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DUSTS and DISEASE

Edited by: **RICHARD LEMEN**
University of Illinois, School of Public Health, Chicago IL 60680

JOHN M. DEMENT
University of North Carolina, School of Public Health, Chapel Hill, NC 27514

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MORTALITY PATTERNS AMONG MINERS AND MILLERS OCCUPATIONALLY EXPOSED TO ASBESTIFORM TALC

David P. Brown, John M. Dement
U.S. Department of Health, Education and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations and Field Studies, Industry-wide Studies Branch, Cincinnati, Ohio 45226

Joseph K. Wagoner
U.S. Department of Labor, Occupational Safety and Health Administration, Office of the Assistant Secretary, Washington, D.C. 20210

INTRODUCTION

The term "talc" in the mineralogical sense denotes a specific rock-forming mineral of the sheet silicate category; however, "talc" when referenced in the industrial or commercial setting may represent a varied mixture of associated minerals with similar physical properties as the mineral talc (Rohl *et al.*, 1976). Minerals commonly found associated with the talc include calcite, quartz, diopside, magnesite, serpentines (chrysotile, antigorite and lizardite) and fibrous and non-fibrous amphiboles (tremolite, anthophyllite and actinolite) (Rohl *et al.*, 1976; Stemple and Brindley, 1960). Few studies, however, have been undertaken which adequately characterize the various minerals to which talc workers are exposed and simultaneously delineate the latent disease manifestations associated with those work environments.

Recognizing the need for additional research with regard to health hazards from industrial talc exposure, the National Institute for Occupational Safety and Health (NIOSH) has undertaken an industrywide program to study the talc mining and milling industry for two different geographic areas, New York State (fibrous talc) and Vermont (non-fibrous talc). This program included detailed industrial hygiene studies to characterize the various agents to which workers have been exposed, cross-sectional medical surveys to evaluate respiratory impairment and retrospective cohort studies to evaluate latent disease patterns among workers having been exposed to talc in the work environment.

The present report will restrict itself to an investigation of fibrous talc as mined and milled in the Gouverneur Talc District of upper New York State. This "talc" mining district located in St. Lawrence County represents a complex association of amphiboles (anthophyllite, tremolite, etc.), talc, quartz, and serpentines (Ross, 1974). Previous studies by Kleinfeld *et al.* (1967, 1974) of asbestiform talc miners and millers in this district have demonstrated a significantly increased proportionate mortality due to both malignant and non-malignant respiratory diseases. One company mining talcs in this district maintains that these studies are not appropriate with regard to all talcs in the Gouverneur Talc District. This company has stated that talcs extracted from its original mine in the Gouverneur Talc District did not contain asbestiform minerals and has so certified these talcs as such. In contrast, however, Kleinfeld *et al.* (1973) demonstrated the presence of asbestiform tremolite and anthophyllite in talc extracted from this mine. To address this contradiction, the present study was restricted to that one mine and mill reported to be exploiting

The talc mine and mill chosen for this study began operations in the Gouverneur Talc District of upper New York State in 1947. Talcs extracted from this mine are used for a variety of applications including ceramincs, pottery artware, electrical insulators, ceramic tile glaze and flux, paint fillers in putties, and in spackling compounds.

METHODS

A retrospective cohort study was initiated to determine whether workers who have been employed at this mine and mill have experienced any unusual mortality patterns. The study cohort was defined as all white[1] males initially employed sometime between January 1, 1947 and December 31, 1959. This cutoff date was selected to allow for a sufficient latent period for any development of chronic disease. An effort was made to determine the vital status of each individual in the cohort as of June 30, 1975 and person-years at risk and duration of employment were accumulated until this date. Vital status was determined through records maintained by Federal and State agencies, including the Social Security Administration, state vital statistics offices, and state motor vehicle registration. For those individuals who could not be located through these sources, U.S. Postal Mail Correction Services and other follow-up searches were used.

For all those who were known to be deceased, death certificates were requested and causes of death were interpreted by a qualified nosologist according to the International Classification of Diseases (ICD Codes) in effect at the time of death and then converted to the 7th Revision of the ICD Codes. A modified life table technique was used to obtain person-years at risk of dying by five year calendar time periods, by five year age groups, by duration of employment and by number of years since initial employment at the talc company. Comparison was made between the observed number of deaths among the study cohort and the number expected for this population using age, calendar time, cause specific mortality rates of the U.S.

