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THE DUST HAZARD IN TREMOLITE TALC MINING*

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From time to time the attention of the Division of Industrial Hygiene has been drawn, through compensation claims, to incapacitating fibrosis in talc workers. Since silicate dusts, of which talc is one, have been considered relatively innocuous in the opinion of most authorities (the single exception being asbestos), the occurrence of these cases has naturally raised several questions—the obvious question as to whether this incapacity has resulted from talc exposure alone, and the second and more interesting question as to whether industrial hygienists, with few exceptions, have erred in considering asbestos to be the only injurious silicate dust.

In an attempt to answer these questions, the study here reported was undertaken. It consisted of an investigation of the talc industry and an examination of talc miners and mill workers in northern New York State (St. Lawrence County) made, as a joint enterprise of the Division of Industrial Hygiene of the State Department of Labor and the Division of Tuberculosis of the State Department of Health.†

Nature of talc

Talc is a hydrous magnesium silicate with the formula $H_2Mg_3(SiO_3)_4$ composed, according to Ladoo[13] of about 63 per cent SiO_2, 32 per cent MgO, and 5 per cent H_2O. It is usually a secondary mineral resulting from the alteration of other magnesium silicates or carbonates. While its own silica is present in the combined form, most talcs mined commercially contain varying amounts of such impurities as quartz, calcite, dolomite, iron oxide, etc.

Talc has a characteristic soapy feeling and a pearly luster. It may be pure white, silvery white, gray, or green and, when impure, yellow, brown, or reddish. The most common commercial variety is a massive, foliated, or granular type, but it may also occur in a micaceous, or in a fibrous form.

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Soapstone is a closely related substance, being essentially an impure talc, and when pulverized it may be used for the same purposes. Tremolite, which is a calcium magnesium silicate, changes over to talc. It may be mined with it and subsequently ground and sold as talc.

Geographical distribution

The United States produces about 65 per cent of the world's supply of talc, the leading states in its production being Vermont, New York, California, North Carolina, and Georgia.

Industrial uses of talc

According to the Minerals Year Book (1938) of the United States Bureau of Mines, the use of talc and soapstone is steadily increasing. Ladoo[13] states that at least 60 different uses for talc have been noted, though most of them are of minor importance. Its value depends chiefly on its usefulness as a filler, inert extender, dusting powder, and absorbent. In 1921, according to Ladoo, the marketed, ground talc production in this country was industrially distributed as follows: paper, 38 per cent; paint, 23 per cent; prepared roofing, 18 per cent; rubber, 9.5 per cent; textiles, 4 per cent; toilet powder, 2.5 per cent; other uses, 5 per cent.

The other uses for which ground talc is adapted are: as a filler in soap; in foundry facings; in wire-insulating compounds; in dry lubricants; as a filler in cotton textiles; in the dressing and manufacture of leather; as a cleaning and polishing agent for rice, peas, coffee beans, peanuts, etc.; in making colored crayons; as a filler in the windowshade cloth; as a dusting agent in making candy, chewing gum, etc.; and as an ingredient of concrete, plastics, and insecticides.

Since 1921 there has been a marked increase in its use in the ceramic industry. Fourteen thousand more tons of talc and related materials were sold in 1937 than in 1936 and about 10,000 tons of this increased amount went to the ceramic industry where talc is chiefly used as a constituent of glazed wall tile.

Review of literature on the effects of talc dust

Experimental studies. During the last ten years a certain amount of experimental work with talc dust has been reported, but on reviewing this literature most of the inhalation experiments are found to have been of insufficient duration to be helpful in regard to the probable effect of long-continued industrial exposure.

In 1931, Haynes[10] included talc in a series of dusts studied for their reactions on guinea-pigs. Twelve pigs were dusted two hours daily, except Sunday, for a fortnight. The author saw no sign of pulmonary damage, but found that bronchial and lymphatic removal occurred unusually briskly. He concludes that the substances dissolved from talc are of a low degree of toxicity, but are sufficiently obnoxious to neighboring tissues to cause the removal of cells containing them.

