SMC 6298

DRAFT. SUBJECT TO REVISION. NOT TO BE QUOTED

JOHNS-MANVILLE CORPORATION HEALTH, SAFETY & ENVIRONMENT DEPT. LIBRARY

MARGINALIA REDACTED

ESTIMATES OF DOSE-RESPONSE FOR RESPIRATORY CANCER AMONG CHRYSOTILE ASBESTOS TEXTILE WORKERS

J.M. Dement,* R.L. Harris, Jr.,** M.J. Symons,** C. Shy**

* National Institute for Occupational Safety and Health, Morgantown, West Virginia

** University of North Carolina, Chapel Hill, North Carolina

ABSTRACT

Methods for reconstructing historic dust exposures, taking into account jobs and controls, were developed and combined with a retrospective cohort mortality study of chrysotile asbestos textile workers, between 1940 and 1975, to evaluate dose-response relationships for lung cancer and non-malignant respiratory diseases. Among 768 white males, statistically significant excess mortality was observed for lung cancer (SMR = 348) and nonmalignant respiratory diseases (SMR = 263). There were fifteen deaths due to asbestosis or pulmonary fibrosis. Using estimated fibre dose by job and calendar time, combined with detailed work histories, mortality by cumulative dose was investigated. For lung cancer, a linear dose-response relationship was obtained with an SMR of 223 in the lowest cumulative dose category. Significant dose-response relationships were also observed for nonmalignant respiratory diseases excluding acute upper respiratory infection, influenza, pneumonia, and bronchitis. Of the 191 deaths among white males, only one was due to mesothelioma.

INTRODUCTION

It is well established that occupational exposure to asbestos is associated with increased risks of many diseases including pulmonary fibrosis (asbestosis), respiratory cancer, mesothelioma of both pleural and peritoneal tissues, and cancer of the gastrointestinal tract. These health effects have been shown repeatedly using different populations and study methods (NIOSH, 1976; IARC, 1977).

Although there has been a large amount of research devoted to asbestos, there have been few epidemiological studies of cancer risks among workers exposed only to chrysotile, which accounts for more than 90 percent of all asbestos used in the United States. Even fewer studies have attempted to develop exposure estimates and to investigate dose-response relationships in a quantitative manner.

To provide further information on lung cancer risks associated with chrysotile exposures, a retrospective mortality study was conducted among a cohort of asbestos textile workers. The mortality data was combined with fiber exposure estimates to investigate dose-response relationships for lung cancer and nonmalignant respiratory diseases.

The plant selected for study is unique in several ways. First, only an insignificant quantity of asbestos fiber other than chrysotile was ever processed. Secondly, the plant was engaged in a preventive dust control program beginning in the mid-1930's; therefore, the possibility of evaluating effects at exposure levels lower than those of previous studies existed. Perhaps more important is the fact that a considerable quantity of exposure data was available for estimation of worker exposures.

METHODS

Cohort Mortality Study

Although the plant under study began production of asbestos products in 1906, detailed personnel records were first maintained beginning in approximately 1930. The record system has remained remarkably unchanged since that time. For each worker, an employment card was completed at initial employment giving name, date of birth, sex, race, social security number, marital status, and address. This same card also contained the detailed work history giving exact dates of employment by plant department and specific job. All information from these cards were entered onto a computer data file.

The cohort was limited to 768 white males employed six or more months in textile production operations with at least one month of employment between January 1, 1940, and December 31, 1965. The cohort was followed through December 31, 1975. The 1965 cut-off date for cohort entry was chosen to insure that all workers would have a minimum "latency" of 10 years as of the study end date.

An attempt was made to determine the vital status of all cohort members as of December 31, 1975. The primary sources of information used for this follow-up included the Social Security Administration (SSA), Internal Revenue Service (IRS), U.S. Postal Mail Correction Service, state drivers licenses files and state vital statistics offices. Individuals not located through these primary sources were traced using local records such as telephone listings, Polk directories, property records, voter records, records of funeral homes, and various other local sources.

Published by AsbestosClaims.Law
asbestosclaims.law/library/25485/1

Cause specific standardized mortality ratios (SMR's) were calculated using a life table analysis based on the technique developed by CUTLER and EDERER (1958). Person-years at risk of dying were distributed by five year age, calendar time, and time since initial employment (latency) groups. Person-years were accumulated for each cohort member beginning when all requirements for cohort entry were met until the date of death or December 31, 1975. Those whose vital status remained unknown were assumed alive as of the study cut-off date, thereby contributing their maximum possible person-years to the analysis.

The follow-up period for this study spans the Fifth through Eighth Revisions of the International Lists of Diseases and Causes of Death. Death certificates were coded by a qualified nosologist according to the ICDA revision in effect at the time of death. All death codes were then grouped into 89 death categories based on the Seventh Revision for purposes of standardization. Individuals known to be deceased, but for whom no death certificates were available were assumed to be deceased, cause unknown.

