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A Study of Workers Exposed to Asbestiform Minerals in Commercial Talc Manufacture

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A clinical and environmental study was made of a group of 39 workers exposed to commercial talc dust, of which tremolite and anthophyllite were the major fibrous components and the findings were compared with a control group. The data showed that in spite of a mean exposure of 16.2 yr with a range of 11–22, only one of the workers exposed to commercial talc dust showed a chest roentgenogram consistent with pneumoconiosis. The only significant difference between talc workers and control was in the number of people having dyspnea and its severity. The authors considered both the element of smoking and the exposure to commercial talc as aggravating factors which accounted for the dyspnea. The findings of the 39 workers in the present study were compared to those obtained from 35 workers studied earlier in another talc plant. Both groups had similar mean durations of exposure to commercial talc but the degree of exposure of the group of 35 was appreciably greater. In the latter group there was a significantly increased prevalence of pneumoconioses. It is possible that commercial talc containing tremolite and anthophyllite as major fibrous constituents may be less fibrogenic than chrysotile or amosite at the degrees of dust exposure present in this study.

Studies of the biologic response to different types of asbestos indicate that inhalation of chrysotile and/or amphibole asbestos dusts in concentrations, present in some industrial environments, can produce pulmonary fibrosis (1). Disabling pneumoconiosis may occur after inhalation of an asbestos dust after an appreciable elapsed time from onset of exposure, up to 20 years or more (15). Morris *et al.* (2) in a study have reported that chrysotile produced less plumonary fibrosis than amosite or crocidolite when comparable concentrations of these asbestos minerals were inhaled. These investigators have attributed the lesser pathogenicity of chrysotile to the ability of the lungs to eliminate it more rapidly than amosite or crocidolite. Recent data on anthophyllite exposure indicates the fiber to be both a fibrogen (16) and a carcinogen (17). Meurman (3) has suggested that pleural plaques and calcification seem to occur more frequently among people exposed to anthophyllite, but whether one type of asbestos is more pathogenic than another still remains to be established. The difficulty arises due to the influences of fiber size, other minerals and cofactors present in the asbestos dusts (4). Vigliani (5) cites Selikoff as having stated that differences in fibrogenicity may exist even between different sources of the same type of asbestos. Experimentally, observations in the guinea pig lung by Holt, Mills, and Young (6) show no differences in the fibrogenic response to four types of asbestos, namely, chrysotile, crocidolite, amosite, and anthophyllite. On the other hand, Parazzi, Pernis, Secchi, and Vigliani (7) have shown that crocidolite produces a more marked cytotoxic action on guinea pig macrophages than does chrysotile. Schnitzer and Pundsack (8) in an earlier study observed that chrysotile fibers produce a marked hemolytic effect on suspension of washed sheep erythrocytes whereas crocidolite, amosite, tremolite, and anthophyllite produced negligible hemolytic effects. In a more recent study (personal communication to A.M.L.), the same authors found that the relative surface areas of chrysotile versus the amphibole group were among the major factors in determining whether or not the materials were potentially capable of producing hemolytic effects. Although the various authors cited above have shown different responses to different types of asbestos, their results do not justify drawing firm conclusions as to the relative pathogenicity of the different types of asbestos.

The present study deals with a group of 39 individuals who were exposed to commercial talc dust with tremolite and anthophyllite as its major fibrous component. The purpose of the study was to (a) correlate the environmental exposure with the clinical and roentgenographic findings in order to obtain information on a dose–response relationship among workers, all of whom had relatively long-term occupational exposure to commercial talc; and (b) obtain additional data on the composition and morphology of the commercial talc dusts.

