avenue
Vancouver, B.C. V6T 1Z3
CANADA

December, 2000

Table of Contents

List of Abbreviations

BC, British Columbia

BCLHDB, BC Linked Health Database

CI, Confidence Interval

COPD, Chronic Obstructive Pulmonary Disease

DDAC, didecyldimethyl ammonium chloride

FEV_1, Forced Expiratory Volume over 1 second

ICD9, International Classification of Disease, 9^{th} Revision

IPBC, 3-iodo-2-propynyl butyl carbamate

LTAS, Life Table Analysis System

RR, Rate Ratio

SMR, Standardized Mortality Ratio

TCMTB, 2-(thiocyanomethylthio) benzthiazole

WCB, Workers' Compensation Board of British Columbia

List of Tables

Significant Findings

This study did not find any evidence for an association between the risk of respiratory disease, based on either hospitalization and mortality, and exposure to the fungicides DDAC (didecyldimethyl ammonium chloride), IPBC (3-iodo-2-propynyl butyl carbamate), TCMTB (2-[thiocyanomethylthio] benzthiazole) and borates in sawmills. This could be due to a true lack of effect, low levels of exposure, or limitations in the study's design.

However, compared to the general population of BC, workers from all types of sawmills in this study were at an increased risk of respiratory disease. An elevated risk of hospitalization for overall respiratory disease and COPD was observed for all types of sawmills that could not be explained by differences in smoking rates. An increased risk of asthma was also observed for all but the cedar mills. The lack of an excess among cedar workers could be explained by good management of asthma cases, but the cause for the excess among other types of sawmill workers warrants further investigations. Sawmill workers are also exposed to wood dust and bioaerosols, both of which have been associated with respiratory disease.

Usefulness of Findings

This study demonstrated the utility of hospital discharge data for studying the health effects of exposures in workplace-based cohort studies. The primary advantage relative to mortality data, which is traditionally used in cohort studies, was greatly increased power. In this study there were 41 cases available for the mortality analysis versus 1,136 cases based on counting only the first hospital visit for respiratory disease. In addition, because cases are identified earlier in the disease process, the ability to assess the impact of newly introduced chemicals or other workplace changes is greatly enhanced.

Abstract

This study examined the association between respiratory disease and exposure to fungicides used to combat sap-staining moulds on softwood lumber products. A retrospective cohort study was conducted of 11,745 British Columbia sawmill workers employed in 14 mills between 1979 and 1994. Non-fatal respiratory disease was identified using provincial hospital discharge records using the British Columbia Linked Health Database. Exposure to fungicide was estimated as none, low and high by industrial hygienists based on observations made at the mills and interviews with senior employees. Cumulative exposure for each participant was calculated by summing the products of exposure level and duration of employment at each job held. Standardized mortality ratio analyses were conducted for fatal respiratory disease. Respiratory hospitalization rates among exposed workers were compared to unexposed workers and rates among sawmill workers were compared to the general population using Poisson regression.

Nine mills used fungicides during the study period. Of the non-using mills, two processed only Western red cedar and three were located in the interior of the province. Four fungicides were commonly used in the participating mills: DDAC (didecyldimethyl ammonium chloride), IPBC (3-iodo-2-propynyl butyl carbamate), TCMTB (2-[thiocyanomethylthio] benzthiazole) and borates. Relatively few workers had been exposed to the four fungicides: 553 to TCMTB, 322 to borates, 359 to IPBC, and 478 to DDAC. Record linkage to the Canadian Mortality Database identified 720 deaths between 1950 and 1995. There were 41 deaths due to respiratory disease and no evidence of an association with fungicide exposure was observed. Overall, 1,136 persons were hospitalized with a diagnosis of respiratory disease between April, 1985 and July, 1997, including 261 for chronic obstructive pulmonary disease (COPD) and 105 for asthma. The hospitalization rates for overall respiratory disease, COPD, and asthma in the fungicide-using mills were similar to those for the cedar mills and significantly less than those for the interior mills, which did not use fungicides. The risk of COPD was elevated among workers who had been employed for 10 or more years in all three types of mills but did not appear to increase with further duration of employment. Overall respiratory disease, COPD, and asthma did not appear to be associated with exposure to any of the fungicides, but very few COPD and asthma cases were observed among exposed workers.

After adjustment for sex, age group, and region of the province, workers from all three types of sawmills had somewhat increased rates of hospitalization for respiratory disease compared to the general BC population. The rate ratios (RRs) were 1.4 for fungicide-using, 1.3 for cedar, and 1.5 for interior sawmills. Hospitalization rates for COPD were also elevated for all three types of sawmills with rate ratios of 1.3, 1.5, and 1.8, respectively. Asthma rates were elevated for fungicide-using (RR=2.2) and interior mills (RR=2.7), but no excess was observed for cedar mills (RR=0.8).

In summary, this study did not find any evidence for an association between respiratory disease and DDAC, IPBC, TCMTB, and borates. This could be due to a true lack of effect, low levels of exposure, or limitations in the study's design. An elevated risk of hospitalization for overall respiratory disease and COPD was observed for all types of sawmills that could not be explained by differences in smoking rates. An increased risk of asthma was also observed for all but the cedar mills. The lack of an excess among cedar workers could be explained by good management of asthma cases, but the cause for the excess among other types of sawmill workers warrants further investigations.

Background

Respiratory Disease among Sawmill Workers

Employment in sawmills has been associated with an increased risk for a variety of respiratory diseases, including bronchitis, asthma, extrinsic allergic alveolitis, and chronic airflow obstruction [Chan-Yeung and Malo, 1995; Demers et al., 1997a; Enarson and Chan-Yeung, 1990; Goldsmith and Shy, 1988]. Asthma has generally been associated with dust from specific tree species, such as Western red cedar. The association between exposure to dust from Western red cedar (*Thuja plicata*) and the development of specific occupational asthma is well recognised and attributable to plicatic acid, a naturally occurring chemical in the wood [Chan-Yeung, 1993]. Vedal et al [1986] found the prevalence of occupational asthma to be 6% and 5% among low and medium exposed workers and 15% among the highest exposed workers based on symptoms and history. Brooks et al [1981] found occupational asthma among 24% of sawyers, 10.5% of packers, and 5% of splitters based on cross-shift changes in lung function. In a study in which occupational asthma was diagnosed based on a positive specific laboratory challenge to plicatic acid, the prevalence rate was 1.7% among Western red cedar workers at a low exposure mill [Chan-Yeung and Desjardins, 1992]. Cases of occupational asthma among wood workers in which the responsible agent is not known have also been identified. For example, Malo and colleagues [1986] reported a series of 11 cases of work-related asthma among sawmill workers in Quebec and Northern Maine exposed to dusts from black spruce (*Picea mariana*), balsam fir (*Abies balsamea*), and jack pine (*Pinus contorta*), but not to cedar. However, it was not clear which tree species or other exposure may have been responsible.

An increased prevalence of respiratory symptoms and decreased pulmonary function compatible with chronic obstructive pulmonary disease has been observed in cross-sectional studies of softwood sawmill workers who have only been exposed to non-allergenic tree species, as well as workers exposed to Western red cedar. An increase prevalence of dyspnea, cough, wheeze, and bronchitis has been observed [Brooks et al, 1981, Halpin et al, 1994, Hessel et al, 1995]. Decreased lung function has also been observed in several studies [Chan-Yeung et al, 1980; Hessel et al, 1995; Noertjojo et al, 1996]. However, the few industry-based cohort studies of sawmill and related workers have observed a decreased risk of fatal respiratory disease compared to the general population [Demers et al, 1995; Hertzman et al, 1997; Jappinen, 1989; Robinson et al, 1986]. Some evidence of an increased risk of overall respiratory disease, COPD, and asthma was observed among workers in wood related industries in a recent study using data from the American Cancer Society's CPS-II cohort [Demers et al, 1998].

Sawmill workers are exposed to a variety of respiratory hazards, including dusts from different tree species that may vary substantially in their chemical composition, and bioaerosols [Demers et al, 2000]. While an increased risk of asthma has been often associated with dust from specific tree species and extrinsic allergic alveolitis has been associated with exposure to moulds and bacteria, most respiratory health effects have usually been attributed to wood dust exposure or employment in the industry in general. One potential hazard in sawmills that has not been studied in relation to non-malignant respiratory effects is exposure to fungicides.

Fungicides in Pacific Northwest Sawmills

Lumber manufactured in the Pacific Northwest region of North America is susceptible to overgrowth by a number of staining fungal species, which render the product less saleable, especially in export markets that require long product travel times. Fungicide application to control sapstain began early in the 20^{th} century with the use of borax and sodium carbonate. In the 1940's the lumber industry widely adopted the use of sodium salts of pentachlorophenol, then switched to tetra/pentachlorophenol mixtures in the 1960's. However in the 1970's and 1980's, concern about the safety of these products mounted as chemical analyses indicated that they were among the chlorinated phenolics subject to dioxin contamination during manufacture, and as epidemiologic studies suggested that they may cause certain cancers, in particular non-Hodgkin's lymphomas [Hertzman et al, 1997; Teschke et al, 1994a]. Chlorophenols are currently classified as suspected (group 2B) human carcinogens by the International Agency for Research on Cancer. Chlorophenols are also known to have irritant effects on both the respiratory tract (mucous membrane) and skin [Kelly et al, 1998].

In the late 1980s, the worldwide lumber market no longer welcomed products treated with chlorophenols, and sawmills quickly substituted several new anti-sapstain fungicides. Initially 2-(thiocyanomethylthio) benzthiazole (TCMTB), copper-8-quinolinolate, and borax formulations were used and, later, didecyldimethyl ammonium chloride (DDAC) and 3-iodo-2-propynyl butyl carbamate (IPBC) were used [Teschke et al., 1994a].

Although substitution of alternate chemicals is considered one of the best possible controls to mitigate dangers presented by hazardous chemicals, this control is meant to include assurances that the substitute agents do not present an equal or greater hazard. Exposure to borates has been found to be associated with respiratory tract and eye irritation. Garabrant et al. [1984] found an increased prevalence of productive cough, eye irritation, and sore throat among exposed workers. Acute irritant effects and decreased peak expiratory flow have also been observed [Hu et al, 1992; Wegman et al, 1994]. However, very little data is available regarding the health effects of the other substitutes. Bryld et al. [1997] found positive skin patch tests in 3 of 311 subjects tested with a 0.1% solution of IPBC. Teschke et al. [1992] found an increase in self-reported symptoms of dry skin around the eyes, blood-stained mucus from the nose, nose bleed, peeling skin, burning or itching skin, and skin redness or rash among lumber mill workers working in mills where TCMTB was used compared to those in mills using copper-8 quinolinolate.

A few studies have found respiratory effects of other chemicals in the same classes to which DDAC (quaternary ammonium compounds), TCMTB (thiazoles), and IPBC (carbamates) belong. Chataigner et al. [1991] reported 45 accidental poisonings (corrosive burns of the alimentary and respiratory tracts) among mentally disturbed patients who ingested a quarternary ammonium disinfectant in powdered form. Ten of these individuals died of inhalation pneumonitis. Preller et al. [1996] and Vogelzang et al. [1997, 1998, 1999] investigated respiratory disease among pig farmers in the Netherlands. Preller et al. [1996] found a 7-fold increase in atopic sensitization among farmers using quaternary ammonium disinfectants, and 4- to 8-fold increases in asthma symptoms among atopics with exposures to these disinfectants, but no increases among non-atopics. Vogelzang et al. [1997, 1998, 1999] have found increases in the prevalence of asthma symptoms and mild bronchial responsiveness, and a decrease in FEV1, among farmers using quaternary ammonium disinfectants. Moscato et al. [1997] reported a single case of asthma from exposure to the thiazole, 1,2-benzisothiazolin-3-one. Senthilselvan et al. [1992] found a 2-fold increase in the prevalence of self-reported asthma among farmers who reported use of carbamate pesticides. None of these studies measured exposure levels, and many could not specify the particular disinfectant or pesticide to which the subjects were exposed.