The number of expected deaths, standardized for sex, age, race and calendar time, were calculated by application of cause specific death rates for the total United States to the person-years at risk of dying. Death rates specific to the 89 Seventh Revision death groups were calculated from yearly tallies of deaths and census data.

For evaluating dose-response, cumulative exposure strata were created and a worker was moved from one stratum to the next as his cumulative exposure increased during the course of follow-up (BRESLOW, 1976; LUNDIN et al., 1971). By this method, a worker contributed person-years and thus expected deaths in several exposure strata while contributing observed death to only the highest stratum achieved. Each worker's cumulative exposure was estimated by combining detailed work histories from plant employment records with estimates of exposure by job.

Statistical significance of observed cause specific excesses or deficits was evaluated using the Poisson distribution (PEARSON and HARTLEY, 1958).

Exposure Estimates

From 1930 to 1975, 5952 environmental samples were collected in the plant under study as shown in Table 1. Prior to 1965, all samples were of the impinger type; from 1965 until 1971 membrane filter samples were also collected. In 1971, the impinger method was entirely replaced by the membrane filter method.

TABLE 1. SUMMARY OF SOURCES OF INDUSTRIAL HYGIENE SAMPLING DATA FOR 1930-1975

SOURCE OF SAMPLE DATA	NUMBER OF SAMPLES 1930-1945	1945-1960	1960-1975
Company Sampling Program	---	179	4919
Company Insurance Carrier	112	---	---
State Board of Health	12	4	---
U.S. Public Health Service	69	---	657
TOTAL NUMBER OF SAMPLES	193	183	5576

For purposes of estimating worker exposure levels, it was necessary that all exposure data be of the same unit of measure; therefore, a conversion from impinger counts, measured in millions of particles per cubic foot of air (MPPCF), to membrane filter counts, measured as fibers longer than 5 μm per cubic centimetre of air (fibers/cc) was necessary. Fortunately, there were two relatively good sources of data for this estimate: 120 paired impinger-membrane filter samples collected in this plant by the U.S. Public Health Service in 1965 and 906 concurrent samples by these two methods in plant operations collected during 1968-1971. Relationships between the two methods were investigated using multiple linear regression. Results of these conversion estimates and approximately 95 percent confidence intervals are given in Figure 1. For all textile operations except preparation, a conversion of 3 fiber/cc for 1 MPPCF was used. For preparation, a conversion of 8 was used. Using these conversion values, all sample data were expressed as fibers/cc.

Mean exposure levels by job between 1930 and 1975 were estimated using linear statistical models. Textile operations were divided into 16 exposure zones according to similarity of processes and exposures as described by COHN and ECKHR (1977). All jobs within each exposure zone were further analyzed in one of four Uniform Job Categories (UJC) based upon tasks associated with the particular job (ECKHR, 1977).

Using the exposure zone and Uniform Job Categories, linear models were developed to allow estimation of worker exposures in each exposure zone over time; taking into account changes in processes and engineering controls. The linear model for each exposure zone took the following form:

$$\bar{y}_i = \sum_k \beta_{ik} z_{ik} + \sum_j \alpha_{ij} z_{ij} + \sum_t \lambda_{it} z_{it}$$

where:

$\bar{y}_i$ = mean of log of concentration values for exposure zone i
β_{ik} = multiple regression parameter for UJC k in exposure zone i
z_{ik} = independent variable used to identify UJC k in exposure zone i
α_{ij} = multiple regression parameter for control j in exposure zone i

Published by AsbestosClaims.Law
asbestosclaims.law/library/25485/2

DRAFT. SUBJECT TO REVISION. NOT TO BE QUOTED

Z_{ij} = independent variable used to represent dates of control changes for exposure zone i
λ_{it} = multiple regression parameter for time interval t in exposure zone i
Z_{it} = independent variable used to represent calendar time periods.

The first term in the model for each exposure zone takes into account Uniform Job Category, the second term accounts for process or control changes and the last term is used to account for any residual time trends in the data. Details regarding process and control changes were determined through studies of plant engineering records and reports, discussions with long-term employees and from data collected by the U.S. Public Health Service.

Parameters of the exposure models were estimated by multiple linear regression using the historic industrial hygiene data. The regression models predict the mean for the log of dust concentration values; however, others have shown that the arithmetic mean may give the best estimation of the average concentration to which workers are exposed (SHERWOOD, 1965; COHEN, 1966; COHEN, 1971; LEIDEL and BUSCH, 1975). This is especially true when short "grab" samples of approximately equal sampling duration are used to estimate worker exposures, as in the present study. Mean exposures were estimated by the following expression:

$$\bar{x} = \exp\left(\bar{y} + \tfrac{1}{2}\sigma^2\right)$$

where

$\bar{x}$ = estimated arithmetic mean concentration
$\bar{y}$ = mean of log concentration values
σ^2 = pooled estimate of variance of y from the regression model.