MATERIALS AND METHODS

All of the workers in the study group were exposed to commercial talc for 10 or more yr. Each worker underwent a clinical evaluation which included a detailed occupational history, a physical examination and chest roentgenogram. A similar evaluation was made of 41 workers who lived in the same area as the talc workers and who were of the same sex and mean age and range but who had had no occupational dust exposure in their working environment. The 41 workers served as a control group. Dyspnea was graded using a modification of Fletcher's criteria (9). Only four of the five grades categorized by Fletcher were adopted for this study. The criteria for a positive smoking history was smoking of 20 or more cigarettes per day for a minimum of 5 yr.

In addition to the clinical and roentgenographic examinations, air samples were taken in both the workers' breathing zones and general air at various locations where the mining and milling of tremolite talc took place. Total particle counts as well as fiber counts were determined. The dust was collected by means of a midget impinger and the samples were taken at a rate of 0.1 cpm for 10 min according to the Public Health Service method (10). Several 10-min samples were taken during the individuals work day to obtain results representative of a given worker's actual exposure. Particles were counted using the light field low-power method. The fibers were collected on a millipore filter and concentrations were determined using phase contrast illumination at 400×. The mineral nature of 16 talc samples from New York State was determined. These samples represented talc specimens obtained at different mining and milling operations, as well as the finished product. Techniques of analysis included polarized light microscopy, transmission electron microscopy with selected area diffraction, x-ray diffraction, and electron microprobe analysis.

TABLE 1
CLINICAL AND ENVIRONMENTAL DATA OF EXPOSED AND CONTROL GROUP

	Study group	Control	P
No.	39	41	
Age (yr) mean	45.9	48.8	N.S.
range	34–75	32–71	
Exposure (yr) mean	16.2	0 (0.0%)	
range	11–22	0 (0.0%	
Radiologic findings compatible with pneumoconioses	1 (2.6%)	0 (0.0%)	N.S.
Clinical findings			
Cough	10 (25.65)	5 (12.2%)	N.S.
Dyspnea	9 (23.1%)	3 (7.3%)	<0.05
Lung crepitations	2 (5.1%)	3 (7.3%)	N.S.
Clubbing	0 (0.0%)	0 (0.0%)	N.S.
Positive smoking history	19 (48.7%)	19 (46.3%)	N.S.

FINDINGS

Clinical. A summary of the clinical and environmental data of the 39 individuals in the study group as compared to the control group is shown in Table 1. Data showing the relationships of dyspnea and cough to age, smoking and duration of exposure are given in Table 2. The characteristics for each grade are given in Table 2. Table 3 summarizes the mean dust concentrations obtained for specific years between 1954 and 1970. Fiber counts were made only in 1970 as shown in Table 3. Comparative environmental, clinical and chest roentgeno-

TABLE 2
RELATIONSHIPS OF DYSPNEA AND COUGH TO AGE, SMOKING AND DURATION OF EXPOSURE IN THE STUDY GROUP

Case number	Age	Years exposure	Dyspnea grade[a]	Cough	Smoking	No. packs cigarettes/ day	Years
1	45	14	1	Productive	+	1	25
2	36	19	1	0	0		
3	45	15	1	Productive[b]	0		
4	53	15	1	Productive[b]	+	1	30
5	45	20	4	Productive	+	2	20
6	49	20	1	0	+	1.5	18
7	58	14	2	Productive	0		
8	50	19	4	Productive	+	2	31
9	55	15	1	0	0		

[a] Four grades of dyspnea, a modification of Fletcher's grading (7), were used: Grade 1—able to walk normally without breathlessness on the level, but breathless on hurrying or climbing slight hills; Grade 2—able to keep on walking at own, slower than average pace on the level; Grade 3—forced to stop for breath when walking at own slow pace on the level; and Grade 4—breathless on slightest exertion such as washing or undressing.

[b] Morning only.