Specific Aims of the Study

The objectives of this study are:

- to determine whether hospitalizations for asthma, COPD, and other respiratory diseases are associated with exposure to specific fungicides within a cohort of sawmill workers,
- to compare the risks of hospitalization for asthma and COPD between sawmill workers using different fungicides and sawmill workers who are not exposed to fungicides,
- to estimate the risks of these diseases among the sawmill cohort compared to the risks among the general population of British Columbia,
- if there are excess risks, to estimate the number of cases attributable to fungicides and to compare this estimate to the number of accepted WCB claims arising from fungicide exposure, in order to determine whether there is under-reporting, and
- to examine the feasibility of using the British Columbia Linked Health Data Base as a means of identifying of occupational diseases and injuries for epidemiologic studies and surveillance.

Methods

Study Population

The BC Sawmill Workers Cohort consists of approximately 29,000 workers who were employed for one year or more in 14 sawmills between 1950 and 1997. It is the largest cohort of sawmill workers ever enumerated for epidemiologic study. The 14 mills participating in the study are all located in the Western Canadian province of British Columbia. Three mills are located in the interior of the province, and the remainder are located on Vancouver Island (n=6) and the coast of the BC mainland (n=5). The mills are all large commercial processors with annual production volumes between 27 and 383 million board feet (average, 160). Nine of the coastal mills process primarily Douglas Fir (*Psuedotsuga menziesii*), hemlock (*Tsuga heterophylla*), and sitka spruce (*Picea sitchensis)*. Two of the coastal mills process solely Western red cedar (*Thuja plicata*). The three interior mills process a mixture of Engelmann spruce (*Picea engelmannii),* white spruce (*Picea glauca),* lodgepole pine (*Pinus contorta*) and sub-alpine fir (*Abies lasiocarpa*). Most mills went through significant modernization in the early 1980's, resulting in considerable downsizing of their workforces to current levels. All the mills were fairly stable with respect to process layout and flow during the period when post-chlorophenol fungicides were being introduced. Periodic temporary shutdowns of some mills occurred, generally for economic reasons, and two coastal mills shut down completely in 1998.

In order to enumerate the cohort, personal identifying information (including surname and given names, birth date, and social insurance number if available) were abstracted from the personnel records at each mill. In addition, job history information (including start and end dates, job title, and department for every sawmill job; leave periods; termination date at the mill; and reason for termination) were also abstracted to aid in assessing exposure. Work histories were last updated in 1997. National follow-up for mortality (1950-1995) and cancer incidence (1969-1995) have been conducted using the Canadian Mortality Data Base and the Canadian Cancer Registry, both operated by Statistics Canada. Follow-up to minimise the number of person-years unaccounted for included use of pension records, BC motor vehicle license records, and union records. Workers of East Indian origin, predominantly ethnic Sikh's, were identified on the basis of name by a research assistant of the same ethnic origin.

The cohort was initially assembled to examine the association between cancer (in particular non-Hodgkin's lymphoma, Hodgkin's disease, soft tissue sarcoma, nasal cancer, and lung cancer) and exposure to the chlorophenol fungicides [Hertzman et al, 1997;Teschke et al, 1994a]. The cohort is currently being used to study a wide range of issues related to sawmill workers, including the health impact of psychosocial factors as well as exposure to traditional occupational hazards, such as noise and dust [Teschke et al, 1998].

The current study is limited to workers who were employed in the industry at any time between 1979 and 1994 and were also employed for at least one year. This inclusion criteria was chosen because the fungicides of interest came into usage in the mid-1980's and hospital discharge follow-up was only available for 1985 and later. The beginning date of 1979 was chosen to increase the number of workers in the study who had never been exposed to the new fungicides and facilitate internal analysis. In addition, a sub-cohort of 9,830 members of the sawmill cohort who were employed as of 1979 had already been linked to the BC Linked Health Database (see below) as part of a study to examine the effects of technological and economic change.

Respiratory Disease Morbidity

Non-fatal respiratory disease cases were identified using the BC Linked Health Data Base (BCLHDB). The BCLHDB was developed by the Centre for Health Services and Policy Research of the University of British Columbia. This data set includes records for the entire province regarding hospital discharges and deaths (700,000 per year), patient encounters billed to the Medical Services Plan (50,000,000 per year), drug prescriptions for the elderly (4,500,000 per year), long term care services (16,000 assessments per year), death certificates (20,000 per year), and birth certificates (40,000 per year). Recently, data on accepted workers' compensation claims for fatalities, pensions, and short-term disabilities (80,000 per year) were added to the data set. Almost all records within these data sets are linkable by common identifiers to a single master file. The BCLHDB currently has records for the period from April of 1985 through the end of 1998.

For the present analysis, the hospital discharge file was used to identify hospitalizations and emergency room visits for respiratory diseases between April 1, 1985 and July 31, 1997. The end date was chosen because it was the last date for which complete work history follow-up was available. Up to 16 diagnostic codes are available for each hospital discharge record. These include codes for principal, primary, and secondary diagnoses as well as complications. The principal diagnosis is the immediate reason for the hospital visit while primary diagnoses are the underlying causes or the other conditions which have a significant influence on patient's length of stay. Secondary diagnoses are other conditions that may contribute to a patient's length of stay while complications are conditions arising after admission. Hospital visits for which respiratory disease was the principal or primary diagnosis were used in the analysis. Three categories of respiratory disease were used for the cohort analyses: all respiratory disease (International Classification of Diseases, 9th Revision code = 460-519), chronic obstructive pulmonary disease (COPD, including bronchitis and emphysema, ICD9=490-492, 496), and asthma (ICD9=493).

External rates were created with data prepared by the BC Ministry of Health for the Population Utilization and Referral Rates for Easy Comparative Tables (PURRFECT) program (version 5.0, BC Ministry of Health, Victoria, BC, Canada). Data, stripped of all individual identifiers, was available for all hospital visits aggregated into 211 diagnostic categories based on principal diagnosis. The same three categories of respiratory disease were used for the external rates: all respiratory disease, chronic obstructive pulmonary disease, and asthma. The definition of COPD used by the BC Ministry of Health was slightly broader than used in the cohort analysis and included bronchiectasis (ICD9=494) and extrinsic allergic alveolitis (ICD9=495). To all direct comparison, cohort cases were defined in the same manner for the external analysis. General population data, stratified by 5-year age group, sex, and health region, was only available for a 5-year period from 1994 to 1998. Because reference population data was not available for the entire follow-up period, cohort data for 1990 through the end of follow-up was used for the external analysis. The province is divided into 20 health regions for which annual population estimates are available and health care utilization patterns do appear to vary by health region. Because the home address of cohort members was not known, each member was assigned to the health region in which their sawmill was located. Although this may result in some misclassification, it does allow for adjustment by health region, which may be a potential confounder in this analysis.

Use of Fungicides in Sawmills

Generally, liquid fungicides are delivered to the lumber mills as chemical concentrates, then formulated in "mixing rooms" by diluting to desired concentration and adding anti-foaming agents. The dilute mixture is then piped to "spray boxes" where high-pressure nozzles surround the lumber. The lumber can traverse the boxes aligned either end to end (a "linear" box) or side-by-side (a "cross-chain" box). Typically these boxes are enclosed and ventilated and include a recovery system to recycle over-spray and mists. In a smaller number of mills, lumber in large bundles may be "submerged" into pools (dip tanks) of fungicide.

Treatment of lumber occurs after sawing or planing and before lumber it is to be yard-stored, or to be packaged for shipping. A typical process flow through a lumber mill is shown in Appendix 1, indicating potential locations where fungicides may be applied. The actual location varies by mill, but it is usually located with the "back-end" processes of the sawmill (i.e. after debarking and initial sawing operations) or in the planer mill. In the sawmill, chemical applications are made only after the wood has been reduced to its final "dimensional" size – the smaller pieces (under approximately 4" X 4") being termed "lumber" and the larger pieces "timbers." Application of chemical can then occur at any of several points among the grading, trimming (to length), sorting, stacking, and stacking processes. Some treated lumber re-enters that sawmill for reprocessing (e.g. to be re-sawn to a smaller dimension). In planer mills, chemical application can occur at various points after the planing machine.

Following widespread major technology upgrades in the early 1980's the number of workers required to operate a typical BC lumber mill was reduced by 2- to 3-fold. A significant portion of this downsizing occurred in the back-end of mills where labor-intensive sorting areas were replaced by automated sorting machines. Today, a typical back-end crew (and therefore those working in closest proximity to fungicide application) comprises trim saw operators, lumber graders, automatic sorter "patrollers," stacker operators, and packaging machine operators. Other "downstream" jobs may include forklift operators, timber-deck operators and shipping personnel (e.g. tally persons). Maintenance jobs working with fungicide application equipment include the equipment operator (i.e. "chemical attendant"), although this is not a full-time position in many mills, plus millwrights, welders, electricians, pipe-fitters and cleaning personnel.

Little published airborne exposure measurement data exists for the modern (post-chlorophenol) anti-sapstain fungicides. Two studies of airborne exposure to TCMTB were conducted in BC lumber mills in 1988 [McDonald, 1989; Occupational Health Group, 1989]. Both measured several potentially exposed jobs in the sorting and packaging area, plus the chemical attendant. The ranges of exposure were approximately one order of magnitude (6.6 and 16-fold, respectively), and the chemical attendant was the most highly exposed.

Exposure Assessment

Nine of the 14 sawmills included in the study used fungicides during the follow-up period. The two mills that processed cedar alone did not use fungicides because Western red cedar is highly resistant to mould growth. The three interior mills did not use fungicides because the drier climatic conditions in the interior do not favor the growth of staining mould on lumber.

Because of the paucity of exposure monitoring data, an industrial hygiene team familiar with sawmill processes used observational and descriptive data to assign relative levels of inhalation exposure to each job in the exposed sawmills for each fungicide formulation used.

Detailed information on fungicide use in the period between their introduction on a commercial scale (mostly chlorophenol-based) and the mid 1980's was reviewed in an earlier study [Teschke et al 1994a]. In order to bring this information up to date, the following activities were performed:

- an industrial hygienist revisited all participating mills to observe plant layout, job locations etc.;
- current and former mill workers were interviewed with respect to mill's operational histories, with a focus on changes to fungicide practices in the period of interest;
- schematics were obtained showing equipment and worker locations;
- technical documentation and purchase records relating to fungicides were gathered where available; and
- additional data was also gathered from records of Environment Canada (the federal governmental agency responsible for monitoring and regulating environmental discharge of toxic chemicals) and from key informants such as chemical suppliers, design engineers and chemists.