TABLE 1. Vital Status of 398 Talc Workers Employed Between 1947-1960

Known to be Alive	308	(77%)
Known to be Deceased	74	(19%)
Unknown Vital Status	16	(4%)
Total	398	

general white male population. The vital status of 96% of the cohort was confirmed (Table 1). Those with an unknown vital status are assumed to be alive as of June 30, 1975 so as not to overestimate the true risk of mortality associated with exposure to talc.

[1] Those cohort members where racial status was unknown were considered white for purposes of the

RESULTS

A total of 398 workers meeting the study cohort definition generated 8,733 person years at risk of dying. Fifty percent of the workers were employed less than one year, while less than twenty-five percent were emplyed for ten years or more. Tables 2 and 3 illustrate the distribution of the study population by duration of employment and by date of initial employment.

TABLE 2. Study of Cohort of Talc Workers According to Length of Employment

Duration of Employment	Number	
<1 month	74	(18%)
1 month - 6 months	97	(24%)
6 months - 12 months	31	(8%)
1 year - 10 years	90	(23%)
>10 years	106	(27%)
Total	398	

TABLE 3. Study Cohort of Talc Workers According to Date of Initial Employment

Date of Initial Employment	Number	
1947 - 1949	174	(44%)
1950 - 1954	156	(39%)
1955 - 1959	68	(17%)
Total	398	

Tables 4 and 4a summarize the deaths observed from the study cohort and those expected based on death rates for the U.S. whilte male population. Although the overall observed mortality is higher than expected, this difference is not statistically significant. However, several specific causes of death exhibit increased mortality. The standardized mortality ration (SMR)[2] is significantly elevated for the cause of

TABLE 4. Observed and Expected Deaths According to Major Cause Among Talc Miners and Millers

Cause of Death	Number	Observed	Expected	SMR
Respiratory T.B.	001-008	3.0	0.49	610[1]
Malignant Neoplasms	140-205	19.0	10.6	180[1]
Diseases of the Heart	400-443	27.0	26.5	102
All Non-Malignant Respiratory Disease	470-493	8.0	2.9	277[1]
Accidents	E800-E999	10.0	6.4	156
Other Known Causes	---	7.0	14.4	---
Total		74.0	61.3	120

[1] $p<0.05$
[2] $p<0.01$

TABLE 4a. Observed and Expected Deaths According to Specific Cause Among Talc Miners and Millers

Cause of Death	Number	Observed	Expected	SMR
Malignant Neoplasms	140-205	19.0	10.6	180[2]
Digestive System	150-159	3.0	3.0	100
Respiratory System	160-164	10.0	3.5	290[2]
Bronchogenic	162-163	9.0	3.3	270[1]
Lymphatic and Hematopoietic	200-205	4.0	1.2	330[1]
Other Neoplasms	---	2.0	2.9	69
All Non-malignant Respiratory Disease	470-527	8.0	2.9	280[1]
Influenza, Pneumonia, Bronchitis and Acute Upper Respiratory Infection	470-502	3.0	1.5	200
Other Non-malignant Respiratory Disease	510-527	5.0	1.3	380[1]

[1] $p<0.05$
[2] $p<0.01$

death category "all malignant neoplasms", which is partly due to the significant increase in bronchogenic cancer (9 obs. vs. 3.3 exp.; $p<0.05$). Other statistically significant increases for specific causes of death occurred in the categories: "non-malignant respiratory disease other than influenza, pneumonia, bronchitis and

T.B." (3 obs. vs. 0.49 exp.; $p<0.05$ - two of which mention occupational disease of the lung) and "lymphatic and hematopoietic diseases" (5 obs. vs. 1.3 exp.; $p<0.05$). One case of mesothelioma was observed.

Table 5 demonstrates the association between bronchogenic cancer and interval since initial date of employment (latency). As seen, there is an increasing risk of bronchogenic cancer with increasing latency, a trend consistent with an occupational etiology. In addition, the deaths due to bronchogenic cancer have an average latency of 20 years a period previously observed for a population occupationally exposed to anthophyllite and other minerals (Kiviluoto and Meurman, 1969; Meurman *et al.*, 1974; Nurminen, 1962).