TABLE 3
ENVIRONMENTAL DATA OBTAINED AT VARIOUS MINE AND MILL OPERATIONS

	Mean dust counts (mppcf)						Fiber count (fiber > 5 μm/ml)
	1954	1958	1963	1964	1969	1970	1970
Mine							
Drilling	5		5		13	7	8
Dragline loading			7			10	16
Tramming & mucking					29	11	22
Primary crushing	2	26	23	18	13	48	260
Hoist loading				70	140	14	29
Mill							
Secondary crushing	12	23	8	10	12	13	13
Grinding (Wheeler mills)	15	13	5	3	11	19	30
Grinding (Hardinge mills)	18	14	4	7		8	33
Bagging	25	15	5	9	4	8	30
Palletizing	40			25	10	6	27
Bulk loading						10	8
Direct R.R. car loading of bags		109	39	31		62	

TABLE 4
DATA IN PRESENT PLANT COMPARED TO ANOTHER PLANT STUDIED PREVIOUSLY

	Present plant study	Comparative plant study	P
Environmental data[a] (mppcf)			
Mining			
Drilling	6	182	
Mucking	20	31	
Milling			
Crushing	15	117	
Milling	13	60	
Bagging	16	106	
R.R. car and truck load	68	77	
Workers examined			
Number in group	39	35	
Age (yr) mean	45.9	49.1	N.S.
range	34–75	29–67	
Exposure (yr) mean	16.2	17.4	N.S.
range	11–22	11–22	
Radiographic findings compatible with pneumoconioses	1 (2.6%)	12 (34.3%)	<0.01
Clinical findings			
Cough	10 (25.6%)	10 (40.0%)	N.S.
Dyspnea	10 (25.6%)	22 (62.9%)	<0.01
Lung crepitations	2 (5.1%)	8 (22.9%)	<0.05
Clubbing	0	7 (20.0%)	
Smokers	19 (48.7%)	23 (65.7%)	N.S.

[a] The dust count data represent mean dust concentrations over 20-yr periods.

TABLE 5
COMPARATIVE DUST COUNTS AND FIBER COUNTS IN THE TWO PLANTS

	Present plant data obtained in 1970		Comparative plant data obtained in 1969	
	Dust count (mppcf)	Fiber count (fibers > 5 μm/ml)	Dust count (mppcf)	Fiber count (fibers > 5 μm/ml)
Mine				
Drilling	7	8	16	371
Dragline loading	10	11	—[a]	—
Tramming & mucking	11	22	2	62
Primary crushing	48	260	—	—
Hoist loading	14	29	—	—
Mill				
Secondary crushing	13	13	19	112
Grinding (Wheeler)	19	30	21	84
Grinding (Hardinge)	8	33	—	—
Bagging	8	30	12	135
Palletizing	6	27	—	—
Bulk loading	10	8	—	—
R.R. car and truck loading	—	—	70	198

[a] (—) Not done.

graphic data compiled from a previous study made 6 yr earlier in another talc mining and milling plant in the same regional area are shown in Table 4. Table 5 shows the comparative dust and fiber counts in the two plants; the counts in the present plant study were taken in 1970 and those at the comparative plant were taken in 1969. A flow sheet of the mining and milling operations in the plant most recently studied is shown in Fig. 1.

Mineral analysis of talc samples. Optical, x-ray, electron microscopic and electron microprobe examination of the talc samples taken from the plant studied most recently indicated that the true mineral talc, as defined mineralogically, is only one of many mineral components in the materials mined, milled and sold as commercial talc and that it is present as either a major or minor component. The asbestiform minerals tremolite and anthophyllite may constitute major fractions of commercial talc. Figures 2, 3 and 4 show the various constituents of the dust samples as viewed under plane polarized light (Fig. 2) and electron microscopy (Figs. 3 and 4).