The results of this data-gathering exercise were summarized. Key informants at each mill (selected for their employment-seniority and broad knowledge of mill operations) were then asked to review their mill's data, and to report corrections or updates to a member of the hygiene team during a phone interview. The following items were specifically queried:

- current fungicide application locations, agents, techniques;
- changes to fungicide systems since substitution for chlorophenols;
- job titles of the persons primarily responsible for: (a) fungicide system daily operations, (b) clean up of fungicide systems, (c) routine maintenance on or around fungicide-contaminated equipment, and (d) working with fungicide-contaminated waste;
- job titles "downstream" (in the production flow) of the fungicide application process ;
- volume of lumber: processed by the planer mill, that was treated with fungicide; processed by the planer mill, that was kiln dried; re-entering sawmill for re-processing after fungicide treatment; and
- route that previously-treated lumber took through the sawmill

Job titles abstracted from the mill's personnel records were re-classified into 82 standardized job titles. Exposure assessment for production jobs was based on the physical location of the job with respect to the point of fungicide application, and by task for maintenance jobs. The corrected summary data was used to identify the following jobs:

- production workers working in close proximity to fungicide application, or working with lumber expected to be wet with chemical;
- production workers downstream in the process flow from points of fungicide application; and

- non-production workers working on or around fungicide application equipment or contaminated waste.

Workers exposed to treated lumber that was re-entering the sawmill for "re-manufacturing" were considered unexposed, as the review showed that a very small fraction (≤ 10%) lumber was processed in this way. Several maintenance trades were identified in the survey as being potentially exposed during routine daily operations and cleaning. These included the chemical attendant, planer mechanic, pipefitters, and millwrights. Planer mechanics were judged not to have received significant exposure. While some trades (millwrights, welders, electricians) would be highly exposed on a periodic basis individually, they form a large and non-uniformly exposed group. It was decided to ignore their exposure to emphasize specificity over sensitivity in the exposure assignment. Production jobs that were not necessarily downstream or proximal to application points, but that routinely participated in at least two maintenance operations (e.g. daily operations and cleanup), were considered exposed.

All jobs were assigned to one of three fungicide exposure categories: (a) unexposed, (b) low-exposure and (c) high-exposure. The unexposed, low exposed and high exposed categories were assigned weights of 0, 1 and 10 respectively. The weight of 10 for high exposure jobs was selected to reflect their much greater potential for air borne exposure and to be consistent with the limited air sampling data available. The criteria for assignment were as follows:

- *High exposure:* Production jobs less than 50 feet from fungicide application equipment; or working with wet lumber immediately after its treatment; or non-production jobs involved with routine maintenance of fungicide equipment.
- *Low exposure*: All production jobs not already assigned "high exposure," who were downstream of fungicide application in the production flow
- *Not exposed*: All other jobs

For the analyses, indices of cumulative exposure were developed for each of the four fungicides suspected to have respiratory effects (TCMTB, borates, IPBC, and DDAC) by summing the product of the exposure weight and the duration of exposure for each exposed job. Because DDAC was present in three formulations at greatly differing concentrations, a fifth exposure index was developed which weighted the cumulative DDAC index to reflect formulation concentration.

Analyses

Standardized mortality ratio analysis was performed using the PC version of the Life Table Analysis System (LTAS) software developed by NIOSH. Reference rates for British Columbia were used with cause of death categories developed by the Canadian Laboratory Centre for Disease Control. Only persons eligible for inclusion in the morbidity analysis were used in the mortality analysis in order to allow direct comparison of the results. Follow-up for each cohort member began after they had achieved the one year necessary for entry into the cohort or April 1, 1985, which ever was later. Follow-up ended at death or December 31, 1995, whichever was earlier. People were assumed alive until end of follow-up because successful linkage to the BCLHDB was required for eligibility. All SMR's were adjusted for 5-year age and calendar period (1985-1989, 1990-1994, and 1995). Stratified analyses were performed by sex, ethnic group (East Indian versus other), type of mill (cedar, interior, and fungicide-using), and duration of employment. Analyses were also performed to examine mortality among the sub-populations exposed to each of the four fungicides

Respiratory disease hospitalization rates were examined using Poisson regression with workers from either the unexposed mills or the workers in the unexposed jobs in the same mills acting as the reference population. Cases were identified on the basis of either principal or primary diagnosis on hospital discharge or underlying cause of death on death certificate. Only the first occurrence was used for each individual and separate analyses were performed for all respiratory disease, COPD, and asthma. LTAS was used to convert the cohort data into the form necessary for the analysis and EGRET (Version 2.0.3, Cytel Corporation, Cambridge, MA) was used to perform the regression analyses. Entry into follow-up was the same as that used for the mortality analysis. Follow-up ended at the hospital admission date for the first occurrence of the outcome being studied, at death, or July 31, 1997, whichever was earlier. All analyses were adjusted by 5-year age and calendar periods (1985-1989, 1990-1994, and 1995-1997). Sex and ethnic group (East Indian versus other) were considered as potential confounders. Stratified analyses were performed by type of mill (cedar, interior, and fungicide using), and duration of employment. Analyses were also performed to examine respiratory hospitalization rates among the sub-populations exposed to each of the four fungicides. Where the numbers allowed, analyses by level of exposure were also performed. Where there were less than five cases in a stratum, categories were generally collapsed.

Poisson regression analyses were also performed to directly compare the cohort to the general population of BC. Cases were identified on the basis of primary diagnosis on hospital discharge and all occurrences were used. Because of this, follow-up was counted until death or July 31, 1997, whichever was earlier. Separate analyses were performed for all respiratory morbidity, COPD, and asthma. Cohort data from January 1, 1990 through July 31, 1997 was compared to BC data for 1994 through 1998. All analyses were adjusted for 5-year age group and sex. In addition, health region was considered as a potential confounder. Stratified analyses were performed by type of mill (cedar, interior, and fungicide-using). External analyses were primarily performed to provide a benchmark for the internal analyses and to explore the impact of regional difference.

Results

A total of 12,350 cohort members met the entrance criteria for the current analysis. Of these, 11,745 (95.1%) were successfully linked to the BCLHDB. Of the 596 workers who could not be linked, at least 242 (2.0%) had lived in the province during the follow-up period, based on work history or residence at time of death or diagnosis of cancer, and should have been linked. Nine workers had lived out-of-province while for the remaining 354 (2.9%) there was no data with which to assess residency.

Vital status ascertainment was 95.4% complete among the workers included in the analysis (Table 1). There were 1,088 males of East Indian origin (the vast majority with Sikh names) included in the analysis. The Sikh religious group is though to have lower smoking rates than the general population of BC. There were 140 women included in the analysis, of whom three had East Indian names. There were 7,351 workers employed by the nine fungicide-using mills, 2,403 employed by the two Western red cedar mills, and 1,991 employed by the three interior mills.

Exposure to Fungicides

The figure in Appendix 2 shows the pattern of fungicide usage, between 1984 and 2000, at the participating mills. The general pattern that emerges is a shift from chlorophenate-based products in a transition phase beginning in 1987 and lasting to 1992. During this period a number of new agents were used, the most common of which was TCMTB. After 1992 there was a general movement to DDAC and IPBC-based agents. The most common method (67%) of chemical application was by linear spray box. In half as many instances (33%), lumber was treated in cross-chain spray boxes. In two locations dip-tanks were in use but were not the sole method of application. In one case some hand spraying was reported. Six post-chlorophenate fungicide formulations were identified: Timbercote®, F2®, NP1®, Busan®, Ecobrite®, Nytek®, and PQ-8®. These seven formulations used five active ingredients: TCMTB, DDAC, IPBC, Borates, and copper-8-quinolinolate. Exposure to copper-8-quinolinolate was not assessed it was not widely used within the study mills and there was no evidence suggesting it was associated with respiratory effects

A relatively small percentage of workers were classified as being exposed to each fungicides (Table 1). TCMTB was used at six sawmills and 558 workers were considered exposed. Borate containing formulations (F2 and Ecobrite) were used at six sawmills and 322 workers were considered exposed. All nine mills had used NP1, the formulation containing IPBC, and 359 workers were considered exposed. All nine mills had used DDAC containing formulations (Timbercote, F2, and NP1) and 478 workers were considered exposed.

Respiratory Mortality

A breakdown of person years at risk by age and calendar period is provided in Table 2. There were 720 deaths due to all causes among members of the cohort between April 1, 1985 and December 31, 1995. Forty-one deaths were due to respiratory disease. A breakdown of respiratory deaths by age and calendar period is provided in Table 3. Standardized mortality ratios (SMRs) and observed and expected deaths by major category are listed in Table 4. Mortality for major causes of death are similar to expected. Relatively little evidence of a healthy worker effect was observed. Respiratory disease mortality was also similar to expected, as was COPD mortality. Asthma mortality was slightly higher than expected, but based on only three cases. No deaths were observed among the 140 women included in the analysis. Compared to the general BC population, East Indian males had slightly lower than expected mortality from all causes (SMR=0.94, 95% CI=0.69-1.27). No deaths due to respiratory disease occurred among East Indian males (versus 2.03 expected).

Mortality due to all respiratory disease, COPD, and asthma by type of mill is presented in Table 5. Overall respiratory disease mortality was less than expected for fungicide-using, cedar, and interior mills. COPD mortality was less than expected for fungicide-using and interior mills, and similar to expected for cedar mills. Two fatal asthma cases occurred among workers from fungicide-using mills and one among interior mill workers. A further breakdown by duration of employment and type of mill is provided in Table 6. No patterns consistent with a duration-response relationship were observed.

Because of small numbers, the results for workers exposed to specific fungicides were uninformative. Among the 553 workers exposed to TCMTB there were 12 deaths (SMR=0.86), however there were no deaths due to respiratory disease (versus 0.45 expected). Among the 322 workers exposed to borates there were six deaths (SMR=0.74), one of which was due to pneumonia (respiratory disease SMR=3.27, pneumonia SMR=9.44). Among the 359 workers exposed to IPBC there was 1 death (SMR=0.28) and no deaths due to respiratory disease (versus 0.10 expected). Among the 478 workers exposed to DDAC there were 2 deaths (SMR=0.36) and no deaths due to respiratory disease (versus 0.15 expected).

Table 1: Description of Study Population and Vital Status at 12/31/1995

Population	Total	Vital Status as of 12/31/95 Alive	Dead	Unknown	Person Years
Full Cohort	11,745	10,490	720	535	113,178
East Indian Males	1,088	1,021	44	23	10,721
Other Males	10,517	9,331	676	510	101,465
Females	140	138	0	2	992
Cedar Mills	2,403	2,156	153	94	23,278
Interior Mills	1,991	1,782	51	158	18,309
Fungicide Mills	7,351	6,552	516	283	51,592
TCMTB exposed	553	548	12	3	4,113
Borate exposed	322	312	6	4	2,168
IPBC exposed	359	357	1	1	1,218
DDAC exposed	478	474	2	2	1,813

Table 2: Person Years of Mortality Follow-up by Age and Calendar Period

AGES	1985-1989	1990-1994	1995	Total
15-24	2,176	1,158	152	3,486
25-29	8,225	3,587	410	12,223
30-34	7,810	9,544	1,234	18,589
35-39	6,216	8,675	2,109	17,000
40-44	5,072	6,958	1,546	13,576
45-49	4,179	5,625	1,334	11,138
50-54	3,621	4,545	1,052	9,217
55-59	3,567	3,824	807	8,198
60-64	3,166	3,595	722	7,483
65-69	2,747	3,005	635	6,387
70-74	1,343	2,429	511	4,283
75+	49	1,128	411	1,599
TOTAL	48,172	54,073	10,934	113,178

Table 3: Respiratory Disease Deaths by Age and Calendar Period

Age Group	1985-1989	1990-1994	1995	Total
50-54	0	0	1	1
55-59	1	3	0	4
60-64	1	3	0	4
65-69	3	6	1	10
70-74	2	8	2	12
75-79	0	3	5	8
80-84	0	1	1	2
TOTAL	7	24	10	41

