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A STUDY OF ASBESTOSIS IN THE ASBESTOS TEXTILE INDUSTRY

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INTRODUCTION

Several important properties of asbestos have led to its widespread use in industry. As everyone knows, it is noncombustible and an excellent insulator against heat and electricity. Fewer people seem to be aware that its fibers are sufficiently long and flexible to be carded, spun, and woven like wool, flax, or cotton. Utilizing these properties of asbestos, industries have been developed in this country which employed more than 6,000 men and women in slightly more than 60 establishments in 1935.

Another property of asbestos has been discovered more recently. When asbestos dust is inhaled daily, year in and year out, a lung disease termed asbestosis may develop. In many respects asbestosis resembles silicosis, but it differs from silicosis in several important particulars which will be discussed in the medical section of this report.

The first record of a case of asbestosis seems to have been made by Montague Murray in 1900. The first complete description of the disease and of the "curious bodies" seen in lung tissue and sputum appeared in 1927 when Cooke (9) and McDonald (22) reported two cases of asbestosis and listed their reasons for believing that asbestosis bodies originate from asbestos fibers that reach the lungs. The publication of their papers aroused general interest in the subject and numerous papers appeared soon afterward. Hoffman (46) appears to have been the first American to call attention to the magnitude of the asbestosis problem. In 1918 he reported that 13 deaths from asbestosis had occurred among asbestos textile workers, and about the same time Panconst, Miller, and Landis (29) reported on 17 cases of asbestosis. Mill's (26) paper was the first pathological report on asbestosis published in the United States, and in the same year, 1930, Lynch and Smith (38) reported on asbestosis bodies found in the sputum of asbestos workers.

Because several satisfactory literature reviews of asbestosis have appeared in recent years there seems to be no need to present a complete literature review in this report. Some of the more useful literature reviews have been listed in the annotated bibliography. In Merewether's (25) review emphasis is laid on the relation of asbestosis

to working conditions. The clinical aspects of the subject are well treated. Gloyne's (16) discussion of the pathology of asbestosis is particularly helpful. Middleton's (47) Milroy lectures on pneumoconiosis contain a section on asbestosis. Egbert (13) has summarized the literature reports on 28 fatal cases of asbestosis. "Active pulmonary tuberculosis was present in 6 instances of the total 28 cases; the fatal outcome was primarily the result of tuberculosis in 3 instances."

OBJECTIVES OF THE STUDY

The Public Health Service was requested by the State Board of Health and the Industrial Commission (administrator of the Workmen's Compensation Act) of North Carolina to assist them in making an engineering and medical study of health hazards in the asbestos textile industry.[1] The objectives of this study were threefold: (1) To make a medical study of the effects of long-continued inhalation of asbestos dust on the human body; (2) to identify the manufacturing processes that create dust and to recommend practices and, when necessary, equipment that will reduce the dust exposure of workers; and (3) to find out what concentration of asbestos dust can be tolerated without injury to health.

[1] This represents one of the first uses of Social Security funds for a cooperative project carried on by the Public Health Service and a State health department.

METHODS.

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INCIDENCE OF ASBESTOSIS

Preceding sections of this bulletin have stressed the importance of the X-ray findings in establishing a diagnosis of asbestosis. The reason, of course, is that X-ray examination is the most direct means now available for detecting the primary effect of inhaled asbestos dust on the body; namely, initiation of interstitial fibrosis of lung tissue. Classification of asbestosis into a series of stages which follow one another in their development is a difficult matter because it depends to a great degree on the interpretation of relatively minor changes in the lung-field markings. Other investigators have encountered the same difficulty. Lanza, McConnell, and Fehnel (17) and Fulton, Dooley, Matthews, and Houtz (15) set up a category of doubtful cases of asbestosis. Stage 1 in the accompanying tabulation more or less corresponds to their category of doubtful cases. It comprises cases in which diagnosis rests largely on X-ray evidence. Stage 2 represents early cases of asbestosis, and stage 3 designates moderately advanced cases. More advanced cases (stage 4) are relatively infrequent. Stage 5 was reserved for bed-ridden cases.