TABLE 5. Bronchogenic Cancer Among Talc Miners and Millers According to Interval Since Onset of Employment (Latency)

Interval Since Onset of Employment (Years)	Observed	Expected	SMR
<10	0	0.5	---
10 - 19	3	1.5	200
20-28	6	1.3	460[1]
Total	9	3.3	270[1]

[1]$p<0.01$

Three additional deaths due to bronchogenic cancer are known to have occurred among study members. However, these deaths occurred shortly after the cutoff date (6/30/75) for analysis and therefore were not included as observed deaths. One individual worked for 17 continuous years at the talc company under study and died at the age of 50. The latency period was 24 years. Another individual who worked for 2 months at the talc company died at the age of 54. The latency period was 27 years. The third lung cancer death was that of a worker employed for 12 years at the company under study and 12 years previously at another New York talc company. He died at the age of 59 and had a latency period of 23 years.

At least three cases of non-malignant respiratory disease among study cohort members are known to have been reported to the New York State Workmen's Compensation Board. These individuals filed workmen's compensation claims for: (1) pneumoconiosis, chronic bronchitis; (2) talcosis, pulmonary fibrosis. These individuals worked at the talc company under study for 18 years, 18 years and 25

DISCUSSION

The results of the present study demonstrate an excessive risk of mortality due to both lung cancer and non-malignant respiratory disease among a cohort of talc workers occupationally exposed to asbestiform tremolite, anthophyllite and little free silica. However, several possible confounding factors must be taken into consideration before one can attribute these observed mortality patterns to occupational exposure received at this talc mine and mill.

One such factor that has been shown to be correlated with the causation of lung cancer is cigarette smoking. The smoking patterns are largely unknown for this cohort as is the case with most retrospective studies. However, it has been estimated that in a heavy smoking worker population, smoking by itself would increase the expected lung cancer mortality risk by no more than 49% (Lundin *et al.*, 1971). Thus, cigarette smoking is unlikely *per se* to account for the increased bronchogenic cancer risk observed among these talc miners and millers.

Another factor to be considered is other occupational exposure among cohort members resulting from prior employment. Several of these individuals worked at other New York State talc companies located in the Gouverneur Talc District. Due to these considerations, an industrial hygiene analysis was carried out to compare the make-up of talcs in neighboring mines. These comparisons are given in Table 6. The analysis of amphibole fiber exposure characteristics between the talc operations acknowledged to have asbestiform talc and the mine and mill under study showed them to be substantially the same. Thus, while exposure levels in other talc companies may have been higher, all operations involve exposures to asbestiform

TABLE 6. Comparison of Airborne Fiber Characteristics in Study Mine and Mill Operations with New York Talc Operations Acknowledged as Containing Asbestiform Minerals

Airborne Fiber Characteristic	Asbestiform Mine and Mill	Study Mine and Mill	Statistical Significance
Proportion Positive	0.50	0.58	$p<0.05$
Proportion Anthophyllite	0.47	0.45	NS[2]
Proportion Tremolite	0.03	0.13	$p<0.001$
Median Fiber Length			
Anthophyllite	1.61 μm	1.45 μm	NS
Tremolite	[1]	1.55 μm	—
Median Fiber Diameter			
Anthophyllite	0.16 μm	0.13 μm	NS
Tremolite	[1]	0.19 μm	—
Median Fiber Aspect Ration			
Anthophyllite	9.9	9.5	NS
Tremolite	[1]	7.5	—
% of Fiber <5 μm in Length			
Anthophyllite	92	90-92	NS
Tremolite	[1]	97	—

[1]Insufficient number of fibers observed for calculation of size distribution parameters.

amphiboles with similar fiber characteristics. These operations when measured in 1975 were shown to have fiber exposures far in excess of established OSHA asbestos standards. Thus, exposures to asbestiform tremolite and anthophyllite stand out as the prime etiologic factors associated with the observed increase in bronchogenic cancer and nonmalignant respiratory disease among this study cohort.

Of interest is the fact that four of ten deaths due to bronchogenic cancer in this cohort were employed less than one year in the operations under study and only two of these cases are known to have previous exposures to talcs containing asbestiform minerals. (One of the two was employed in such operations less than six months.) Although this cohort is relatively small to assess actual risk due to these particular exposures, it may be plausible that brief periods of exposure to elevated concentrations of asbestiform minerals may be associated with an increased bronchogenic cancer risk. Such an observation has previously been reported (Seidman *et al.*, 1976).