Table 4: Sawmill Worker Mortality: April 1, 1985 to December 31, 1995

Cause of Death (ICD9)	Observed	Expected	Ratio (95% CI)*
All Deaths	720	747.32	0.96 (0.89-1.04)
Infective & Parasitic Diseases	7	22.84	0.31 (0.12-0.63)
All Cancers	232	228.69	1.01 (0.89-1.15)
All Buccal Cavity and Pharynx	7	6.12	1.14 (0.46-2.36)
All Digestive Cancers	65	63.56	1.02 (0.79-1.30)
All Respiratory Cancers	78	80.03	0.97 (0.77-1.22)
Female Genital	0	0.08	0.00 (0.0-44.72)
Male Genital	23	20.34	1.13 (0.72-1.70)
Urinary	17	11.37	1.50 (0.87-2.40)
Other Cancers	25	27.24	0.92 (0.59-1.35)
Lymphatic & Hematopoietic Neoplasms	17	19.95	0.85 (0.50-1.36)
Benign & Unspecified Neoplasms	1	1.42	0.70 (0.02-3.92)
Endocrine/Nutritional/Metabolic	23	16.54	1.39 (0.88-2.09)
Blood Diseases	3	1.79	1.68 (0.35-4.90)
Mental Disorders	12	11.19	1.07 (0.55-1.87)
Nervous System/Sense Organ Disease	9	12.92	0.70 (0.32-1.32)
Circulatory Disease	251	246.20	1.02 (0.90-1.15)
Respiratory Disease	41	47.13	0.87 (0.62-1.18)
Acute Respiratory Infection	0	0.20	0.00 (0.0-18.58)
Other Upper Respiratory Tract Diseases	0	0.07	0.00 (0.0-49.96)
Pneumonia	12	14.16	0.85 (0.44-1.48)
Influenza	0	0.36	0.00 (0.0-10.39)
Chronic Obstructive Pulmonary Disease	21	24.25	0.87 (0.54-1.32)
Asthma	3	2.07	1.45 (0.30-4.23)
Pneumoconioses	0	0.35	0.00 (0.0-10.41)
Other Respiratory System Diseases	5	5.67	0.88 (0.29-2.06)
Digestive Disease	33	30.37	1.09 (0.75-1.53)
Genitourinary Disease	3	6.11	0.49 (0.10-1.44)
Musculoskeletal Disease	1	1.49	0.67 (0.02-3.74)
Symptoms/Ill-Defined	22	21.36	1.03 (0.65-1.56)
Accidents/Poisoning/Violence	81	96.28	0.84 (0.67-1.05)
All Other Causes of Death (residual)	1	3.00	0.33 (0.01-1.85)

* Standardized mortality ratio relative to BC general population rates standardized for sex, 5-year age, and calendar period.

Table 5: Respiratory Mortality by Type of Sawmill

Cause of Death/Type of Mill	Observed	Expected	Ratio (95% CI)*
All Respiratory			
Fungicide Mills	30	31.87	0.94 (0.64-1.34)
Cedar Mills	9	11.79	0.76 (0.35-1.45)
Interior Mills	2	3.48	0.57 (0.07-2.08)
Chronic Obstructive Pulmonary Disease			
Fungicide Mills	13	16.42	0.79 (0.42-1.35)
Cedar Mills	7	6.20	1.13 (0.45-2.33)
Interior Mills	1	1.63	0.62 (0.02-3.42)
Asthma			
Fungicide Mills	2	1.38	1.45 (0.18-5.22)
Cedar Mills	0	0.50	0.00 (0.00-7.38)
Interior Mills	1	0.19	5.26 (0.13-29.19)

* SMR: standardized mortality ratio adjusted for age, sex, calendar period.

Table 6: Respiratory Mortality by Duration of Employment and Type of Sawmill

	1-9 Years SMR (O/E)*	10-19 Years SMR (O/E)	20-29 Years SMR (O/E)	30+ Years SMR (O/E)
All Respiratory				
Fungicide Mills	0.9 (3/3.4)	1.1 (6/5.7)	1.0 (8/8.4)	0.9 (13/14.4)
Cedar Mills	0.0 (0/1.1)	1.8 (3/1.7)	1.4 (4/3.0)	0.3 (2/6.0)
Interior Mills	0.0 (0/0.9)	1.5 (2/1.3)	0.0 (0/0.5)	0.0 (0/0.7)
All Mills	0.6 (3/5.4)	1.3 (11/8.7)	1.0 (12/11.9)	0.7 (15/21.1)
Chronic Obstructive Pulmonary Disease				
Fungicide Mills	0.7 (1/1.4)	0.4 (1/2.8)	0.9 (4/4.3)	0.8 (13/16.4)
Cedar Mills	0.0 (0/0.5)	3.5 (3/0.9)	2.6 (4/1.6)	0.0 (0/3.3)
Interior Mills	0.0 (0/0.3)	1.6 (1/0.6)	0.0 (0/0.3)	0.0 (0/0.4)
All Mills	0.5 (1/2.2)	1.2 (5/4.2)	1.3 (8/6.2)	0.6 (7/11.6)
Asthma				
Fungicide Mills	0.0 (0/0.2)	3.4 (1/0.3)	2.8 (1/0.4)	0.0 (0/0.5)
Cedar Mills	0.0 (0/0.1)	0.0 (0/0.1)	0.0 (0/0.1)	0.0 (0/0.2)
Interior Mills	0.0 (0/0.1)	13.4 (1/0.1)	0.0 (0/0.02)	0.0 (0/0.03)
All Mills	0.0 (0/0.3)	4.5 (2/0.4)	2.0 (1/0.5)	0.0 (0/0.8)

* SMR: standardized mortality ratio adjusted for age, sex, calendar period; O: observed deaths; E: expected deaths

Morbidity: Overall Respiratory Disease

A summary of hospital visits for respiratory disease among cohort members is presented in Table 7. Overall, 1,136 persons in the cohort were hospitalized with a principle or primary diagnosis of respiratory disease. Thirty-five of these died of respiratory disease during the mortality follow-up period. In addition, six cohort members died during the mortality follow-up period with an underlying cause of respiratory disease, but were not hospitalized with a diagnosis of respiratory disease. For the analyses both the hospital and death certificate-only cases were included for a total of 1142 cases. A breakdown of person years of follow-up by age and calendar period is presented in Table 8. A breakdown of respiratory disease cases by age and calendar period is presented in Table 9.

Workers compensation claims were associated with 22 hospital admissions made by 18 individuals. Respiratory disease was the principal diagnosis for 13 of the admissions (made by nine individuals) and four of these were for asthma (for two individuals). The nine remaining hospital admissions associated with workers compensation claims had non-respiratory principal diagnoses, although primary diagnoses for respiratory disease were made and were, therefore, considered to have contributed to their length of stay. Of these, one had a primary diagnosis of asthma and another of COPD.

Women appear to have a similar risk for hospitalization for respiratory disease as men (RR=0.9, 95% CI=0.4-1.9), although this result was based on only seven cases. East Indian males were at an increased risk of respiratory disease (RR=1.6, 95% CI=1.3-1.9) based on 133 cases. Because of this all subsequent results are adjusted for ethnic group. Respiratory hospitalization rates among workers from interior and cedar mills relative to workers from fungicide-using mills is presented in Table 10. Interior sawmill workers were at increased risk compared to workers in coastal mills using fungicides (RR=1.4, 95% CI= 1.2-1.6). Cedar mill workers had a similar risk of respiratory disease compared to all other sawmill workers (RR=1.1, 95% CI= 0.9-1.3). No clear pattern of respiratory disease risk by duration of employment was seen (Table 11).

Overall respiratory disease hospitalization by level of exposure to fungicides is presented in Table 12. There were 29 cases among workers exposed to TCMTB, 20 cases among workers exposed to formulations containing borates, 13 cases among workers exposed to IPBC, and 18 cases among workers exposed to formulations containing DDAC. No pattern of increasing risk by level of exposure was observed for any of the fungicides.

Morbidity: Chronic Obstructive Pulmonary Disease

During the follow-up period 261 persons in the cohort were hospitalized with a principal or primary diagnosis of COPD. Fifteen of these died of COPD during the mortality follow-up period and an additional two died of asthma. Six additional cohort members died during the mortality follow-up period with an underlying cause of COPD but were not hospitalized for COPD. For the analyses both the hospital and fatal only cases were used for a total of 267 cases. Only one case was observed among women (RR=1.1, 95% CI=0.2-8.0). A decreased risk was observed among East Indian males (RR=0.3, 95% CI=0.1-0.7), based on 5 cases. Risk in cedar mills was similar to the fungicide-exposed mills (RR=1.1, 95% CI=0.8-1.4) while workers from interior sawmills were at an increased risk (RR=1.8, 95% CI=1.3-2.6) (Table 10). Workers employed 10 years or more were at an increased risk of COPD regardless of type of sawmill (Table 11). However, workers employed for 10 to 19 years had the highest risk and no clear pattern of respiratory disease risk by duration of employment was seen.

COPD hospitalization among workers exposed to fungicides is presented in Table 13. There was 1 case observed among workers exposed to TCMTB, none among workers exposed to formulations containing borates, 1 among workers exposed to IPBC, and 1 among workers exposed to formulations containing DDAC. No evidence for an increased risk was observed and analysis by level of exposure was not possible.

Morbidity: Asthma

There were 105 persons in the cohort hospitalized with a principal or primary diagnosis of asthma. Two of these died of asthma during the mortality follow-up period and an additional four died of COPD. One additional cohort member died during the mortality follow-up period with an underlying cause of asthma but was not hospitalized for asthma. For the analyses both the hospital and fatal only cases were used for a total of 106 cases. Only one case was observed among women (RR=1.4, 95% CI=0.2-10.1). A increased risk was observed among East Indian males (RR=3.7, 95% CI=2.4-5.9), based on 26 cases. Workers from cedar mills were similar to the fungicide-exposed mills 1.0 (0.6-1.7) while workers from interior sawmills were at an increased risk (RR=2.2, 95% CI=1.3-3.6) (Table 10). Workers employed 10 years or more in interior mills were at an increased risk of asthma (Table 11). There was no clear pattern of respiratory disease risk by duration of employment among workers from other types of sawmills.

Asthma hospitalization among workers exposed to fungicides is presented in Table 13. There were three cases observed among workers exposed to TCMTB, one among workers exposed to formulations containing borates, two among workers exposed to IPBC, and two among workers exposed to formulations containing DDAC. An increased risk was observed among workers exposed to IPBC, but no other evidence for an increased risk was observed for other fungicides and analysis by level of exposure was not possible.

Table 7: Respiratory Disease-related Hospital Admissions: 4/1/85 to 7/31/97*

Respiratory Disease Category (ICD9 codes)	All Admissions	First Admissions
All respiratory disease (460-519)	1,879	1,136
Chronic Obstructive Pulmonary Disease (COPD, as used for analysis)	559	261
Chronic Bronchitis (490-91)	124	94
Emphysema (492)	73	41
Chronic Obstructive Pulmonary Disease (496)	362	174
Asthma (493)	211	105
Extrinsic allergic alveolitis (495)	3	2
Coal workers pneumoconiosis (500)	1	1
Asbestosis (501)	1	1
Silicosis (502)	1	1
Pneumoconiosis due to other inorganic dusts (503)	0	0
Pneumopathy due to other inorganic dusts (504)	0	0
Pneumoconiosis, unspecified (505)	0	0
Respiratory conditions due to chemical fumes and vapors (506)	1	1
Pneumonitis due to solids and liquids (507)	35	29
Respiratory conditions due to other and unspecified external agents (508)	0	0
Other alveolar and parietoalveolar pneumonopathy (516)	13	8

* Hospital admissions identified on the basis of principal or primary discharge diagnosis.