TABLE 41.—*Relation of asbestosis to lung-field markings*

X-ray findings	Asbestosis absent	Stages of asbestosis				Total
		1	2	3	4	
Total	372	24	26	18	7	445
First-degree linear	297					297
Second-degree linear	48	11	3			79
First-degree ground glass	8	13	22	8		43
Second-degree ground glass	4		1	8	7	20

Table 41 illustrates the relationship of stages of asbestosis to the X-ray findings. Although diagnoses of early stages of asbestosis were occasionally made in the absence of definite ground-glass lung-field markings when cough, dyspnoea, and objective findings were present in sufficiently advanced degree, diagnoses of the later stages of asbestosis were not made unless unmistakable ground-glass markings were present in the lung fields.

The incidence of asbestosis increases rapidly with increasing dust exposure. A fifth of the workers with an exposure of 50 to 99 million particle years, and half of the workers having an exposure of more than 100 million particle years had asbestosis. In comparison with anthraco-silicosis these are exceedingly low dust-exposure values

The relation of asbestosis to dust concentration and length of employment, in table 43, is of great practical importance because it shows what working conditions are most likely to cause asbestosis and how long a period of exposure may elapse before the disease becomes evident.

TABLE 42.—*Relation of asbestosis to total dust exposure* [1]

Diagnosis	Million particle years				Total
	Less than 25	25 to 49	50 to 99	Over 100	
Essentially normal	191	81	43	32	347
Asbestosis 1	6	2	6	13	25
Asbestosis 2	0	1	1	23	25
Asbestosis 3	0	0	6	11	17
Asbestosis 4	0	0	0	7	7
Total	198	84	56	105	441

[1] 20 persons whose exposure could not be estimated and 2 persons with active pulmonary tuberculosis have been excluded from this table.

TABLE 43.—*Occurrence of asbestosis in relation to dust concentration and length of employment*

PERCENTAGE WITH ASBESTOSIS

Dust exposure, million particles per cubic foot		Years in asbestos industry		
		0 to 4.9	5 to 9.9	Over 10
0 to 4.9	Affected	2	1	0
	Exposed	84	19	5
	Percentage	2%	5%	0%
5 to 9.9	Affected	0	8	13
	Exposed	70	37	19
	Percentage	0%	18%	68%
Over 10	Affected	6	22	21
	Exposed	134	43	16
	Percentage	4%	51%	84%

The percentage of persons with asbestosis increases greatly with increasing length of employment. Lanza, McConnell, and Fehnel (17) reported a similar trend; their percentage values are higher than these. There are two explanations for the small number of persons employed 15 years or more. This group of asbestos textile factories has been in operation from 6 to 16 years, and because of the relatively short life of the industry in this section of the country comparatively few persons have been exposed to asbestos dust for a long time. Another explanation is suggested by the fact that almost three-fourths of the workers employed more than 15 years have the early stages, at least, of a disabling disease, asbestosis. Since there is no satisfactory way of locating and examining persons who drop out of an industry because of disability incurred therein, the percentage values of the foregoing tables are necessarily minimal estimates of the prevalence of asbestosis.

The incidence of asbestosis increases with increasing dust concentration. In their report of a similar study carried on in Pennsylvania asbestos textile factories, Fulton, Dooley, Matthews, and Houtz (15) found that 8 percent of the workers exposed to an average dust concentration of 5 million particles per cubic foot had asbestosis; 22 percent of the 17-million-particle group; and 57 percent of the 44-million-particle group had asbestosis.

THRESHOLD CONCENTRATION OF ASBESTOS DUST

From a practical standpoint, one of the most important results of a medical and engineering study such as this is the definition of safe working conditions in the industry under study. Ideally, a threshold concentration of dust should be the highest dust concentration that would not produce pneumoconiosis in originally healthy workmen during their entire working life. The chief difficulty in this study, as in most of the earlier studies of the Public Health Service, is that very few workmen are exposed for a long period of time to low concentrations of asbestos dust. Because of the importance of the problem, it seems to be desirable to use such data as are at hand to define tentative safe working conditions that may serve as standards for the guidance of factory managers and engineers until more complete data are available.