DISCUSSION

A correlation of the clinical and environmental findings noted in Table 1 shows that in spite of a mean exposure of 16.2 yr with a range of 11–22, only one individual showed a chest roentgenogram consistent with pneumoconiosis. This occurred in a 75-yr-old individual who had a nonproductive cough, Grade 1 dyspnea and who worked as a janitor for 11 yr. Although the absence of positive roentgenographic shadows does not conclusively exclude the presence of pneumoconiosis

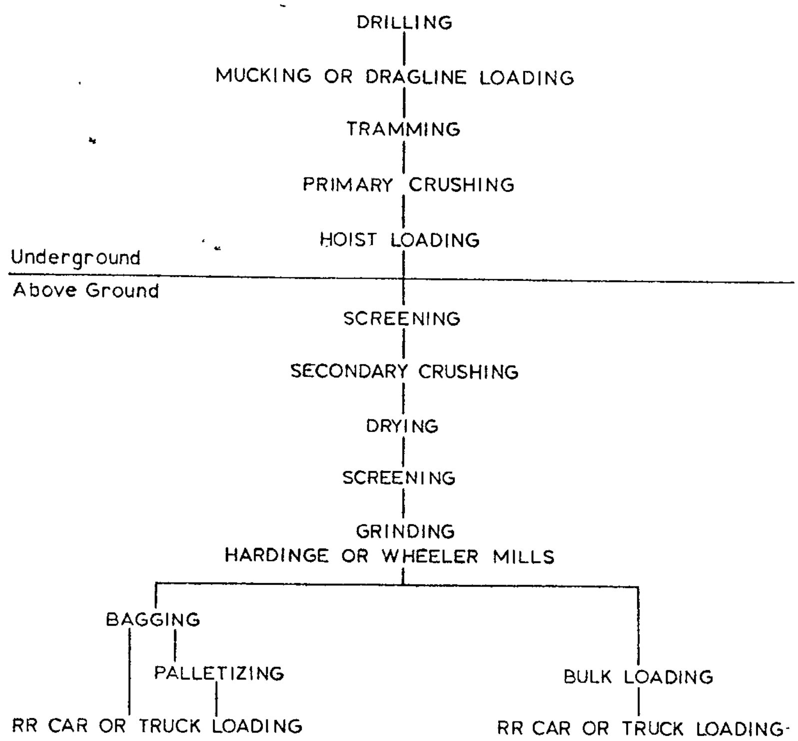

FIG. 1. Flow chart of commercial talc mining and milling operations in the plant studied.

in the other individuals who had positive clinical findings, it makes the presence of pneumoconiosis less likely. Usually the criteria for asbestotic pneumoconiosis is a history of prolonged exposure coupled with positive roentgenographic shadows and a restrictive breathing disorder. When the clinical data on the workers was compared with the control group (Table 1), there was no appreciable difference in the presence of cough or lung crepitations, the only difference being in the number of people with dyspnea and its severity. In the control group there were three individuals who had dyspnea which was categorized as Grade 1. Of the nine individuals in the study group with dyspnea, six showed Grade 1, one showed Grade 2 and two showed Grade 4. Of the two with Grade 4 dyspnea, one was a cardiac who had sustained a myocardial infarction and the other had pulmonary emphysema prior to his employment. These two individuals were heavy smokers, one having smoked two packs daily for over 20 yr and the other two packs daily for a period of 31 yr. Hence, the element of smoking must be included as an important etiologic factor. Although the dyspnea in these two individuals was not primarily related to their occupational exposure, it may very well have been that their prolonged exposure to the commercial talc dust acted as an additional causal element. By and large, as shown in Table 2, there was no good correlation between dyspnea and cough when related to age, smoking habits and duration of exposure.