Details of all methods used in this study have been presented elsewhere (DEMENT, 1980).

RESULTS

Mortality Study

Results of the follow-up efforts are summarized in Table 2. Vital status was determined for 97.1 percent of the cohort. Of the 191 deaths, all but 13 death certificates were obtained.

TABLE 2. -SUMMARY OF COHORT DEMOGRAPHIC DATA AND VITAL STATUS AS OF DECEMBER 31, 1975, WHITE MALES

Vital Status	White
Known to be alive	555
Known to be deceased	191
Death certificate obtained	178
Death certificate not obtained	13
Unknown vital status	22
Total	768

A total of 21, 158 person-years at risk were experienced by white males between January 1, 1940, and December 31, 1975. Observed and expected deaths by cause are given in Table 3.

Among white males, 191 deaths were observed whereas only 141.84 were expected (SMR = 135, $p<0.01$). Other disease categories showing significant excesses were all malignant neoplasms (SMR = 174, $p<0.01$) and nonmalignant respiratory diseases (SMR = 263, $p<0.01$).

Table 3 shows the elevated SMR for all malignant neoplasms among whites to be largely accounted for by cancer of the trachea, bronchus, and lung. A total of 26 lung cancers were observed and only 7.47 were expected (SMR = 348, $p<0.01$). Table 4 shows observed and expected lung cancer deaths by interval since initial employment (latency). Of the 26 deaths due to lung cancer, 15 occurred after 30 or more years latency. The SMR for lung cancer demonstrated an increasing trend with latency reaching 444 at greater than 30 years.

Using duration of employment as a surrogate for cumulative fiber dose, dose-response relationships for lung cancer are given in Table 4. These data demonstrate an increasing trend in the lung cancer SMR with duration of employment.

All 10 of the nonmalignant respiratory disease deaths fall into the category "other respiratory diseases" excluding upper respiratory infection, influenza, pneumonia, and bronchitis. Of these 10 deaths, asbestosis or pulmonary fibrosis was the underlying cause of death for 5, one was due to emphysema, one septicemia and one pulmonary edema. Other significant conditions mentioned on the death certificates of the 5 asbestosis deaths include bronchitis on two certificates and chronic obstructive lung disease on one certificate.

The SMR for other nonmalignant respiratory diseases also demonstrated no trend with latency but some increasing trends with employment duration (Table 5). Nine of the 10 deaths occurred after 30 or more years since initial employment (SMR = 763, $p<0.01$).

Published by AsbestosClaims.Law
asbestosclaims.law/library/25485/3

TABLE 3. OBSERVED AND EXPECTED DEATHS BY CAUSE FOR WHITE MALE ASBESTOS TEXTILE WORKERS, 1940-1975

Cause of Death	ICDA 7th List No.	Obs.	Exp.	SMR
All Causes		191	141.04	**
Malignant Neoplasms		43	24.66	174**
Digestive System	150-159	9	7.10	127
Trachea, Bronchus & Lung	162-163	26	7.47	348**
Other & Unspecified Sites		8	10.09	79
Disease of the Central Nervous System	330-334, 345	9	7.72	117
Diseases of the Circulatory System	400-468	58	57.43	101
All Tuberculosis	001-019	4	2.77	144
Nonmalignant Respiratory Disease		18	6.85	263**
Acute Upper Respiratory Infection	470-475	0	0.04	—
Influenza	480-483	0	0.37	—
Pneumonia	490-493	0	2.98	—*
Bronchitis	500-502	0	0.41	—
Other Respiratory Diseases	510-527	18	3.05	590**
Accidents	800-962	14	16.64	84
Other Violent Deaths	963-964, 970-985	7	6.10	115
All Other Known Causes		23	17.92	128
Unknown Causes		15	1.75	—

* $p<0.05$

** $p<0.01$

TABLE 4. OBSERVED AND EXPECTED DEATHS DUE TO LUNG CANCER (ICDA 162,163) BY TIME INTERVAL SINCE INITIAL EMPLOYMENT AND DURATION OF EMPLOYMENT, WHITE MALES

Years Since Initial Employment	Obs.	Deaths Exp.	SMR
<10	0	0.37	—
10-19	3	1.40	214
20-29	8	3.00	267**
≥30	15	2.70	444**
Years Employed	**Obs.**	**Deaths Exp.**	**SMR**
<10	9	4.98	181
10-19	4	1.00	400*
20-29	12	1.00	1200*
≥30	1	0.47	213
Total	26	7.47	348*