In an analysis of this kind the cases that occur at relatively low dust exposures are of especial significance because they indicate what the safe limits of exposure may be. These cases must be examined individually, as well as statistically, in order to be sure that there are no unusual features that would complicate statistical analysis. Below 2.5 million particles per cubic foot, the interpretation of table 43 offers no difficulties. None of the 39 persons exposed to dust concentrations below 2.5 million particles per cubic foot had a case of asbestosis, although, as a matter of fact, only 6 persons had been employed more than 5 years. Three doubtful cases of asbestosis fell in the range 2.5 to 4.9 million particles.

Because clean-cut cases of asbestosis were found only in dust concentrations exceeding 5 million particles per cubic foot, and because they were not found at lower dust concentrations, 5 million particles per cubic foot may be regarded tentatively as the threshold value for asbestos-dust exposure until better data are available.

In order to find out the levels to which asbestos-dust concentrations have been reduced in practice, an engineering study (7) was made in an asbestos textile factory in which dust control equipment has been recently installed. This shows that means are already available for reducing the dust exposure of a majority of asbestos textile workers to less than 5 million particles per cubic foot.

The data of table 43 provide a simple means of comparing asbestosis with other pneumoconioses. In a previously reported study of the Public Health Service (51) it was found that workmen in anthracite mines could be divided into three groups which differed with respect to the nature of the dust to which they were exposed. The percentages of men having any stage of anthraco-silicosis (1, 2, or 3) have been tabulated separately for each group in relation to average dust concentration and length of employment. In passing, it may be of interest to call attention to the difference between the pneumoconiosis-producing power of the three kinds of dust encountered in anthracite mines. If one compares groups of men with the same dust exposure and the same length of employment, in general the percentage of men with anthraco-silicosis increases with the free silica content.

TABLE 44.—*Percentages of workers exposed to certain concentrations of asbestos dust in asbestos textile factories where dust control measures are used to a limited extent and in factories where effective dust control is practiced*

Dust concentration (million particles per cubic foot)	Limited use of dust-control measures [1]	Extensive use of dust-control measures [2]
Over 10	46	7
5 to 9.9	26	17
2.5 to 4.9	15	32
Under 2.5	9	44

[1] Data from table 43.
[2] Data from (7).

TABLE 45.—*Percentage of men having anthraco-silicosis* [1]

Dust count in million particles per cubic foot	1,433 anthracite miners exposed to dust containing less than 5 percent free silica			872 men employed in haulageways who were exposed to dust containing about 13 percent free silica			151 rock workers exposed to dust containing about 35 percent free silica		
	Years in industry			Years in industry			Years in industry		
	Less than 15	15 to 24	Over 25	Less than 15	15 to 24	Over 25	Less than 15	15 to 24	Over 25
6 to 99	1.1	1.5	2.4	0.4	3.1	25.3	(2)	(2)	(2)
100 to 199	1.8	14.1	56.0	0	0	29.3	12.5	(2)	(2)
200 to 299	0	26.9	71.1	(2)	(2)	(2)	21.5	21.4	(2)
Over 300	1.7	54.5	86.8	(2)	(2)	(2)	4.8	56.2	92.0

[1] From table 30, p. 76, Public Health Bulletin No. 221.
[2] Less than 10 men examined.

As in asbestosis, the incidence of pneumoconiosis among anthracite miners increases with increasing length of employment. There is a much more definite increase in the incidence of anthraco-silicosis with increasing dust concentration than there is in asbestosis, probably

because men were exposed to a much greater range of dust concentrations in anthracite mines than in asbestos textile factories.

In comparison with the three kinds of dust encountered in anthracite mines, relatively low concentrations of asbestos dust and relatively short lengths of employment in the asbestos textile industry result in pneumoconiosis.

There was no free silica (quartz) in the dust encountered in the asbestos textile factories.