In order to obtain some information on the dose–response relationship, it was

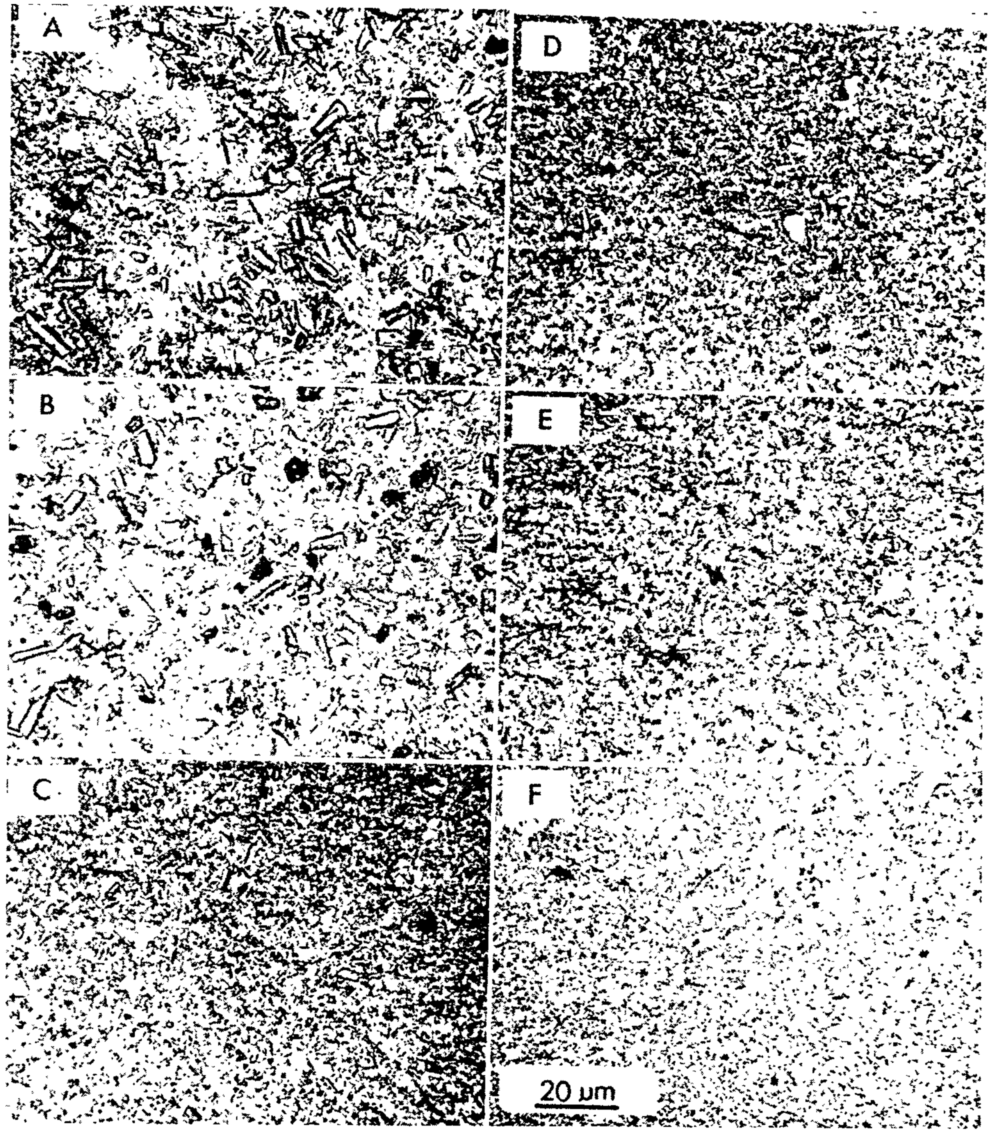

FIG. 2. Talc samples as viewed in plane polarized light. All magnifications are as shown in (F). Sample (A), a primary crushing area; (B), drilling area; (C), mill; (D), talc "N200L"; (E), talc "N200"; (F), talc "N300." These samples represent materials from source to end-product. In addition to the mineral species, rock fragments were observed in the first three samples.

possible to compare a group of 35 individuals of the plant studied earlier (Table 4) who were of the same age and range and who had a similar mean duration of exposure as well as range but whose degree of exposure in terms of total particle counts was appreciably greater than those in the plant recently studied as shown in Tables 4 and 5. As would be expected, the group exposed to higher dust concentrations and fiber counts showed a significantly increased prevalence