* p<0.05

** p<0.01

DRAFT. SUBJECT TO REVISION. NOT TO BE QUOTED

Published by AsbestosClaims.Law
asbestosclaims.law/library/25485/4

DRAFT. SUBJECT TO REVISION. NOT TO BE QUOTED

TABLE 5. OBSERVED AND EXPECTED DEATHS DUE TO "OTHER NONMALIGNANT RESPIRATORY DISEASES" BY TIME INTERVAL SINCE INITIAL EMPLOYMENT AND DURATION OF EMPLOYMENT, WHITE MALES

Years Since Initial Employment	Obs.	Deaths Exp.	SMR
<10	1	0.21	—
10–19	4	0.51	784**
20–29	4	1.14	350*
≥30	9	1.18	763**
Years Employed	**Obs.**	**Deaths Exp.**	**SMR**
<10	3	1.99	157
10–19	6	0.39	1538**
20–29	7	0.42	1667**
≥30	2	0.22	895
Total	18	3.05	590

* $p<0.05$
** $p<0.01$

Only one mesothelioma was observed among white males. This was a peritoneal mesothelioma confirmed by autopsy. The interval (latency) between initial employment and death was 34 years. There were several other deaths which mentioned "cancer of the abdomen" which may be suspect; however, no autopsy or other confirmatory data were available.

Digestive system cancers were only slightly elevated in this cohort. In addition to the peritoneal mesothelioma mentioned above, other digestive system cancers included one esophageal, two stomach, one intestinal, two liver, and two pancreatic cancers; however, none of these sites were statistically elevated.

Exposures and Dose-Response

Estimated mean exposures by Uniform Job Category and time period are summarized in Table 6. Before 1940, mean exposures as high as 78.0 fibers/cc were estimated for certain dusty jobs in the preparation department. After 1940, mean exposures generally were between 5 and 10 fibers/cc except for persons handling raw fiber.

Both lung cancer and asbestosis require lengthy periods from initial exposure to become clinically evident. In the present study, no asbestosis or lung cancer deaths occurred among white males prior to 15 years after initial employment (latency). For dose-response studies, it is important to restrict the analyses to those achieving sufficient latency to be "at risk" of dying from lung cancer or asbestosis. For this reason, the present dose-response analyses were restricted to those achieving 15 or more years since initial employment (latency). This was accomplished by beginning accumulation of person-years for each worker after the 15 year latency period was satisfied. Those dying before reaching 15 years latency were excluded.

Results of the dose-response analyses for all causes, diseases of the circulatory system, lung cancer, and other nonmalignant respiratory diseases are given in Table 7. The SMR for all causes was elevated for all exposure categories increasing to 235 in the 40,000-100,000 fiber/cc x days exposure group. Diseases of the circulatory system were statistically elevated only in the second dose category and demonstrated no consistent patterns of dose-response.

In contrast, strong dose-response trends were observed for both lung cancer and the disease group referred to as other nonmalignant respiratory diseases. For lung cancer, statistically excess mortality was observed in all exposure groups with an SMR for the low cumulative exposure category of 223 and 5000 for the highest exposure category. Although statistically significant, the SMR in the highest exposure category is based on only two deaths; thus, the SMR is unstable.

The SMR for other nonmalignant respiratory diseases was 71 in the lowest dose category; it rose to 2500 in the highest category. Statistically significant excesses were observed in all of the three highest dose groups. Again, the SMR in the highest group was based on only two deaths and stability of the SMR should be considered.

It is realized the SMR's for the four exposure groups may not be strictly compared to each other; however, it is useful to plot the dose-response data to observe patterns and trends. Such a plot is given in Figure 2. The data points for the highest exposure category are not included since these were judged to be unstable.

Although only based on three data points, Figure 2 suggests a linear dose-response relationship for lung cancer with no threshold. The data for nonmalignant respiratory diseases are not as linear as lung cancer; however, the SMR rises much more steeply with increasing dose and may reasonably be described by a linear relationship.