Table 8: Person Years of Morbidity Follow-up by Age and Calendar Period

Age Group	1985-1989	1990-1994	1995-1997	Total
15-24	2,176	1,158	359	3,693
25-29	8,225	3,587	971	12,783
30-34	7,810	9,544	2,651	20,005
35-39	6,216	8,675	5,468	20,359
40-44	5,072	6,958	4,217	16,247
45-49	4,179	5,625	3,560	13,364
50-54	3,621	4,545	2,789	10,955
55-59	3,567	3,824	2,166	9,557
60-64	3,166	3,595	1,861	8,621
65-69	2,747	3,005	1,692	7,444
70-74	1,343	2,429	1,334	5,105
75+	49	1,128	1,209	2,387
TOTAL	48,167	54,069	28,275	130,520

Table 9: Respiratory Morbidity Cases* by Age and Calendar Period

Age Group	1985-1989	1990-1994	1995-1997	Total
15-24	18	11	0	29
25-29	40	17	10	67
30-34	65	52	15	132
35-39	39	47	22	108
40-44	32	40	18	90
45-49	34	34	21	89
50-54	37	28	12	77
55-59	44	38	15	97
60-64	47	50	18	115
65-69	57	57	25	139
70-74	31	67	24	122
75+	1	34	42	77
TOTAL	441	471	220	1,142

* Morbidity cases include all 1,136 first admissions for respiratory disease and six additional cases identified on the basis of death certificate alone.

Table 10: Respiratory Morbidity in Interior and Cedar Mill relative to Fungicide-Using Mills

	Fungicide* RR, cases	Cedar RR# (95% CI), cases	Interior RR (95% CI), cases
All Respiratory	1.0, n = 698	1.1 (0.9-1.3), n = 258	1.4 (1.2-1.6), n = 186
COPD	1.0, n = 163	1.1 (0.8-1.4), n = 64	1.8 (1.3-2.6), n = 40
Asthma	1.0, n = 61	1.0 (0.6-1.7), n = 22	2.2 (1.3-3.6), n = 23

* Fungicide-using mills used as reference category.

Rate Ratios from Poisson regression models adjusted for age group, calendar period, and ethnic group.

Table 11: Respiratory Morbidity by Duration of Employment and Type of Sawmill

	1-9 Years RR, cases*	10-19 Years RR# (95% CI), cases	20-29 Years RR (95% CI), cases	30+ Years RR (95% CI), cases
All Respiratory				
Fungicide Mills	1.0, n=194	1.2 (0.9-1.5), n=188	1.0 (0.8-1.3), n=144	1.0 (0.8-1.4), n=172
Cedar Mills	1.0, n=91	1.1 (0.7-1.6), n=48	0.9 (0.6-1.5), n=57	0.7 (0.4-1.0), n=62
Interior Mills	1.0, n=99	1.2 (0.8-1.7), n=70	0.9 (0.5-1.9), n=11	0.6 (0.3-1.6), n=6
All Mills	1.0, n=384	1.1 (1.0-1.4), n=306	1.0 (0.8-1.2), n=212	0.9 (0.7-1.1), n=240
COPD				
Fungicide Mills	1.0, n=14	2.1 (1.1-3.9), n=40	1.4 (0.7-2.7), n=38	1.8 (1.0-3.3), n=71
Cedar Mills	1.0, n=5	2.9 (0.9-8.6), n=13	1.9 (0.7-5.6), n=46	
Interior Mills	1.0, n=10	2.6 (1.2-5.9), n=21	1.7 (0.6-4.7), n=9	
All Mills	1.0, n=29	2.3 (1.4-3.5), n=74	1.6 (1.0-2.6), n=64	1.5 (1.0-2.4), n=100
Asthma				
Fungicide Mills	1.0, n=16	0.8 (0.8-1.6), n=14	1.0 (0.4-2.0), n=17	0.8 (0.3-1.9), n=14
Cedar Mills	1.0, n=7	0.6 (0.2-2.4), n=4	0.7 (0.2-2.2), n=11	
Interior Mills	1.0, n=10	1.5 (0.6-3.8), n=9	1.7 (0.4-7.1), n=4	
All Mills	1.0, n=33	0.9 (0.5-1.5), n=27	1.1 (0.7-2.0), n=31	0.5 (0.2-1.0), n=15

* One to nine years of employment used as the reference category.

Rate Ratios from Poisson regression models adjusted for age group, calendar period, and ethnic group.

Table 12: Overall Respiratory Disease Morbidity by Level of Exposure

	Unexposed* RR, cases	Low Exposure RR# (95% CI), cases	High Exposure** RR (95% CI), cases
TCMTB	1.0, n = 669	0.9 (0.6-1.6), n = 14	0.9 (0.5-1.5), n = 15
Borates	1.0, n = 678	1.0 (0.5-1.9), n = 9	1.1 (0.6-2.1), n = 11
IPBC	1.0, n = 685	1.3 (0.6-2.8), n = 7	1.3 (0.6-2.8), n = 6
DDAC	1.0, n = 680	1.3 (0.6-2.6), n = 8	1.1 (0.6-2.1), n = 10
DDAC (weighted)	1.0, n = 680	1.2 (0.7-2.2), n = 11	1.1 (0.5-2.4), n = 7

* Reference category

** A series of cut points were selected *a priori* and the point which came closest to equally dividing the cases was chosen. For TCMTB and IPBC this was 3600 units while for borates and DDAC this was 1800 units.

Rate Ratios from Poisson regression models adjusted for age group, calendar period, and ethnic group.

Table 13: COPD and Asthma Morbidity among Fungicide Exposed Workers

	COPD RR* (95% CI), cases	Asthma RR* (95% CI), cases
TCMTB	0.3 (0.01-1.9), n = 1	0.9 (0.3-2.9), n = 3
Borates	0.0, n = 0	0.4 (0.05-2.7), n = 1
IPBC	1.1 (0.2-8.1), n = 1	2.0 (0.5-8.6), n = 2
DDAC	0.7 (0.1-5.4), n = 1	1.2 (0.3-5.0), n = 2

* Unexposed workers from fungicide-using mills used as reference category. Rate Ratio from Poisson regression model adjusted for age group, calendar period, and ethnic group.

Respiratory Morbidity Compared to the General Population

Respiratory hospitalization among sawmill workers relative to the general BC population is presented in Table 14. Unlike the internal cohort analyses, cases in this analysis are restricted to those who had hospital visits where respiratory disease, COPD, or asthma was the principal diagnosis. In addition, all visits meeting this criteria were used, rather than the first alone. The analysis was restricted to the period from 1/1/1990 to 7/31/97. Of the 1,879 cases described in Table 7, 1,355 had a principal diagnosis of respiratory disease of any kind and, of these, 897 occurred in 1990 or later. Analyses are presented by type of mill after adjustment for sex and age group. An additional analysis with further adjustment for health region is also presented. The 14 sawmills were located in seven different health regions. Adjustment for health region did alter some of the rate ratios and primary emphasis is placed on the health region-adjusted results.

No rates for racial and ethnic sub-populations are available for British Columbia. When East Indian sawmill workers were compared to the general population the rate ratios were 1.88 (95% CI=1.53-2.30) for all respiratory disease, 0.15 (95% CI=0.02-1.09) for COPD, and 6.66 (95% CI=4.45-9.96) for asthma based on 94, 1, and 24 cases, respectively. For other male sawmill workers the rate ratios were 1.32 (95% CI=1.23-1.42) for all respiratory disease, 1.49 (95% CI=1.27-1.75) for COPD, and 1.57 (95% CI=1.22-2.03) for asthma. Women sawmill workers had slightly higher risk for respiratory disease overall (1.22, 95% CI=0.58-1.56) compared to all women in the province, based on seven cases. Higher risks were observed for COPD (RR=1.74, 95% CI=0.24-12.34) and asthma (RR=5.32, 95% CI=1.99-14.20), based on one and four cases, respectively.

The sawmill workers as a whole had a somewhat higher risk of hospitalization for respiratory disease overall and COPD than the general population. For asthma, a two-fold risk increase in was observed. Adjustment for health region had the effect of slightly reducing the magnitude of the excess risks. Workers from the fungicide-using mills had results that were quite similar to the full sawmill cohort. Cedar mill workers had a slightly lower risk of respiratory disease overall and a slightly higher risk of COPD than workers from the fungicide-using mills. In contrast, no excess of asthma was observed. Workers from the three interior mills had a similar risk of respiratory disease overall, but a somewhat higher risk of both COPD and asthma than the workers from the fungicide-using mills.

If the relative risks compared to the general population are valid, the attributable risks for the full cohort would be 26% for overall respiratory disease admissions, 29% for COPD admissions, and 50% for asthma admissions. This would correspond to 237 respiratory admissions, of which 47 would be for COPD and 42 would be for asthma.

Table 14: Respiratory Morbidity among Sawmill Workers by Type of Mill Relative to the General BC Population: 1/1/1990 to 7/31/1997

	Cases	Age and Sex Adjusted RR (95% CI)	Age, Sex, Region Adjusted RR (95% CI)
All Respiratory			
Fungicide Mills	565	1.38 (1.27-1.50)	1.36 (1.25-1.48)
Cedar Mills	174	1.23 (1.06-1.43)	1.29 (1.11-1.50)
Interior Mills	158	1.86 (1.59-2.17)	1.45 (1.23-1.69)
All Mills	897	1.41 (1.32-1.51)	1.36 (1.28-1.46)
COPD			
Fungicide Mills	98	1.32 (1.08-1.61)	1.32 (1.08-1.62)
Cedar Mills	36	1.31 (0.94-1.82)	1.45 (1.05-2.02)
Interior Mills	26	2.59 (1.76-3.81)	1.82 (1.24-2.69)
All Mills	160	1.43 (1.23-1.68)	1.41 (1.21-1.66)
Asthma			
Fungicide Mills	59	2.35 (1.82-3.04)	2.17 (1.67-2.81)
Cedar Mills	7	0.83 (0.40-1.75)	0.84 (0.40-1.76)
Interior Mills	19	3.31 (2.11-5.20)	2.74 (1.73-4.34)
All Mills	85	2.17 (1.75-2.69)	2.00 (1.61-2.49)

Discussion

Respiratory Effects of Sawmill Fungicides

No evidence of an excess risk of overall respiratory disease, COPD, or asthma mortality was observed among workers at sawmills using fungicides. The risk of all respiratory disease and COPD did not appear to increase with duration of employment. With only three fatal asthma cases observed, it was not possible to reliably examine the risk in stratified analyses. There was no ability to assess the risk of respiratory disease mortality among workers exposed to the specific fungicides that were the objective of this study because the number of workers was relatively small. In addition, the usage of the fungicides of interest was relatively recent and the follow-up period was short. Only one fatal case of respiratory disease was identified among the workers specifically identified as having been exposed to fungicides in the exposure assessment and that was among workers exposed to TCMTB, the first of the four to be introduced and the one with the largest number of exposed workers.

There was also no evidence of increased hospitalization for respiratory disease, COPD, or asthma among workers in the fungicide-using mills relative to workers in non-fungicide using sawmills in the internal analysis. The adjusted rates were similar to those of cedar mills and less than those for the interior mills. All three groups of sawmill workers were at an increased risk of hospitalization for overall respiratory disease and COPD relative to the general population of BC. Workers from the fungicide-using and interior mills had over twice the risk of asthma while no excess was observed among cedar mill workers. As with the internal analyses, interior mill workers consistently had the highest relative risks.