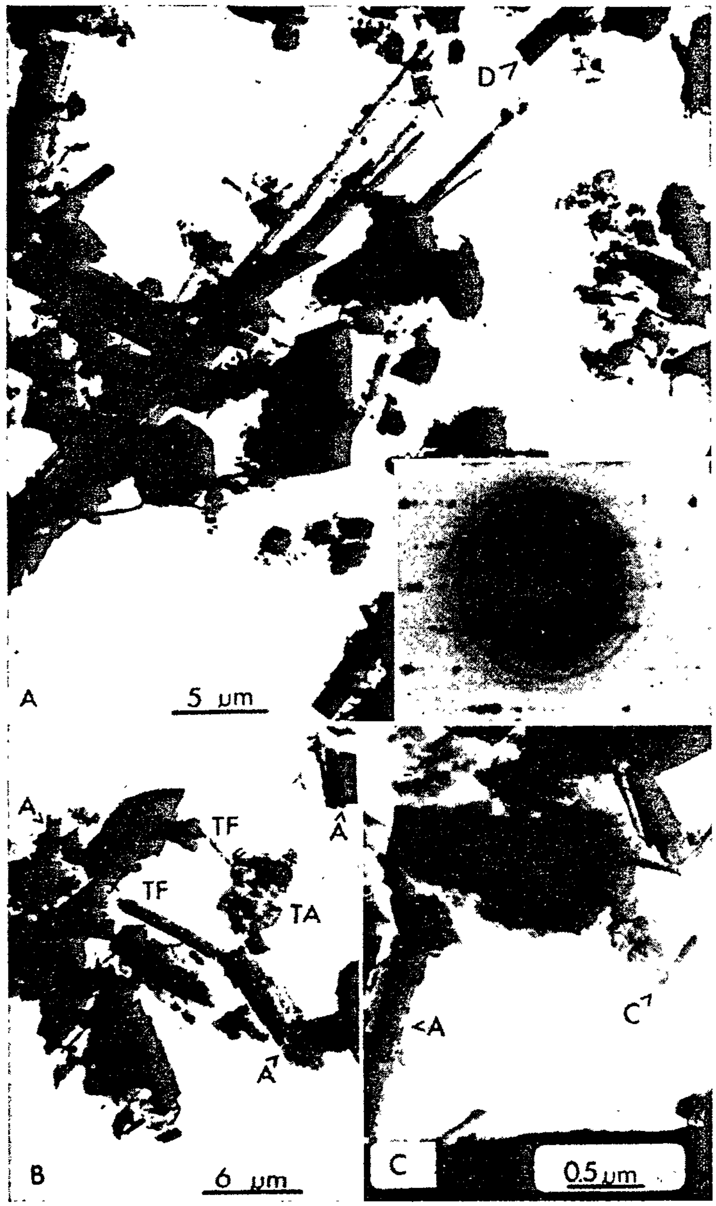

FIG. 3. Amphibole fibers present in talc. This sample was examined for amphibole fibers and electron diffraction patterns obtained on selected fibers (3A; insert 3A). The structural array is clearly different than that obtained on talc fibers. 3B shows the presence of talc fibers (TF), amphibole fibers and fragments (A), and the presence of talc aggregate grains (TA). 3C shows a chrysotile (C) fibril and an amphibole (A) fiber admixed in the talc.

of positive chest roentgenographic findings consistent with pneumoconiosis as well as more positive clinical findings.