Published by AsbestosClaims.Law
asbestosclaims.law/library/25485/5

TABLE 6. SUMMARY OF ESTIMATED MEAN FIBER EXPOSURES BY OPERATION, CALENDAR TIME, AND UNIFORM JOB CATEGORIES

PLANT OPERATION AND CALENDAR TIME PERIOD	ESTIMATED MEAN EXPOSURE BY UJC (fibers > 5 μm/cc)						
	A	B. MACHINE OPERATORS				C	D
	GENERAL AREA	SUB-CATEGORY 1	SUB-CATEGORY 2	SUB-CATEGORY 3	SUB-CATEGORY 4	CLEAN-UP	RAW FIBER HANDLING
Preparation/Waste Recovery							
1930-1944	26.2	78.0	78.0	45.9	—	54.4	35.0
1945-1964	8.1	23.9	23.9	14.1	—	16.7	10.8
1965-1975	5.8	17.2	—	10.1	—	12.0	7.3
Carding							
1930-1935	10.8	13.3	—	—	—	18.1	22.8
1936-1945	5.3	6.5	—	—	—	8.8	11.0
1946-1965	2.4	2.9	—	—	—	4.0	5.0
1966-1975	4.3	5.3				7.2	9.0
Ring Spinning							
1930-1965	8.2	6.6	—	—	—	N	N
1966-1970	8.6	6.9	—	—	—	N	N
1971-1975	6.2	5.0	—	—	—	N	N
Mule Spinning 1930-1975	4.6	4.6	—	—	—	6.7	N
Foster Winding							
1930-1937	10.4	13.6	—	—	—	20.9	N
1938-1975	4.2	5.5	—	—	—	8.4	N
Twisting							
1930-1938	24.6	36.0	—	—	—	31.9	31.9
1939-1975	5.4	7.9	—	—	—	7.0	7.0
Universal Winding							
1930-1975	4.1	4.1	—	—	—	8.4	N
Heavy Weaving							
1930-1936	9.2	17.3	9.7	14.3	5.3	30.6	30.6
1937-1975	2.6	4.6	2.6	3.8	1.4	8.2	8.2
Draper Weaving 1930-1975	2.7	2.7	—	—	—	6.9	—

N - No jobs within particular UJC

DRAFT. SUBJECT TO REVISION. NOT TO BE QUOTED

Published by AsbestosClaims.Law
asbestosclaims.law/library/25485/6

TABLE 7. SUMMARY OF DOSE-RESPONSE RELATIONSHIPS FOR SELECTED CAUSES AMONG WHITE MALES ACHIEVING 15 OR MORE YEARS LATENCY

Cumulative Dose (Fiber/cc X days)	All Causes			Diseases of the Circulatory System (400-468)			Lung Cancer (162,163)			Digestive System Cancer (150-159)			Other Nonmalignant Respiratory Diseases (510-527)		
	Obs.	Exp.	SMR	Obs.	Exp.	SMR	Obs.	Exp.	SMR	Obs.	Exp.	SMR	Obs.	Exp.	SMR
<10,000	65	55.17	118*	21	24.37	86	8	3.59	223*	1	2.73	37	1	1.41	71
10,000- 40,000	57	32.83	174**	23	16.94	136*	7	1.96	357**	3	1.85	162	7	0.78	897**
40,000-100,000	32	13.53	235**	7	6.37	110	9	0.92	978**	3	0.79	380	7	0.38	1842**
100,000-200,000	6	3.42	175	1	1.30	77	2	0.04	5000*	0	0.16	—	2	0.08	2500*
Total	160	105.05	151**	52	48.98	106	26	6.51	399**	7	5.53	127	17	2.65	642**

* $p < 0.05$

** $p < 0.01$

DRAFT. SUBJECT TO REVISION. NOT TO BE QUOTED

Published by AsbestosClaims.Law
asbestosclaims.law/library/25485/7

DRAFT. SUBJECT TO REVISION. NOT TO BE QUOTED

DISCUSSION

Statistically excess mortality was observed for lung cancer and nonmalignant respiratory diseases among chrysotile asbestos textile workers. Furthermore, using cumulative dose as the exposure variable and the SMR as the measure of disease risk, strong dose-response relationships were observed for both lung cancer and nonmalignant respiratory diseases. A linear relationship appears to adequately describe the form of the dose-response curve for both diseases. Lung cancer demonstrated a statistically significant excess in even the lowest cumulative exposure category of less than 10,000 fiber/cc x days.

There are several factors which need to be considered in evaluating the occupational contribution to observed mortality patterns. The most important of these are the choice of standard population death rates to estimate expected deaths and cigarette smoking patterns among the cohort. Other potential confounders such as age, race, sex, and calendar time period were dealt with in the study design.

The standard population death rates chosen for this study were those for white males for the entire United States. Table 8 gives a comparison of lung cancer (ICDA 162,163) age-adjusted mortality rates for 1950-1969 for counties in the same area as the study plant with state and U.S. rates (MASON et al., 1975). Lung cancer death rates for the state in which the plant was located were nearly equal to U.S. rates. On the other hand, rates for the county where the plant was located were 75 percent higher than U.S. rates for white males.