The risk of overall respiratory hospitalization and asthma did not increase with duration of employment in sawmills using fungicides. The risk of COPD was significantly higher among workers employed for ten or more years, but a similar pattern was observed in all three types of mills and would, therefore, be difficult to attribute to fungicide use. The risk of overall respiratory disease did not appear to be associated with level of exposure to fungicides. There were too few cases of COPD and asthma among workers exposed to the specific fungicides to confidently assess whether an association exists. Although there was an increased risk of asthma among workers exposed to IPBC, this was only based on two cases.

There are some limitation that should be kept in mind when considering the results of this study. This study had the ability to assess morbidity and, therefore, greatly increased power compared to mortality studies. However, the numbers were still too small to examine the associations between the specific fungicides and COPD or asthma. The number of exposed workers were fewer than anticipated. Because of technological change there are many fewer workers exposed to fungicides in the sawmill industry than in the past. In addition, many of the fungicides were used for relatively few years. There are other, general limitations regarding the use of hospital discharge data that are discussed later in this report.

Despite our best efforts, misclassification of exposure is certain to have occurred. Almost no sampling data for airborne exposure was available and the assessment of exposure relied on the expertise of the study hygienists and people employed in the industry. The classification of exposure was performed without the knowledge of the disease status of the study population and was likely to have been non-differential in nature. Thus, possible associations may have been obscured. When uncertainty was encountered, attempts were made to err in the direction of specificity because this has been shown to result in less attenuation of risk estimates in situations where there is a relatively low prevalence of exposure in the study population [Dosemeci & Stewart, 1996]. A lack of quantitative exposure measurements not only impeded the assessment of exposure in this study, but also limits our ability to assess a safe level of exposure. Traditionally, dermal exposure to fungicides has been the primary concern in this industry and is likely to be the principal route of exposure. Even if the fungicides used do have respiratory effects, it may be that exposures are too low in this industry to observe that effect.

The lack of information regarding smoking and exposure to other potential causes of respiratory disease are a limitation that is common to almost all industry-based cohort studies. Some data on smoking rates among members of the study population and the general population of BC are available and presented in Appendix 3. The appendix also includes data for the general BC population [Heart and Stroke Foundation of BC and Yukon, 2000]. Based on a survey of 1,806 members of the study population, smoking rates among sawmill workers appear to be similar to the general population of BC. The lack of an excess risk of lung cancer among the sawmill workers in this study would also indicate that their smoking rates are likely not higher than the general population. Most key analyses in this study were performed with other sawmill workers as the internal reference population. Thus, in order to be a confounder, cigarette smoking would have to be associated with duration of employment or with fungicide exposure.

Other Respiratory Results

A consistently increased risk of overall respiratory, COPD, and asthma morbidity was observed among workers employed at the interior mills when compared to workers at the coastal mills and the general population. This association was somewhat reduced when adjusting for regional differences, but did persist indicating that variations in health care utilization and environmental risks could not fully account for the association. Smoking rates were somewhat higher among workers from the interior mills (see Appendix 3), but this may reflect higher smoking rates in that region. The interior mills use different tree species (lodgepole pine, sub-alpine fire, white spruce, and Engelmann spruce) than the other mills, but these species are not known to be especially hazardous. Wood dust exposure levels are higher and, despite the lack of problems regarding sapstaining fungi on lumber, exposure to bioaerosols are also thought to be higher. Exposure indices for these other respiratory hazards are currently under development and potential association among members of the cohort will be examined in the near future.

The lack of an excess risk of asthma among cedar workers was a curious result and seemingly at odds with current knowledge. Western red cedar has been recognized as an allergenic wood for a number of years and cross-sectional studies have identified asthma prevalence rates ranging from 1.7% to 24% depending on the criteria for cases and the level of dust exposure [Brooks et al, 1981; Chan-Yeung and Desjardines, 1992; Vedal et al, 1986]. The lack of an association could be an indication that workers with asthma have followed medical advice to leave the industry to prevent worsening respiratory health, or that steps, such as powered air-purifying respirator use, taken to reduce exposure after workers have been sensitized have been effective.

All analyses found a consistently increased risk among East Indian males for all respiratory disease and asthma, but a decreased risk of COPD. The decreased risk of COPD is consistent with lower smoking rates among Sikhs, who form the vast majority of East Indian sawmill workers in this study. The smoking survey results indicate that East Indian workers in the cohort smoke much less than other workers and this pattern also appeared in the study of the general population [Heart and Stroke Foundation of BC and Yukon, 2000]. We know of no reason to suspect that Sikhs are at increased risk of asthma or other respiratory diseases due to genetic or personal factors, but it is possible. It is also possible that they are employed in jobs within the industry that have higher exposure to respiratory hazards. Adjustment for type of mill, duration of employment, or fungicide exposure had no impact on the rate ratios observed for East Indian males and race was not a confounder in the other analyses. This would seem to indicate that East Indian workers do not differ from other workers in their exposure to fungicides. However, their exposure to other potential respiratory hazards may.

Overall mortality and overall cancer and circulatory disease mortality rates were similar to those expected based on BC rates. Respiratory mortality rates were only slightly lower while morbidity rates were somewhat higher than those for the general BC population. This would seem to indicate that there is very little of the healthy worker effect which has been seen in other analyses or that other risk factors exist and have obscured that effect. Canada has universal access to health care, which might result in a smaller healthy worker effect. However, entry level jobs in the sawmill industry are physically very demanding and some healthy worker effect would still be anticipated.

Utility of Hospital Discharge Data

This study demonstrated the utility of hospital discharge data for studying the health effects of exposures in workplace-based cohort studies. The primary advantage relative to mortality data, which is traditionally used in cohort studies, was greatly increased power. There were 41 cases available for the mortality analysis versus 1136 cases based on counting only the first hospital visit for respiratory disease. In addition, because cases are identified earlier in the disease process, the ability to assess the impact of newly introduced chemicals or other workplace changes is greatly enhanced.

Unfortunately, the ability to use hospital discharge data as a research tool is limited by the availability of or access to population-based data. The Canadian provinces of British Columbia and Manitoba have data sets available. Although these were originally constructed for other types of research, particularly health services, they exist in an accessible, linkable form and the proper ethical review systems are in place to ensure patient confidentiality. Because of the universal, single payer health care system in Canada the necessary data sets exist in other provinces and mechanisms similar to those in BC and Manitoba could be established. Forty-four states also collect data on all hospital discharges from acute care hospitals [Stanbury, 2000]. This data has been used for identification of sentinel cases, case-based surveillance, and to examine population-based trends in disease [Reilly and Rosenman, 1995; Rosenman, 1988; Rosenman et al, 1990; Stanbury, 2000]. However, to our knowledge, this data has not been used for cohort studies or other studies involving linkage with large data sets of occupationally exposed individuals.

Cohort mortality studies have generally found sawmill and related workers to be at a somewhat decreased risk of respiratory disease consistent with the healthy worker effect. A number of cross-sectional studies have found an increased prevalence of symptoms, decreased lung function, and evidence of asthma related to certain tree species. The variability in the results of studies using different designs may be due to differences in the choice of disease end-points, choice of appropriate comparison populations, classification and assessment of exposure, and ability to adjust for potentially confounding factors. Hospitalization for respiratory disease represents an intermediate disease end-point and the results of this study support the conclusion that sawmill workers are at an increased risk of respiratory disease. While this study has not overcome all limitations, the increased power does allow for internal comparisons. The primary limitation remaining is the lack of data regarding non-occupational risk factors for respiratory disease, particularly cigarette smoking. However, the results of the smoking survey presented in Appendix 3 indicate that the overall results of this study are unlikely to be due to confounding by smoking.

Hospital discharge data has a number of limitations regarding the consistency of coding and the accuracy of diagnoses. Occupational health researchers have had long experience interpreting the results of cohort studies based on mortality and cross-sectional studies using data from pulmonary function testing or symptom surveys. In the context of cohort studies there is little experience to draw upon. The results for the cedar mill workers presents an interesting example of potential differences in interpretation. These workers are exposed to a well established cause of asthma and surveillance at one of the mills has identified cases in the past. While hospital discharge data is a measure of serious morbidity, it is not a measure of incidence. Thus we are left with the question of whether the lack of an increased risk is due to safe levels of exposure (primary prevention) or medical removal (secondary prevention).

Conclusions

This study did not find any evidence for an association between the risk of respiratory disease and exposure to DDAC, IPBC, TCMTB, and borates in sawmills. This could be due to a true lack of effect, low levels of exposure, or limitations in the study's design. An elevated risk of hospitalization for overall respiratory disease and COPD was observed for all types of sawmills which could not be explained by differences in smoking rates. An increased risk of asthma was also observed for all but the cedar mills. The lack of an excess among cedar workers could be explained by good management of asthma cases, but the cause for the excess among other types of sawmill workers warrants further investigations.

Acknowledgments

We would like to thank workers and management of the 14 sawmills that participated in this study for their consistent cooperation with all our BC sawmill workers studies. We would also like to thank the unions representing the workers and the companies owning the mills for their support despite economic downturns in the industry which could have presented a legitimate excuse for turning us away. This research could not have been completed without the diligent efforts of Ruth Hershler and Lisa Chen our programmers/data analysts.

Possible Future Publications

The following publication is anticipated as a result of the research funded by NIOSH:

Demers PA, Davies H, Ronald L, Hirtle R, Hertzman C, Teschke K. Hospitalization for respiratory disease and fungicide exposure among softwood lumber mill workers.

In addition, this study has acted as a pilot study on the usefulness of hospital discharge data for studying respiratory disease among sawmill workers. In the near future, a quantitative exposure assessment for wood dust (funded by the Medical Research Council of Canada) and a semi-quantitative assessment for mould exposure (funded by the BC Lung Association) will be completed. Respiratory disease hospitalization rates among members of the cohort will then be examined in relationship to these exposures.

References

Brooks SM, Edwards JJ Jr, Apol A, Edwards FH (1981): An epidemiologic study of workers exposed to western red cedar and other wood dusts. Chest 80(1):305-25.

Bryld LE, Agner T, Rastogi SC, Menne T (1997): Iodopropynyl butyl carbamate: a new contact allergen. Contact Dermatitis 36:156-8

Bureau of the Census (1987): 1987 Census of Manufacturers. Washington DC, Department of Commerce.

Chan-Yeung M, Wong R, Maclean L, Tan F, Korken E, Schulzer M, Dennis R, Grzybowski S (1980): Respiratory survey of workers in a pulp and paper mill in Powell River, British Columbia. Am Rev Resp Dis 122(2):249-57.

Chan-Yeung M, Desjardins A (1992): Bronchial hyperresponsiveness and level of exposure in occupational asthma due to western red cedar (Thuja plicata). Serial observations before and after development of symptoms. Am Rev Respir Dis 146:1606-9.

Chan-Yeung M (1993): Western Red Cedar and Other Wood Dusts. in Bernstein L, Chan-Yeung M, Malo J, Bernstein DI (Eds). Asthma in the Workplace. Marcel Dekker Inc. New York. 503-531.

Chan-Yeung M, Malo JL (1995): Occupational respiratory diseases associated with forest products industries. In: Occupational and Environmental Respiratory Diseases. (Eds: Harber P, Schenker M, Balmes J). Mosby, St. Louis.

Chataigner d, Garnier R, Sans S, Efthymiou ML. (1991): Acute accidental poisoning with hospital disinfectant. 45 cases of which 13 with fatal outcome. Presse Medicale 20:741-743.

Demers PA, Boffetta P, Kogevinas M, Blair A, Miller B, Robinson C, Roscoe R, Winter P, Colin D, Matos E, Vainio H (1995): A pooled re-analysis of cancer mortality among five cohorts of workers in wood-related industries. Scand J Work Environ Health 21:179-190

Demers PA, Teschke K, Kennedy SM (1997): What to do about softwood dust? A review of respiratory effects and recommendations regarding exposure limits. Am J Indust Med 31(4):385-398.