In both talc plants there was no correlation between the fiber count and mean dust counts indicating the desirability of utilizing both total particle concentra-

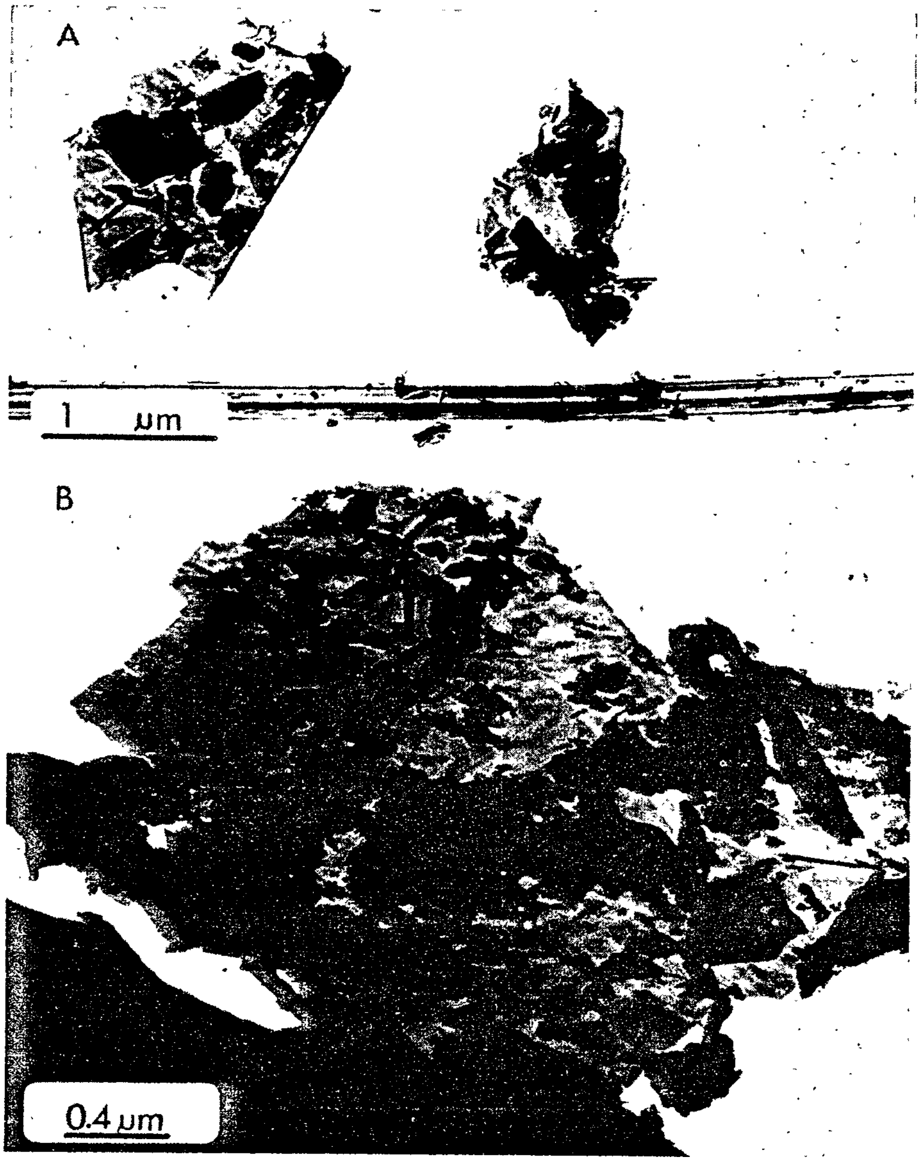

FIG. 4. Talc aggregate grains as viewed with transmission electron microscopy. These grains are apparently intergrowths of true talc, talc fibers, serpentine minerals and after fragments, and amphibole fibers and fragments. (A) These grains appear to survive the milling operations as entities. Particles making up the grain may range from several thousand to several hundred angstroms in size. (B)