TABLE 8. COMPARISON OF LUNG CANCER MORTALITY RATES (ICDA 162,163) BETWEEN COUNTY IN WHICH STUDY PLANT WAS LOCATED AND CONTIGUOUS COUNTIES, 1950-1969

	Age-Adjusted Deaths/100,000 White Males
United States	37.98
State in Which Plant Located	37.83
County in Which Plant Located	66.5
Contiguous Counties	
A	40.1
B	43.3
C	42.5
D	40.2
E	53.4
Counties One Removed	
1	40.1
2	44.1
3	25.9
4	30.7
5	36.7
6	43.2
7	30.2

The choice of an appropriate comparison population for mortality analyses is difficult and arguments could be made for using rates for a set of counties contiguous to the county in which the plant was located. However, there are serious limitations to this approach which were considered in this study and resulted in rejecting the use of local county rates. First, the county in which the plant was located is the site of a large shipyard industry with peak employment of approximately 20,000 persons in 1943 (BLOT et al., 1978). Employees for this industry were largely drawn from the local population. Many of these workers are thought to have been exposed to asbestos during ship construction and repair. In an ecological study, BLOT et al. (1978) demonstrated an association between county lung cancer rates and shipyard employment. In a more refined case-control study,

Published by AsbestosClaims.Law
asbestosclaims.law/library/25485/8

BLOT et al. (1979) demonstrated a summary odds ratio of 1.6 for shipyard employment and lung cancer after adjusting for smoking, other occupations, age, race, and county of residence. These data suggest that lung cancer death rates in the area in which the plant was located are likely to be elevated by local shipyard employment.

A second factor to be considered in choosing local rates for comparison is the effect that the plant being studied might have had on local lung cancer death rates. Because of a lack of an employment record system prior to about 1930, it is difficult to estimate the exact number of persons ever employed at this plant; however, this is likely to exceed 10,000 prior to 1965. This number could have a significant impact on local lung cancer death rates assuming an overall lung cancer SMR of 200 or more for these workers.

The effects of shipyard and asbestos plant employment make the use of local death rates inappropriate for this study. However, even if rates for contiguous counties had been used (Table 8), the expected lung cancer rates for white males would have been increased by only approximately 15 percent, not nearly sufficient to account for the observed excess lung cancer risk.

Cigarette smoking is a known risk factor for respiratory cancer and smoking and asbestos exposures have been shown to act in a synergistic manner to greatly increase the risk of lung cancer (HAMMOND et al., 1978). Respiratory symptom questionnaires including questions on smoking history were administered by the U.S. Public Health Service to active workers in this plant in 1964 and again in 1971. In addition, smoking data available from plant medical records were also collected. While smoking histories are not available on all cohort members, these data are useful in estimating the prevalence of smoking in this plant for comparison with smoking patterns among U.S. males who were used as the standard population for estimation of expected lung cancer deaths.

The prevalence of cigarette smoking status among the asbestos study cohort is given in Table 9. These data largely represent the smoking prevalence found by the 1964 PHS survey since cohort entry was limited to those achieving 6 months employment before 1965. The PHS 1971 data and company data were used only for those missed in 1964. Among white males, 52.4 percent were found to be current smokers, 25.3 percent nonsmokers, and 22.3 past smokers.

TABLE 9. SUMMARY OF CIGARETTE SMOKING PATTERNS FOR WHITE MALE ASBESTOS TEXTILE WORKERS AND COMPARISON WITH DATA FOR U.S. WHITE MALES

	Current Smoker %	Past Smoker %	Non Smoker %
Asbestos Workers (N = 292)	52.4	22.3	25.3
U.S. White Adult Males (1965)	51.5	22.1	26.4

Table 9 also compares smoking prevalence among the study cohort members with comparable data for U.S. adults (USPHS, 1979). These data show the prevalence of smoking among white males in the study cohort to be nearly identical to that of U.S. white males. The 22.3 percent prevalence of past smokers is also identical to U.S. figures. Available smoking data for this cohort suggest that the observed lung cancer and nonmalignant mortality excess among white males cannot be explained by cigarette smoking independent of asbestos exposure. This is supported by the dose-response data. While smoking cannot explain the observed lung cancer excess, an interactive effect with asbestos exposure is likely.

An important finding of this study is excess lung cancer and nonmalignant respiratory disease among workers exposed to chrysotile. There are few other published reports with which to compare the dose-response data obtained in this study. In fact, there are no other reports of dose-response using exposures expressed as fibers/cc by the phase contrast method; all other reports have used impinger (MPPCF) data (BITHELINE and HENDERSON, 1973; MCDONALD et al., 1973; HER MAJESTY'S STATIONERY OFFICE, 1979). For comparison with other published data, approximate impinger exposure values, expressed as MPPCF x years, were calculated for data from the current study using the impinger-membrane filter conversions derived in this study. Estimated dose-response for lung cancer based on these estimates are given in Table 10, along with other published data.

The data in Table 10 shows the SMR for lung cancer at a given cumulative dose for the present study to be much higher than other published values. However, there are differences in the designs of the three studies which may account for some of this apparent discrepancy. For example, the MCDONALD et al. (1973) study included person-years prior to 15/10 years latency; thus, expected deaths are overestimated, especially in the lower exposure categories. The study by BITHELINE and HENDERSON (1973) consisted of retirees 65 years or older. In the present study, only 6 of 26 lung cancer deaths were 65 or older. The BITHELINE study may be a survivor population with less lung cancer risk for those surviving to age 65.