Stüber,[22] in 1934, studying the cellular response of lymph nodes to various dust suspensions introduced into the lymphatics, found that talc caused no apparent cellular proliferation within the lymph nodes after five days. After 108 days the nodes were still normal and showed no increase in connective tissue.

Fossel,[6] in 1935, reported experiments in which guinea-pigs were exposed to the inhalation of talc for one hour daily over a period of eight weeks. No significant tissue changes were seen.

Bethune,[2] in 1935, was able to produce pleural adhesions in cats and dogs by blowing commercial talc into the pleural cavity. Miller and Sayers, quoted below, found that adhesions were not related to the subsequent behavior of the dust.

Fienberg,[5] in 1937, having observed granulomas from the surgical use of talc, experimented with the injection of this substance in mice and obtained subcutaneous granulomas in these animals.

Miller and Sayers,[17] in 1936, reported studies in which talc was included among the dusts with which the intraperitoneal reaction in guinea-pigs was studied. They found that it produced an "inert reaction." That is to say, the injected dust was not absorbed; neither did it initiate a cellular proliferation. In interpreting the significance of "inert reactions" the authors conclude that such dusts should be considered as potentially harmful.

Gardner,[7] summarizing experimental work on silicate dusts at the Saranac Laboratory, said at the Fourth Saranac Laboratory Symposium on Silicosis (1939), "a few silicates like true talc . . . and some of the clay minerals have provoked chronic inflammation (of the lungs) but this reaction has tended to retrogress after several months. No progression to a stage of true fibrosis has been observed within periods of one to two years and there is no indication that the progression will occur."

In 1939, Policard[20] reported an experiment in which he dusted white rats with foliated, industrial talc three hours a day for twelve

days. The intensity of the exposure was high. He found that the dust was irritating to the upper respiratory tract and produced a marked dyspnea. In the lungs of animals sacrificed two and six days after inhalation began, he found dilatation of bronchi, acute emphysema, and exudative alveolitis. Many animals died spontaneously with pulmonary congestion and foci of bronchopneumonia. The short duration of the experiments did not permit any conclusion concerning the possibility of pulmonary fibrosis.

McCormick and Ramsey,[15] in 1941, reported postoperative, peritoneal granulomatous inflammation caused by talc in two cases. And Schulz and Williams,[21] in 1942, injected intraperitoneally in guinea-pigs a series of seven commercial talcs with different silicate-carbonate ratios. Animals were sacrificed at intervals ranging from ten days to fifteen months. In all cases, the pathological histology showed the holding of talc particles in a local area by phagocytic cells of the macrophage and giant cell type. Progressive fibrosis was not found. The fibrosis which occurred was only enough to hold and limit the space for storing the foreign material. The greatest amount of fibrous tissue developed in the presence of the two talcs which contained the least carbonate and the most talc and tremolite respectively.

Clinical reports. Talc fibrosis as an occupational disease has received attention in this country only within the past ten years. Policard[20] says that it was in 1896 that the question of the action of industrial talc dust on the human lung was first considered. At that time Thorel, a pathologist of Nuremberg, published the results of the pathological examination of the lung of a tuberculous woman patient of forty-four years, who had worked for many years in soapstone dust. According to Policard, Thorel demonstrated the presence of cells containing soapstone dust in the cavity and walls of certain alveoli and disclosed the existence of formations, more or less nodular, resulting from the accumulation of cells filled with talc. Other nodular formations of a tuberculous nature were present, and Thorel pointed out a combination of tuberculous and pneumoconiotic lesions.

In 1915, according to Policard,[20] Hayhurst stated that work in talc dust favored and exaggerated tuberculosis, but the basis for this opinion is not known.

Zanelli, in 1931, quoted by Teleky,[23] came to the conclusion that talc dust, though belonging to the family of silicates, ought to be considered dangerous and likely to produce typical pneumoconiotic lesions.