tion as well as fiber counts when one correlates the environmental and clinical data. Table 3 shows the lack of correlation between the two indices in the present plant studied. There is at present no conclusive data that it is the fiber per se which is solely responsible for producing both the fibrotic and malignant changes. In addition, the effect of periodic exposures of short duration to high concentrations of fibers and particles or peak concentrations needs further study and clarification. One should therefore consider the particle concentration, fiber count and their peak values in establishing threshold limit values. Furthermore, the nature of the samples analyzed indicates that fiber counts of aerosols may not provide a true picture of exposure to asbestiform minerals because the fiber counts include talc fibers but exclude many small asbestos fibers and "aggregate fibers" which may contain substantial amounts of asbestiform minerals (Fig. 4). Suzuki and Churg (11) have suggested that it is the submicroscopic fibers that are responsible for most of the biologic effects produced by asbestos. Other investigators (6, 12) have also pointed out that the fine dust particles below 1 μm in length may be just as damaging as dust containing both large and small particles.

In a recent paper by Murphy and associates (13) on workers exposed to chronic low concentrations of asbestos dust in ship construction wherein the asbestos used was principally chrysotile and amosite, the authors reported that they did not find any evidence of asbestosis in persons with less than ten years of cumulative exposure. No information on peak exposures was given. The periodic peak exposures may be the more important factor relating to the fibrogenic effect. These authors, however, observed that there was a progressive increase in prevalence of asbestotic pneumoconiosis with the years of exposure thereafter. In terms of time weighted averages, Murphy and associates (13) found no asbestosis in men exposed less than 60 mppcf-years. Although it is difficult to compare their work with the present study, it does nevertheless appear that while an appreciable number of workers in the present study exceeded the 60 mppcf-years, they did not show any evidence of pneumoconiosis, as determined by the criteria of Murphy and associates. It is possible that, in terms of a fibrogenic response, tremolite and anthophyllite are less pathogenic than chrysotile or amosite at the degrees and intensity of dust exposures present in this study.

In terms of the present findings, the data are not sufficiently conclusive for carcinogenicity for it has been shown that the occurrence of malignancy requires a longer elapsed time from onset of exposure. Since the start of its operations, the longest exposure in the plant studied was only 22 yr and the occurrence of malignancy from commercial talcs containing tremolite and anthophyllite in addition to talc has not infrequently required a longer duration or a greater elapsed time from initial exposure as was shown in an earlier study (14). None of the insulation workers studied by Selikoff and Hammond (15) died from carcinoma of the lung, mesothelial tumors or asbestosis before 20 years had elapsed since first exposure. To date, no instances of malignancy have occurred in any of the workers exposed exclusively to commercial talc at the plant studied.

SUMMARY AND CONCLUSIONS

A clinical and environmental study was made of a group of 39 workers exposed to commercial talc dust, of which tremolite and anthophyllite were the major fibrous components. The clinical findings were compared to those obtained from a control group. The data showed that in spite of a mean exposure of 16.2 yr with a range of 11–22, only one of the workers exposed to commercial talc dust showed a chest roentgenogram consistent with pneumoconiosis. When the clinical

data on the workers was compared with the control group, the only significant difference was in the number of people having dyspnea and its severity. Two individuals had severe dyspnea. One of the two had a cardiac condition and the other had primary pulmonary disease prior to his employment. Both were heavy smokers for over 20 yr. The authors considered both the element of smoking and the exposure to commercial talc as aggravating factors which accounted for the dyspnea. The findings of the 39 workers in the present study were compared to those obtained from 35 workers studied earlier in another talc plant. Both groups had similar mean durations of exposure to commercial talc but the degree of exposure of the group of 35 was appreciably greater. In the group previously studied there was a significantly increased prevalence of positive roentgenographic findings consistent with pneumoconioses as well as more positive clinical findings. In the present study where the mean exposure was 16.2 yr with a range of 11–22, no instance of malignancy occurred in any of the workers exposed exclusively to commercial talc. It is possible that commercial talc containing tremolite and anthophyllite as major fibrous constituents may be less fibrogenic than chrysotile or amosite at the degrees and duration of dust exposure present in this study.

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