The current OSHA exposure standard of 2.0 fibers/cc is based on an allowable lifetime exposure of 100 fibers/cc x years (i.e., 2.0 fibers/cc for 50 years). Based on data from this study, elevated risks are predicted for lung cancer and for nonmalignant respiratory diseases at this exposure level. Of course, this is based on use of cumulative dose concept and ignoring any possible "dose rate" effect as average exposures for most members of the cohort were considerably above 2.0 fibers/cc. Historic exposures at this plant have been considerably above 2.0 fibers/cc.

Published by AsbestosClaims.Law
asbestosclaims.law/library/25485/9

DRAFT. SUBJECT TO REVISION. NOT TO BE QUOTED

TABLE 10. COMPARISON OF DOSE-RESPONSE RELATIONSHIPS FOR LUNG CANCER WITH OTHER PUBLISHED DATA

Present Study		Enterline and Henderson (1973)		McDonald et al. (1973)	
Approximate MPPCF x Yrs.	SMR	MPPCF x Yrs.	SMR	MPPCF x Yrs.	SMR
<9.1	223			<10	97
9.1-36.5	357			10-30	84
36.5-91.3	978			30-100	117
		<125	168.2		
		125-249	224.5	100-300	119
		250-499	296.3	300-600	175
		500-749	500.0	>600	281
		>750	555.6		

A noteworthy finding of this study is that only one of 191 deaths (0.5%) among white males was due to mesothelioma. It is possible that mesothelioma is under-diagnosed among this cohort and certain deaths mentioning "cancer of the abdomen" are suspect. However, others have also found lower mortality due to mesothelioma among cohorts exposed only to chrysotile (MCDONALD et al., 1971; NICHOLSON et al., 1979; WEILL, et al., 1979). ROBINSON et al. (1979) observed 17 mesotheliomas among 1040 deaths in a plant using predominately chrysotile; however, some crocidolite and amosite were used in the plant.

REFERENCES

BLOT, W.J., HARRINGTON, M., TOLEDO, A., HOOVER, R., HEATH, C., and FRAUMENI, J.F. (1978) Lung Cancer after Employment in Shipyards During World War II, New England Journal of Medicine, 299, No. 12, 620-624.

BLOT, W.J., STONE, B.J., FRAUMENI, J.F., and MORRIS, L.E. (1979) Cancer Mortality in U.S. Counties with Shipyard Industries During World War II, Environmental Research, 18, 281-290.

CORNEL, W. (Dec. 1971) Measurement of the Concentration of Health - Impairing, Especially Silicogenic Dusts at Work Places of Surface Industries, Staub, 31, 16-23.

CORNEL, W. (May 1966) The Confidence Limits for the Mean Values of Dust Concentration, Staub, 26, 36-45.

CORN, M. and ESMEN, N.A. (1979) Workplace Exposure Zones for Classification of Employee Exposures to Physical and Chemical Agents, American Industrial Hygiene Association Journal, 40, 47-57.

CUTLER, S.J. and EDERER, F.S. (1958) Maximum Utilization of the Lifetable Method in Analyzing Survival, Journal of Chronic Diseases, 8, 699-712.

DEMENT, J.M. (1980) Estimation of Dose and Evaluation of Dose-Response in a Retrospective Cohort Mortality Study of Chrysotile Asbestos Textile Workers, Doctoral Dissertation, University of North Carolina, School of Public Health, Chapel Hill, North Carolina.

ENTERLINE, P.E. and HENDERSON, V. (1973) Types of Asbestos and Respiratory Cancer in the Asbestos Industry, Archives of Environmental Health, 27, 312-317.

ESMEN, N.A. (1979) Retrospective Industrial Hygiene Surveys, American Industrial Hygiene Association Journal, 40, 58-65.

HAMMOND, E.C., SELIKOFF, I.J., and SEIDMAN, H. (June 1978) Asbestos Exposure, Cigarette Smoking, and Death Rates, Presented at the International Conference of Health Hazards of Asbestos, New York Academy of Sciences.

HER MAJESTY'S STATIONERY OFFICE (1979) Asbestos: Final Report of the Advisory Committee, 1 and 2, London.

IARC (INTERNATIONAL AGENCY FOR RESEARCH ON CANCER)(1977) IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man: Asbestos, 14, WHO, Lyon.

LEIDEL, N.A. and BUSCH, K.A. (1975) Statistical Methods for the Determination of Noncompliance with Occupational Health Standards, HEW Publication No. (NIOSH) 75-159, NIOSH, Cincinnati, Ohio.