Merewether,[1] in 1933, reported the cases of 11 rubber-tire workers, exposed from 10 to 32 years to French chalk, a fine granular variety of talc dust, who showed diffuse interstitial fibrosis by roentgen examination without clinical evidence of anything more than a peribronchial increase in fibrous tissue. Thirteen additional workers, with exposures of from 4½ months to 48 years, were examined and reported upon the following year[1] confirming the original findings.

In 1933 a report was made by Dreessen[3] of examinations of a number of workers in silicate dusts, including 57 men exposed to tremolite, a hydrous calcium magnesium silicate containing no free silica. The findings in this group were as follows: more fibrosis than usual, 67 per cent; first-stage pneumoconiosis, 26 per cent; second-stage pneumoconiosis, 2 per cent; normal lungs, 5 per cent.

Dreessen described the first-stage pneumoconiosis as similar to that produced by cement dust; "softer" than that resulting from silica dust, a "diffuse, fine, generalized fibrosis . . . chiefly confined to the lower two-thirds of the lung fields."

In 1935, the same author, together with DallaValle,[4] reported on the effect of exposure to dust in two Georgia talc mills and mines. The dust involved was, again, a calcium magnesium silicate containing no free silica. It was present in excessive amounts, over one and one-half billion particles per cubic foot in some operations, the particle size averaging less than 1 micron. Sixty-six workers were examined. Among these, 22 (33 per cent) showed pneumoconiosis, 8 in stages two or three. The conclusion was reached that exposure to talc dust was either "too severe" in the Georgia study, or that this talc was a more dangerous dust than that previously studied. No particular relationship between talc exposure and tuberculosis was demonstrated.

Middleton,[16] in 1936, referred to an unpublished case of Cunningham's in which pneumoconiosis was found in a talc grinder who had been employed for nine years. He also mentioned an autopsy by Sand in 1910 on a woman exposed to talc dust in which "not much reaction" was found.

In 1938, Nuck and Szczepnaski[19] reviewed the literature on talc fibrosis and added several cases of their own. They concluded that this type of pneumoconiosis resembled asbestosis more than silicosis.

At the International Conference on Silicosis at Geneva[12] in 1938, Riddell reported the results of the examination of 37 workers engaged in grinding talc ore. Thirteen showed fibrosis resembling silicosis.

Gardner on the same occasion said[12] that of 300 films of talc workers which he had examined about 50 showed some evidence of pulmonary reaction which in 17 suggested nodulation.

From a survey of the literature it appears that while experimental studies have hitherto been inconclusive, clinical studies have tended to indicate that talc dust is capable of producing injurious pulmonary changes.

Compensation claims for disability due to talc dust in New York State

The cases which originally drew the attention of the Division of Industrial Hygiene to disability resulting from exposure to talc dust are summarized below. Six such cases have occurred during the past few years. One originated in the manufacture of talcum powder; one in the shoe industry, and four in talc mining and milling. In one case there had been significant previous exposure to dust probably containing free silica. Five of the 6 cases were fatal. In 5 cases summaries are available as follows:

Case I. Aged sixty-three. The claimant had worked for 12 years operating a talcum powder mixing machine not provided with exhaust ventilation for dust control. The talc used was found by the Division of Industrial Hygiene to contain less than 0.5 per cent of free silica. The dust concentrations at this work ranged from 13.9 to 34.8 million particles per cubic foot.

For three or four years before quitting the job, the claimant had complained of cough with expectoration. Examination of the lungs showed moist râles at the bases. The vital capacity was 2,500 (normal estimated as 4,000).

Roentgen examination of the lungs showed an increase of bronchial markings in the lower and middle fields with areas of increased density resembling lipiodol or calcific deposits in both mid-lung fields.

In hospital a diagnosis was made of emphysema and chronic bronchitis with acute exacerbation.

Case II. Aged forty-four. For 22 years the claimant had worked as a "bed laster" in a shoe factory. White shoes were manufactured during about five months of the year and at these times he used talc freely, dusting it on the shoes to prevent soiling of the white leather. The powder used was analyzed by the Division of Industrial Hygiene and found to contain no free silica.