Demers PA, Stellman S, Colin D, Boffetta P (1998). Non-malignant respiratory disease mortality among wood workers participanting in the American Cancer Society Cancer Prevention Study-II (CPS-II). Am J Indust Med 34(3):238-243.

Demers PA, Teschke K, Kennedy SM, Davies H, Leung V (2000). Exposure to dust, resin acids, and monoterpenes in softwood lumber mills. Am Indust Hyg Assoc J 61(4):521-528.

Dosemeci M, Stewart PA (1996). Recommendations for reducing the effects of exposure misclassification on relative risk estimates. Occup Hyg 3:169-176.

Enarson DA, Chan-Yeung M (1990): Characterization of health effects of wood dust exposures. Am J Ind Med 17:33-8.

Garabrant DH, Bernstein L, Peters JM, Smith TJ. Respiratory and eye irritation from boron oxide and boric acid dusts. J Occup Med 1984;26:584-586.

Garabrant DH, Bernstein L, Peters JM, et al. Respiratory effects of borax dust. Br J Ind Med 1985;42:831-837.

Goldsmith DF, Shy CM (1988): Respiratorey health effects from occupational exposure to wood dusts. Scand J Work Environ Health 14:1-15

Halpin DMG, Graneek BJ, Lacey J, Nieuwenhuijsen MJ, Williamson PAM, Venables KM, Newman-Taylor AJ (1994): Respiratory symptoms, immunological responses, and aeroallergen concentrations at a sawmill. Occup Environ Med 51(3):165-72.

Hertzman C, Teschke K, Ostry A, Hershler R, Dimich-Ward H, Kelly S, Spinelli JJ, Gallagher R, McBride M, Marion SA (1997): Mortality and cancer incidence among a cohort of sawmill workers exposed to chlorophenate wood preservatives. Am J Pub Health 87:71-79

Hertzman C, Teschke K, Dimich-Ward H, and Ostry A (1988): Validity and reliability of a method for retrospective evaluation of chlorophenate exposure in the lumber industry. Am J Ind Med 14:703-713

Hessel PA, Herbert FA, Melenka LS, Yoshida K, Michaelchuk D, Nakaza M (1995): Lung health in sawmill workers exposed to pine and spruce. Chest 108(3):642-6.

Hu X, Wegman DH, Eisen EA, et al (1992). Dose related acute irritant symptom responses to occupational exposure to sodium borate dust. Br J Indust Med 49:706-713.

Jappinen P, Pukkala E, Tola S (1989): Cancer incidence of workers in a Finnish sawmill. Scand J Work Environ Health 15:18-23.

Kelly S, Techke K, Hertzman C (1998): Pentachlorophenol and tetrachlorophenol. in Rom WN, editor, Environmental and Occupational Medicine, 3rd Edition. Philidelphia: Lippincott-Raven, chapter 86:1195-1199.

Kipen HM, Gelperin K, Tepper A, Stanbury M (1991): Acute occupational respiratory diseases in hospital discharge data. Am J Indust Med 19(5):637-42.

Kipen HM, Tepper A, Rosenman K, Weinrib D (1990): Limitations of hospital discharge diagnoses for surveillance of extrinsic allergic alveolitis. Am J Indust Med 17:701-709.

Malo JL, Cartier A, Boulet LP (1986): Occupational asthma in sawmills of eastern Canada and United States. J Allergy Clin Immunol 78(3 Pt 1):392-8.

McDonald E. Documentation of Worker Exposure to Antisapstain Chemicals in British Columbia Wood Products Operations. BC Research Corporation, Vancouver, BC, 1989.

Moscato G, Omodeo P, Dellabianca A, Colli MC, Pugliese F, Locatelli C, Scibilia J. (1997): Occupational asthma and rhinitis caused by 1,2-benzisothiazolin-3-one. Occup Med 47:249-51.

Noertjojo HK, Dimich-Ward H, Peelen S, Dittrick M, Kennedy SM, Chan-Yeung M. Western red cedar dust exposure and lung function: a dose-response relationship. Am J Respir Crit Care Med 1996;154(4 Pt 1):968-73.

Occupational Health Group. Industrial Hygiene Survey of Worker Exposure to TCMTB Anti-sapstain Solutions. BC Research Corporation, Vancouver, BC, 1989.

Preller L, Doekes G, Heederik D, Vermeulen R, Vogelzang PF, Boleij JS (1996): Disinfectant use as a risk factor for atopic sensitization and symptoms consistent with asthma: an epidemiologic study. Europ Resp J 9:1407-13

Heart and Stroke Foundation of BC and Yukon (2000). Tobacco Use in BC. Published by the Province of British Columbia. (http://www.hlth.gov.bc/tobacrs/summary/index.html)

Reilly MJ, Rosenman KD (1995): Use of hospital discharge data for surveillance of chemical-related respiratory disease. Arch Environ Health 50(1):26-30.

Robinson C, Fowler D, Brown DP, Lemen RA (1986): Plywood mill workers' mortality patterns 1945-1977. Cincinnati, OH: National Institute for Occupational Safety and Health. NTIS Publication PB90-147075.

Rosenman KD (1988): Use of hospital discharge data in the surveillance of occupational disease. Am J Indust Med 13:281-289.

Rosenman KD, Trimbath L, Stanbury M (1990): Surveillance of occupational lung disease: comparison of hospital discharge data to physician reporting. Am J Public Health 80(10):1257-1258.

Senthilselvan A, McDuffie HH, Dosman JA (1992): Association of asthma with the use of pesticides. Results of a cross-sectional study of farmers. Am Rev Resp Dis 146:884-87.

Stanbury M (2000). Hospital Discharge Data. Chapter 22 in Workplace Health Surveillance, Maizlish N, Ed. Oxford University Press, NY, NY.

Teschke K, Ostry A, Hertzman C, Demers PA, Barroetavena MC, Davies HW, Dimich-Ward H, Heacock H, Marion SA (1998): Opportunities for a broader understanding of work and health: Multiple uses of an occupational cohort database. Can J Pub Health 89(2):132-136.

Teschke K, Hertzman C, Fenske R, Jin A, Ostry A, van Netten C, Leiss W (1994a): A history of process and chemical changes for fungicide application in the western Canadian lumber industry: What can we learn? Appl Occup Environ Hyg 9:984-993.

Teschke K, Hertzman C, Morrison B (1994b): Level and distribution of employee exposures to total and respirable wood dust in two Canadian sawmills. Am Indust Hyg Assoc J 55:245-250.

Teschke K, Hertzman C, Wiens M, Dimich-Ward H, Hershler R, Ostry A, Kelly S (1992): Recognizing acute health effects of substitute fungicides: Are first aid reports effective? Am J Ind Med 21:375-382.

Teschke K, Hertzman C, Dimich-Ward H, Ostry A, Blair J, Hershler R (1989): A comparison of exposure estimates by worker raters and industrial hygienists. Scand J Work Enviro Health 15:424-429.

Vedal S, Chan Yeung M, Enarson D, Fera T, Maclean L, Tse KS, Langille R (1986): Symptoms and pulmonary function in western red cedar workers related to duration of employment and dust exposure. Arch Environ Health. 41:179-83.

Vogelzang PF, van der Gulden JW, Preller L, Tielen MJ, van Schayck CP, Folgering H (1997): Bronchial hyperresponsiveness and exposure in pig farmers. Int Arch Occup Environ Health 70:327-333.

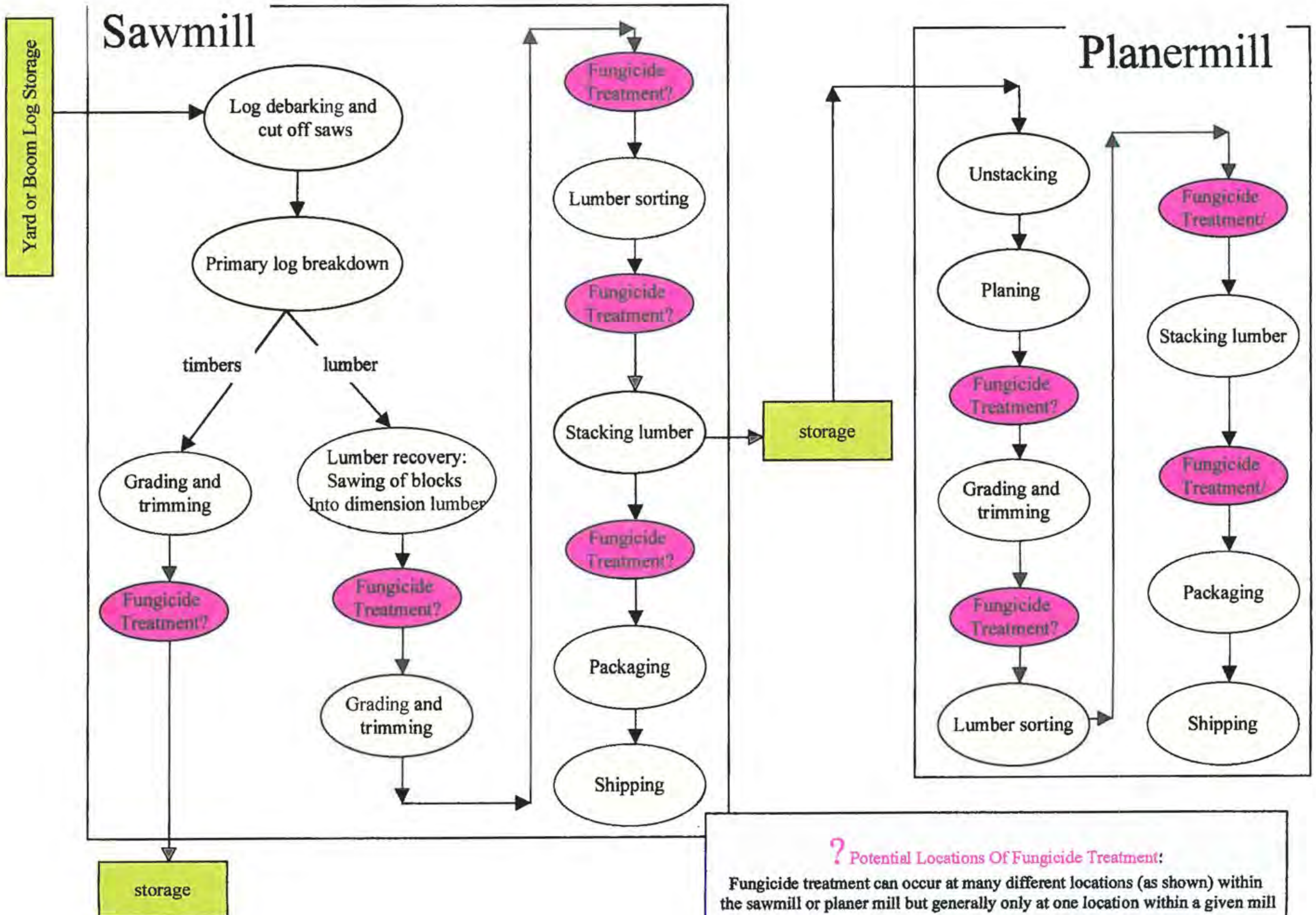
Vogelzang PF, van der Gulden JW, Folgering H, van Schayck CP (1998): Longitudinal changes in lung function associated with aspects of swine-confinement exposure. J Occup Environ Med 40(12):1048-1052.