MASON, T.J., MACKAY, F.W., BLOT, W.J., and FRAUMENI, J.F. (1975) Atlas of Cancer Mortality for U.S. Counties: 1950-1969, National Cancer Institute, U.S. Department of Health, Education, and Welfare, DHEW Publication No. (NIH) 75-780.

Estimates of Dose-Response for Respiratory Cancer Among Chrysotile Asbestos Textile Workers (1982) Published by AsbestosClaims.Law
ACL Doc 25485 · Page 10 of 11 asbestosclaims.law/library/25485/10

MCDONALD, J.C., GIBBS, G.W., SIEMIATYCKI, J., and ROSSITER, C.E. (1971) Mortality in the Chrysotile Asbestos Mines and Mills of Quebec, Archives of Environmental Health, 22, 677-686.
MCDONALD, J.C., ROSSITER, C.E., FYSSEN, G., and MCDONALD, A.D. (1973) Mortality in the Chrysotile Producing Industry of Quebec: A Progress Report, In: Proceedings of the Fourth International Pneumoconiosis Conference, Bucharest.
NICHOLSON, W.J., SELIKOFF, I.J., SEIDMAN, H., LILIS, R., and FORMBY, P. (1979) Long-Term Mortality Experience of Chrysotile Miners and Millers in the Thford Mines, Quebec, Annals of the New York Academy of Sciences, 330, 11-21.
NIOSH (National Institute for Occupational Safety and Health)(1976) Revised Recommended Asbestos Standard, U.S. Department of Health, Education, and Welfare, DHEW (NIOSH), publication No. 77-169.
PEARSON, E.S. and HARTLEY, H.O. (Eds.)(1958) Biometrika Tables for Statisticians, 2nd Edition, 1, Cambridge University Press, Cambridge, Eng.
ROBINSON, C., LEMEN, R. and WAGONER, J.K. (1979) Mortality Patterns, 1940-1975 Among Workers Employed in Asbestos Textile Friction and Packing Products Manufacturing Facility, Dust and Disease, Lemen, R.A. and Dement, J.M., Eds., Society for Occupational and Environmental Health, Washington, D.C.
SHERWOOD, R.J., (1966) On the Interpretation of Air Sampling for Radioactive Particles, American Industrial Hygiene Association Journal, 27, 98-109.
U.S. PUBLIC HEALTH SERVICE (1979) Smoking and Health, A Report of the Surgeon General, U.S. Department of Health Education, and Welfare, Office of Smoking and Health, DHEW Publication No. (PHS) 79-50066, p. A-15.
WEILL, H., HUGHES, J., and WAGENKNACK, C. (1979) Influence of Dose and Fiber Type of Respiratory Malignancy Risk in Asbestos Cement Manufacturing, American Review of Respiratory Diseases, 120, 345-354.

FIGURE 1 Comparison of HPPCF-Membrane Filter Conversions Obtained for Paired Sample and Concurrent Sample Analyses

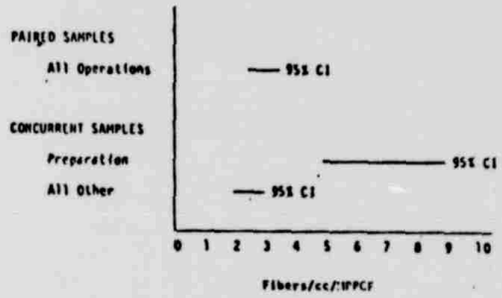
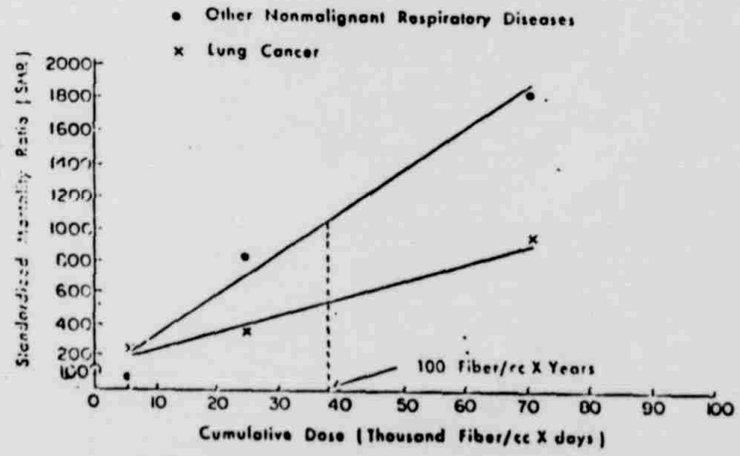


FIGURE 2 Plot of Lung Cancer and Other Nonmalignant Respiratory Disease SMRs by Cumulative Dose, White Males



DRAFT. SUBJECT TO REVISION. NOT TO BE QUOTED