For seven years before quitting work he complained of cough, dyspnea, and increasing weakness. His condition finally necessitated hospital treatment.

Physical examination showed the presence of dyspnea, cyanosis, and clubbing of the fingers. Examination of the lungs revealed dullness on both sides with diminished fremitus and breath sounds.

Roentgen examination of the chest showed marked, confluent, hazy mottling with nodular densities uniformly distributed. The right ventricle was hypertrophied (cor pulmonale).

The diagnosis was chronic pulmonary fibrosis and emphysema. The case terminated fatally nine months after admission to the hospital.

Case III. Aged forty-nine. The claimant had worked as a talc miner for 15 years with 8 months' exposure in other mines 10 years previous to his talc exposure. His illness began five years before death with shortness of breath and a productive cough. He quit work two years after the onset of symptoms because of increasing weakness, and was admitted to a sanatorium.

Physical examination showed an emaciated individual who looked chronically ill. The vital capacity was 1,800 (normal estimated as 3,000). The lungs showed dullness over the middle thirds, râles above second rib anteriorly and posteriorly throughout. Five specimens of sputum were negative for the tubercle bacillus. The temperature was normal.

Roentgen examination showed extensive, bilateral fibrosis with infection, probably tuberculous, and this was the diagnosis.

Case IV. Aged thirty-seven. For 21 years the claimant had worked in talc mines as mucker, driller, and foreman. For two years before quitting work he had noticed cough, shortness of breath, and pain in chest. He was easily fatigued. These symptoms caused him to enter a hospital for treatment.

Physical examination revealed no lung abnormalities, but showed cardiac hypertrophy, hypertension, and evidence of nephrosis.

Roentgen examination of the chest showed fine nodulation through both lung fields below the fifth posterior rib, more marked in the central lung field, an increase in hilum shadows, and cardiac hypertrophy.

The clinical diagnosis was early silicosis with probable infection, hypertensive disease, and severe nephrosis.

The case terminated fatally.

Case V. Aged fifty-two. The claimant had worked in talc mines for 17 years with a previous exposure of 10 years in zinc and iron mines. Illness began six years before death with cough and dyspnea. Following the initial symptoms he developed pain in chest and hemoptysis, and sought hospital treatment.

Physical examination showed an emaciated individual, appearing chronically ill. The fingers were slightly clubbed. The chest expansion was limited. Examination of the lungs showed dullness on the right below the seventh spine with râles and diminished breath sounds. The sputum was positive.

Roentgen examination showed a fine miliary type of increased density on the left, a mass of increased density in the right middle lung field with evidence of excavation, and heavy fibrosis at the right base.

The clinical diagnosis was probable silicosis, complicated by tuberculosis. Death occurred 21 months after admission to the hospital.

A study of talc miners and millers in St. Lawrence County, New York

Scope of study. In the course of this investigation studies of operations and dust concentrations were made by engineers of the Division of Industrial Hygiene in three talc mines and five talc mills. From seven

plants 221 men received an initial roentgen examination. In the case of 28 of these individuals, who showed positive lung findings, at the end of ten months a follow-up examination was made, which included a second roentgenogram, a medical history, and physical examination of the chest, and a detailed occupational history.

The roentgen examinations were made with a 200 milliampere machine mounted on a truck belonging to the Division of Industrial Hygiene.[11] Patterson high-speed screens were used, and exposures were made at a 60-inch distance and with an exposure time of one-tenth of a second.

Type of talc involved. The type of talc produced in St. Lawrence County is of the fibrous variety known as asbestine. It is noted for its clear whiteness and is used chiefly as an ingredient in the manufacture of paint and tile. With it is found tremolite—calcium magnesium silicate ($CaMg_3(SiO_3)_4$)—a mineral similar in appearance occurring in a fibrous or asbestiform state which in the course of time changes over to talc. Gardner[8] reports that anthophyllite, another fibrous silicate, is also present in the talc deposits of the St. Lawrence County region.