According to table 43, 16.3 percent of 69 former asbestos workers and 378 men and women employed at the time of the study in three asbestos textile factories had asbestosis. (Persons who were not exposed to appreciable quantities of asbestos dust have not been included.) Eight percent of the 378 workers employed at the time of study had asbestosis. This does not completely represent the incidence of asbestosis because about 150 employees were discharged from these factories 15 months before the present study was made. Many of the discharged asbestos workers had asbestosis, as the reports of Shull (31), Donnelly (12), and McPheeters (23) show. Although an attempt was made to examine as many as possible of these discharged cases, only 69 could be examined, 43 persons of whom had asbestosis according to the diagnostic standards employed in this study. If one assumes that the number of persons employed in these factories was the same before these 150 persons were discharged as it was when the study was made, and if one assumes that 62 percent of all the discharged cases had asbestosis, then 58 cases of asbestosis escaped observation. Adding these to the 73 that were found, dividing the sum by 447, and multiplying by 100 gives an estimated percentage of 27.5. This is not an unusual percentage value. In numerous studies of the dusty trades the percentage of workers with pneumoconiosis has been found to be between 20 and 25 percent. Two such studies may be mentioned. Of 7,722 miners and men seeking employment in lead and zinc mines at Picher, Okla., who were examined in 1927–28 (49), 21.3 percent had silicosis. In a study of anthracite miners (51), "The prevalence of anthraco-silicosis among the entire group of employees was found to be about 23 percent."

Other investigators have reported the incidence of asbestosis in asbestos textile factories. Lanza, McConnell, and Fehnel (17) reported, "Of the total of 126 X-ray examinations, 4 were diagnosed as second-degree asbestosis, 63 as first degree, 39 as doubtful, and 20 as negative." The persons he studied "were selected more or less at random from among those having more than 3 years of employment in the industry." Since Lanza did not examine all the employees in the factories he studied, percentage values calculated from his data are not directly comparable with rate of incidence for the present study.

Fulton, Dooley, Matthews, and Houtz (15) noted that "Asbestosis was found in 14 persons (12 men, 2 women), or 25 percent of the exposed group."

INCIDENCE OF ASBESTOSIS IN DIFFERENT OCCUPATIONS

The percentage of persons affected by asbestosis varies in different occupations. The numbers of persons employed in many of the occupational groups are so small that caution must be exercised in making comparisons, but the data seem to be of sufficient interest to warrant publication. Classified by departments, the preparation department has the highest percentage of asbestotic persons. Carding is the principal occupation in this department. Although only 8 of the 72 carders had been employed more than 10 years, 29.2 percent had asbestosis. Eleven carders had advanced asbestosis. No other occupational group had so large a proportion of advanced cases.

TABLE 46.—*Number and percentage of workers having asbestosis, classified according to department and occupation*

Department and occupation	Number employed	Percent with asbestosis	Number with asbestosis		
			Stage 1	Stage 2	Stages 3 and 4
Preparation	102	28			
Crushers	5		0	0	0
Willowers and shakermen	5		1	0	1
Pickers and pilers	20		2	0	1
Carders	72		4	6	11
Spinning, twisting, and winding	216	14			
Mule and ring spinners	65		2	9	5
Twisters	66		5	2	2
Yarn spoolers and winders	83		3	2	0
Carders	4		1	0	0
Weaving	99	14			
Cloth weavers	43		3	4	4
Tape and brake lining weavers	41		1	1	0
Creelers	15		1	0	0
Finishing	18	11			
Inspectors, calenderers, and finishers	15		0	1	0
Formers and grinders	3		1	0	0
Superintendence and utility	70	3	0	1	0
Shipping and outside labor	17	0	0	0	0
Office and others	31	0	0	0	0
Total	512	14	28	25	24

In the spinning, twisting, and winding department, the mule and ring spinners have a higher proportion of asbestotic persons than the average, 24.6 percent. Twenty of the sixty-five mule and ring spinners had been employed more than 10 years.

A third occupation with an excessive prevalence rate for asbestosis is cloth weaving, in which 25.6 percent of the workers are affected. Only 3 of the 43 workers had been employed more than 10 years.

Lanza (18) has called attention to a point of interest, namely, that British investigators have found asbestosis more severe and menacing than it was in the United States. He adds that this difference is probably more apparent than real. Lynch and Smith (20) have reported 3 fatal cases whose duration of employment in asbestos textile mills was 11½, 17, and 21 years in occupations having dust exposures of the order of dry weaving. Stock (32) reported a fatal case in a man 27 years of age who worked 8 years as a carder in an asbestos plant. Egbert (13) has also given complete findings of similar case in a man 30 years of age who had worked 13 years as a carder and who died 4 years after onset of symptoms and 3½ years after discontinuing work.