One death due to mesothelioma is known to have occurred in the study population. This individual worked for 16 years in the talc operation and had 11 years previous employment in construction work. Without full knowledge of this individual's exposure as a construction worker, it is difficult to arrive at any conclusions regarding the etiologic role of talc exposure from this mine and mill for this case. Although previous studies (Kiviluoto and Meurman, 1969; Kleinfeld *et al.*, 1967; Kleinfeld *et al.*, 1974; Muerman *et al.*, 1974; Nurminen, 1962) have not shown an association between exposure to asbestiform anthophyllite or tremolite and subsequent development of mesothelioma, a more recent study in Turkey by Baris (1975) has demonstrated an apparent increased risk of developing mesothelioma among residents of a particular community exposed to asbestiform tremolite probably from their drinking water. Therefore, the possible association between exposure to asbestiform tremolite and the risk of developing mesothelioma should be further studied by continual follow-up of the talc workers included in this study.

CONCLUSIONS AND RECOMMENDATIONS

A study of mortality patterns among miners and millers of talc containing asbestiform amphiboles (tremolite and anthophyllite) demonstrated excessive mortality due to non-malignant respiratory disease and bronchogenic cancer. These results are in agreement with other studies of occupational groups exposed to the same or similar minerals or mineral mixtures. Although several cohort members had periods of prior employment in neighboring talc operations, all mines and mills including the operations under study have been shown to have similar fiber exposure characteristics. It must, therefore, be concluded that exposures to talcs from the Gouverneur mining area are associated with an increased risk of bronchogenic cancer and non-malignant diseases of the respiratory system.

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STOMACH CANCER AMONG RUBBER WORKERS: AN EPIDEMIOLOGIC INVESTIGATION

Steve Blum[1], Earl W. Arp, Jr., Allen H. Smith, Herman A. Tyroler

Occupational Health Studies Group, Univ. of North Carolina, Chapel Hill, North Carolina, 27514.

In 1970, the United Rubber Workers Union negotiated with the six major U.S. rubber companies for a comprehensive program of research into work related health problems. The Occupational Health Studies Group (OHSG) at the University of North Carolina is conducting research within four of these companies—Goodyear, Firestone, Uniroyal, and General.

Our first efforts after initiation of the contract included numerous analyses designed to indicate whether mortality from specific disease entities, or categories, was occurring at expected, or greater than expected, frequencies. Expected numbers are based on age, race, and sex, comparable data for the general U.S. population - a population assumed to be nonexposed to the specific pollutants found within the environment of the rubber industry. This procedure yields a ratio, the Standardized Mortality Ratio (or SMR), of observed to expected numbers of deaths from the disease under investigation. When the SMR is greater than 100 we are observing more deaths than expected, while a deficit is indicated by a ratio under 100.

While we observed an overall deficit of deaths from all causes combined, we nevertheless observed specific disease entities which occurred in excess, among which was stomach cancer, which appeared in excess in both companies studied thus far.

The present study is based on the experience of groups within these two companies, referred to as Companies A and B, whose combined cohorts numbered approximately 17,000 employees, and included members of both sex and race groups. To qualify for inclusion in the cohort, employees must have been aged 40-84 years as of 1 January 1964, and were permitted to be either active or retired at that time. Their mortality experience was recorded, with about 98% follow-up, for the ten-year period ending 31 December 1973. As can be seen from Table 1, our initial findings among male production workers revealed excess of stomach cancer in both companies as the SMR's indicate.

Because of this consistently observed excess, we decided to conduct an analytic study to help us determine whether these excesses were artifactual, whether they were non-occupational in origin, or whether the excess was due to occupational factors, presumably involving exposure to known or suspect stomach carcinogens believed to have been present within the environment of the rubber industry (Table 1).

Accordingly, a case-control design was chosen for this investigation, which involved a comparison of the occupational and non-occupational characteristics of the 100 cases and 400 appropriately matched controls, with the analyses conducted separately for each of the companies within the study. These 100 cases were comprised mostly of individuals whose death certificates indicated stomach cancer as the underlying cause of death, although some appeared elsewhere on the death