Analysis of representative samples of talc from two of the mines in the region, submitted by one of the mining companies, shows the following composition:

Analysis	*Sample A*	*Sample B*
Total silica*	68.24	57.50
Calcium oxide	2.72	5.24
Aluminum oxide	—	.27
Iron oxide	—	.17
Manganese oxide	—	.16
Carbon dioxide	—	.38
Magnesium oxide	24.51	30.20
Calcium carbonate	0.23	—
Sulfur trioxide	trace	—
Ignition loss	3.65	5.13
	99.35	99.05

* Includes both free and combined silica.

Free silica content. The free silica content of commercial talc as found in industrial use is very low. Schulz and Williams[21] report that of 51 samples analyzed quartz was not found in 25; traces of quartz were present in 25, while one sample showed a quartz concentration of 3 per cent. The free silica content of the talc in the mills and mines

included in this study was likewise found to be low. Six samples from two talc mines, taken and analyzed by chemists of the Division of Industrial Hygiene, showed 1 per cent or less of free silica. Two of these samples were taken from long-standing accumulations of waste rock; two were from recent three- and four-day-run waste accumulations; and two were from collections of rock destined for the mills. Six samples of ground talc from several mills were also analyzed and in each case the silica content was found to be less than 1 per cent. Dreessen[3] also reported little or no free silica in the composition of the talc in this region.

Gardner,[8] on the other hand, found amounts of quartz ranging from 12 to 20 per cent in mineral samples from two mines in this area. It is difficult to explain the marked difference between Gardner's findings and those of Dreessen[3] and of ourselves, except upon the supposition that Gardner's samples included some of the quartz-bearing stratum overlying the talc deposit proper. That such high percentages are not representative, however, is shown by the fact that material from the mills where all rock is mixed and crushed showed low quartz percentages both in Gardner's studies and in our own.

Description of the talc mining industry

Mining operations. Talc ore is obtained by underground mining. Inclined shafts are used with headings to various depths down to about 1100 feet. The talc occurs in compact, homogeneous seams, so that contact with hard rock is limited to that incurred on entering a seam. Once a seam is entered there is no exposure to anything but talc until it becomes necessary to enter another seam. Since seams may be worked for years, the amount of drilling in hard rock is very small compared with the amount of drilling in talc.

The headings are mined by drift drilling, blasting, and hand or machine mucking. Raising and stoping are resorted to, to obtain the ore from pockets. All drilling is done dry, since every precaution must be taken to avoid wet ore which cannot be milled and is wasted. Drilling crews of one or two men are used, the drillers doing their own blasting. The ore is then mucked as it is required by the mills. It is loaded into muck cars and pushed along the haulage-ways to the shaft where it is dumped into a skip, hoisted to the surface, and dumped into railroad cars or trucks for shipment to the mills. Each mine employs 15 to 17 men underground.

Dust exposure in talc mining operations. The problem of the best method of control of the dust in talc mines is one which is receiving

the attention of the Division of Industrial Hygiene at the present time. Very little dust control was found in the three mines studied. Some attempts had been made to remove the dust, during drift drilling, by means of small, home-made, portable units, but relatively few of these were in actual use during drilling operations. The drillers wore respirators.

Twenty-two dust samples were taken with a midget impinger at various operations and situations. These were counted within ten hours of the time of sampling by means of the low-power, light field technique, and gave the results shown in table 1.

The dust counts where no exhaust device was used gave average dust concentrations as follows: for drilling, 1,350; for stoping, 1,290; for mucking, 35; and in the general air, 17 million particles per cubic foot.

Talc milling

Milling operations. The milling processes in all five mills were found to be essentially alike. The ore is shipped to the mills in railroad cars or trucks and is dumped into chutes leading to a jaw crusher. From the jaw crusher the talc, in most mills, passes through disc or roll crushers, or both, before entering rotary or trommel screens. After passing the screens, the talc is stored in garners before the final milling operation which takes place in pebble mills. The final separation of the finely ground talc is accomplished with air separators, from which the material passes to garners which feed bagging machines.