These examples of American fatalities, some in young individuals, suggest that the period of dust exposure before disability or death ensues is as short as is the case in silicosis.

Bridges (63) in the factory inspector's reports of Great Britain has shown from year to year (table 47) that the duration of employment of fatal cases with asbestosis is only half that of cases with silicosis.

TABLE 47.—*Silicosis and asbestosis in Great Britain*

	Number of deaths	Average age at death	Duration of employment (years)		
			Maximum	Minimum	Average
Through 1935:					
Silicosis	511	45.8	42	2.5	25.1
Silicosis with tuberculosis	2002	42.4	47	2.0	21.7
Asbestosis	53	41.9	22	1.5	12.4
Asbestosis with tuberculosis	30	37.1	20	.8	9.8

More than 90 percent of the raw mineral used in the manufacture of asbestos textiles in this country and Great Britain is Canadian chrysotile, indicating that very little difference is to be expected from the standpoint of biological reaction in the two countries. As near as dust concentrations in the various operations of asbestos manufacture of British practice can be compared with results obtained in this country, no greater differences are found than exist in the inherent limitations of the dust-sampling devices. It would seem, therefore, that quite negligible differences exist in the manifestations of the disease here and abroad with the possible exception of associated or complicating tuberculosis.

121

SUMMARY OF MEDICAL FINDINGS

A medical examination was made of each employee in three asbestos textile plants employing 423 men and 118 women. These persons were much younger than the average industrial employee and they had been employed in this industry for relatively short lengths of time. Almost half of these workers had been previously employed in cotton or woolen textile mills. Only 23 persons had been employed in a trade in which workers are known to be exposed to inorganic dust, and only 1 of these 23 persons had pneumoconiosis. For this reason, it is believed, asbestos-dust exposure can be held responsible for the cases of pneumoconiosis that were found in these three factories.

Asbestosis is a form of pneumoconiosis caused by long-continued inhalation of asbestos dust. The primary effect of asbestos dust on the body is to set up an interstitial, pulmonary fibrosis. This may be seen at autopsy, and reports on three cases appear in the pathological section of this bulletin. This type of fibrosis may also be detected by X-ray examination of the chest. On the X-ray film the shadows cast by this type of fibrosis resemble ground glass in appearance and usually extend over the lower portions of the lung fields, frequently being heavier on the right side. Unlike silicosis, nodular fibrosis has not been detected in asbestos workers.

As in silicosis, the chief symptoms of asbestosis are progressive dyspnoea, variable cough, substernal chest pain, decreased chest expansion, emaciation, weakness, clubbed finger tips, and curved finger nails. Most of these symptoms seem to be the result of the pulmonary fibrosis set up by inhaled asbestos dust, and the concomitant pathologic changes, such as emphysema, bronchiectasis, and bronchiolectasis, which can be demonstrated at autopsy.

The percentage of persons affected by asbestosis or by any one of these symptoms depends upon the dust exposure. In all cases the percentage of persons affected by any given sign or symptom of asbestosis is greater than in control groups of industrial workers who were not exposed to inorganic dust.

A characteristic of asbestosis is the finding of asbestosis bodies in the lungs and in the sputum. Although it does not appear from these data that a finding of asbestosis bodies can be used to establish a diagnosis of asbestosis, nevertheless it is evidence of asbestos exposure.

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Only three cases of asbestosis, all of them diagnosed as doubtful or borderline cases, were found to be exposed to dust concentrations of less than 5 million particles per cubic foot. (These three individuals had dust exposures of about 4 million particles per cubic foot.) Above 5 million particles per cubic foot, numerous cases of well-marked asbestosis were found. It would seem that if the dust concentration in asbestos factories could be kept below 5 million particles (the engineering section of this report has shown how this may be accomplished), new cases of asbestosis probably would not appear.

This page and the preceding eleven (11) pages constitute the Annexure marked with the letter "I" referred to in the Affidavit of Bernard Dominic Brassil sworn this 15 March, 1985 before me:

Solicitor