Vogelzang PF, van der Gulden JW, Tielen MJ , Folgering H , van Schayck CP (1999): Health-based selection for asthma, but not for chronic bronchitis, in pig farmers: an evidence-based hypothesis. European Resp J 13:187-189.

Wegman DH, Eisen EA, Hu X, et al. Acute and chronic respiratory effects of sodium borate particulate exposure. Environ Health Persp 1994;102(suppl 7):119-128.

Appendix 1

Process Flow and Potential Usage of Fungicides in Sawmills



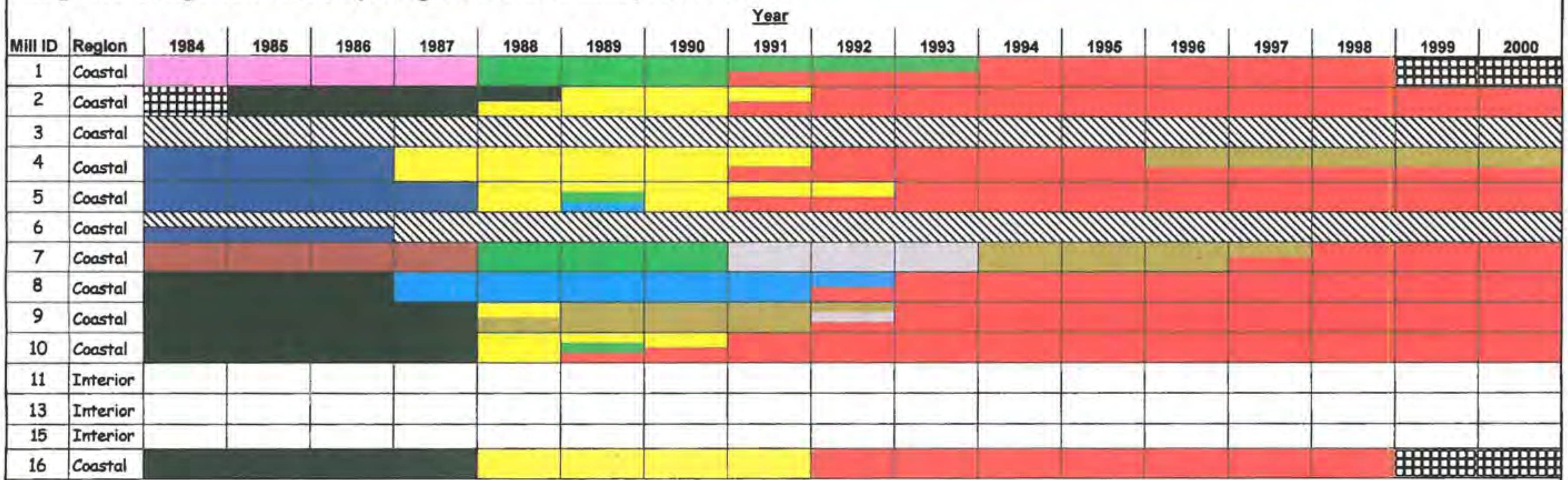
? Potential Locations Of Fungicide Treatment:

Fungicide treatment can occur at many different locations (as shown) within the sawmill or planer mill but generally only at one location within a given mill

Appendix 2

Chronology of Fungicide Usage in the 14 Study Sawmills

Fungicide Usage in 14 Participating BC Lumber Mills, 1984 - 2000.



Key (tradenames in italics)

Sodium Pentachlorophenol (PCP) and Tetachlorophenol (TCP) Salts (Chlorophenates)

DARK BLUE = 19-24% TCP, 5% PCP (*Diatox*)

BLACK = 16% TCP, 8% PCP, 2% borax (*Woodbrite 24*)

DARK RED = 4-8% TCP, 3-6% PCP (*Woodsheath*)

PINK = Mixed Tetrachlorophenol-based products: 6% PCP, 7% TCP (*Seabrite*), 3% PCP, 4% TCP (*Cherry Brown*), and ~8% PCP, ~15% TCP (*Tetra-24*)

Fungicides Containing didecyldimethyl ammonium chloride (DDAC)

GREY = 22% DDAC (*Timbercote*)

GOLD = 11% DDAC, 17% octaborate (*F2*)

RED = 65% DDAC, 8% 3-iodo-2-propynyl butyl carbamate (IPBC) (*NP1*)

Other fungicides

YELLOW = 30% 2-(thiocyanomethylthio) benzthiazole (*TCMTB*) (*Busan*)

BLUE = 5-10% Copper-8-quinolinolate (*Nytek, mill 5, 10%; PQ-8, mill 8, 5%*)

GREEN = 4% Borax and 20% sodium carbonate (*Ecobrite*)

No Fungicide Used

= Western red cedar

= Spruce, pine, fir

= Mill closed

Note: A colour in a cell means that a fungicide was used at a mill for some period during that year.
The area of colour within a cell is *not* proportional to volume of fungicide applied.

Appendix 3

Smoking Rates among BC Sawmill Workers

Smoking rates for sawmill workers were from a survey of members of the cohort employed in 1979 that was conducted as part of another study. Of the ramdom sample of 3000 workers, informed consent was obtained from 2157 (72%). Of these 1,886 cohort members completed a full questionnaire administered, usually in their home, by a trained interviewer. The remaining 271 only completed a telephone administered short questionnaire which did not include a smoking component. Of the 1,886 full respondents, 1,806 were included in the present study and their results are presented below. Ethnic group was coded in the same manner as the current study.

Smoking rates for the general population were obtained from a report published by the BC Ministry of Health [Heart and Stroke Foundation of BC and Yukon, 2000]. The survey of 18,030 randomly selected respondents was conducted by Angus Reed Group and the BC Heart and Stroke Foundation. The number of respondents by age and sex strata were not presented in the report. The results for South Asians were based on 561 telephone interview of persons "who consider the ethnic/cultural background of their parent or grandparents to be from India, Pakistan, Bangladesh, Nepal, Sri Lanka or other similarly situated countries." No results were presented with stratification by both sex and age group for specific ethnic groups.

Smoking Rates among Male BC Sawmill Workers Compared to All BC Males

	Current	Past	Never
Male Sawmill Workers			
25-44 (n=624)	30%	32%	39%
45-64 (n=771)	24%	42%	35%
65+ (n=412)	10%	68%	22%
All BC Males			
25-44	29%	24%	47%
45-64	21%	48%	31%
65+	13%	63%	24%
East Asian Sawmill Workers (n=236)	12%	14%	74%
South Asian BC Males	11%	12%	77%

Smoking Rates among Male BC Sawmill Workers by Race and Age Group

	Current	Past	Never
East Indian Sawmill Workers			
25-44 (n=67)	15%	25%	60%
45-64 (n=149)	11%	9%	79%
65+ (n=20)	5%	10%	85%
Other Sawmill Workers			
25-44 (n=557)	31%	33%	36%
45-64 (n=622)	26%	49%	24%
65+ (n=392)	10%	71%	19%

Smoking Rates among Male BC Sawmill Workers by Type of Mill and Age Group

	Current	Past	Never
Fungicide-using Mills			
25-44 (n=413)	29%	31%	40%
45-64 (n=534)	24%	41%	35%
65+ (n=271)	11%	68%	21%
Western Red Cedar Mills			
25-44 (n=141)	28%	35%	37%
45-64 (n=151)	19%	38%	43%
65+ (n=110)	8%	68%	24%
Interior Mills			
25-44 (n=70)	39%	31%	30%
45-64 (n=86)	27%	49%	24%
65+ (n=31)	7%	68%	26%

Memorandum

Date: May 9, 2001

From: Roy M. Fleming, Sc.D., Director, Research Grants Program RMF
Office of Extramural Programs, NIOSH, D30

Subject: Final Report Submitted for Entry into NTIS for Grant 1 R03 OH003778-01.

To: William D. Bennett
Data Systems Team, Information Resources Branch, EID, NIOSH, P03/C18

The attached final report has been received from the principal investigator on the subject NIOSH grant. If this document is forwarded to the National Technical Information Service, please let us know when a document number is known so that we can inform anyone who inquires about this final report.

Any publications that are included with this report are highlighted on the list below.

Attachment
cc: Sherri Diana, EID, P03/C13

List of Publications None

Title: Respiratory Disease among Sawmill Workers
Investigator: Paul A. Demers, Ph.D.
Affiliation: University of British Columbia
City & State: Vancouver, B.C.
Telephone: (604) 822-0585
Award Number: 1 R03 OH003778-01
Start & End Date: 9/30/1998–9/30/2000
Total Project Cost: $44,133
Program Area: Asthma & Chronic Obstructive Pulmonary Disease
Key Words:

Abstract:
This study examined the association between respiratory disease and exposure to fungicides used to combat sap-staining moulds on softwood lumber products. A retrospective cohort study was conducted of 11,745 British Columbia sawmill workers employed in 14 mills between 1979 and 1994. Non-fatal respiratory disease was identified using provincial hospital discharge records using the British Columbia Linked Health Database. Exposure to fungicide was estimated as none, low and high by industrial hygienists based on observations made at the mills and interviews with senior employees. Cumulative exposure for each participant was calculated by summing the products of exposure level and duration of employment at each job held. Standardized mortality ratio analyses were conducted for fatal respiratory disease. Respiratory hospitalization rates among exposed workers were compared to unexposed workers and rates among sawmill workers were compared to the general population using Poisson regression.

Nine mills used fungicides during the study period. Of the non-using mills, two processed only Western red cedar and three were located in the interior of the province. Four fungicides were commonly used in the participating mills: DDAC (didecyldimethyl ammonium chloride), IPBC (3-iodo-2-propynyl butyl carbamate), TCMTB (2-[thiocyanomethylthio] benzthiazole) and borates. Relatively few workers had been exposed to the four fungicides: 553 to TCMTB, 322 to borates, 359 to IPBC, and 478 to DDAC. Record linkage to the Canadian Mortality Database identified 720 deaths between 1950 and 1995. There were 41 deaths due to respiratory disease and no evidence of an association with fungicide exposure was observed. Overall, 1,136 persons were hospitalized with a diagnosis of respiratory disease between April 1985, and July 1997, including 261 for chronic obstructive pulmonary disease (COPD) and 105 for asthma. The hospitalization rates for overall respiratory disease, COPD, and asthma in the fungicide-using mills were similar to those for the cedar mills and significantly less than those for the interior mills, which did not use fungicides. The risk of COPD was elevated among workers who had been employed for 10 or more years in all three types of mills but did not appear to increase with further duration of employment. Overall respiratory disease, COPD, and asthma did not appear to be associated with exposure to any of the fungicides, but very few COPD and asthma cases were observed among exposed workers.

After adjustment for sex, age group, and region of the province, workers from all three types of sawmills had somewhat increased rates of hospitalization for respiratory disease compared to the general BC population. The rate ratios (RRs) were 1.4 for fungicide using, 1.3 for cedar, and 1.5 for interior sawmills. Hospitalization rates for COPD were also elevated for all three types of sawmills with rate ratios 1.3, 1.5, and 1.8, respectively. Asthma rates were elevated for fungicide-using (RR=2.2) and interior mills (RR=27), but no excess was observed for cedar mills (RR=0.8)

In summary, this study did not find any evidence for an association between respiratory disease and DDAC, IPBC, TCMTB, and borates. This could be due to a true lack of effect, low levels of exposure, or limitations in the study's design. An elevated risk of hospitalization for overall respiratory disease and COPD was observed for all types of sawmills that could not be explained by differences in smoking rates. An increased risk of asthma was also observed for all but the cedar mills. The lack of an excess among cedar workers could be explained by good management of asthma cases, but the cause for the excess among other types of sawmill workers warrants further investigations.

Publications

No publications to date.