The bagging machines utilize open top bags, or sacks, which fit loosely onto the discharge spout of the machines. Hand scoops are used to add or remove talc from the bags to obtain accurate weight. The greater percentage of material is bagged in 50 lb. paper bags, while some is shipped in larger burlap bags. The operators of the bagging machines stack the filled bags on hand trucks and wheel the loaded trucks into railroad cars or automobile trucks for shipment, or into the warehouse for storage.

Dust exposure in talc milling operations. Dust control in the various mills is confined chiefly to the bagging machines and pebble mills. Some control is also used in several mills at the crushers and material transfer points. Dust samples were taken throughout the mills using the technique already described. The samples were taken at the breathing level of the workmen in locations where men are usually stationed.

Table 2 shows the concentrations found at various points throughout the mills. Manual handling of the talc produces concentrations in excess of those found at other operations but, fortunately, there is little manual handling during normal procedure.

TABLE 1
DUST CONCENTRATIONS IN TALC MINES

Operation	*Mine*	*Dust count (million particles per cubic foot)*	*Remarks*
Drilling	A	200	"Upstream" of drill. Rate 2′ per minute.
		300	"Downstream" of drill.
		75	3′ "upstream." Using exhaust.
		110	Same as above. Breathing level of helper.
		600	Exhaust off.
		2700	Exhaust off. Breathing level of helper "downstream."
		5000	Exhaust of dust collector.
		1500	Same as above; 3 minutes after drilling stopped.
		150	General air stream.
	B	65	"Upstream" air movement 50′ per minute.
		265	Same as above. Air turbulent.
	C	90	Dead-end drift.
		300	Just off main airway.
		16	Main airway.
		100	Breathing level driller, top of open stope.
Stoping	A	4000	Dead-end stope. No air movement.
	B	760	Top of dead-end raise.
Mucking	A	40	Bottom of stope, drilling at top.
		50	Same as above.
		6	Top of pile, mucking only operation.
	B	35	"Downstream" of mucker.
		24	Same as above.

The dustiest operation, other than manual handling, is that of paper bagging where the average dust concentration for three mills was found to be 163 million particles per cubic foot.

To make clear the fact that talc is a fibrosis-producing dust the distribution of cases of fibrosis, according to age, in talc workers and in a group of carpet factory workers previously examined by the authors, is shown in table 4.

TABLE 3
FIBROSIS IN TALC WORKERS, BY LENGTH OF EXPOSURE

Years exposed	*All workers examined*	*Fibrosis* *Number*	*Total fibrosis: Cases per cent*	*Fibrosis Exposure group: per cent*
5	82	—	—	—
5-9	32	—	—	—
10-14	47	8	25.0	17.0
15-19	33	13	40.6	39.4
20-24	10	2	6.3	20.0
25-29	9	3	9.4	33.3
30-39	6	5	15.6	83.3
40-49	1	—	—	—
50-59	1	1	3.1	100.0
Totals	221	32	100.0	14.5

TABLE 4
FIBROSIS IN TALC AND CARPET WORKERS, BY AGE

	Talc workers			*Carpet workers*		
	Number	*With fibrosis*		*Number*	*With fibrosis*	
Age	*examined*	*Number*	*Per cent*	*examined*	*Number*	*Per cent*
Less than 20	4	—	—	6	—	—
20-29	71	1	1.4	57	—	—
30-39	72	7	9.7	61	1	1.6
40-49	41	7	17.0	57	1	1.7
50-59	17	9	52.9	49	4	8.1
60-69	13	6	46.1	33	—	—
70-79	3	2	66.6	3	—	—
Totals	221	32	14.5	266	6	2.5

Fibrosis was present in only 2.5 per cent of all carpet workers, and in 4.9 per cent of those 50 years of age and older; while it was present in 51.5 per cent of talc workers in this age group.

Ten months after the original roentgen study, a second visit was made to the same plants for follow-up examinations of selected cases. At this time occupational and medical histories were taken and chest examinations were made. From the occupational histories it was possible

to eliminate those men who had previously been exposed to other types of siliceous dust. In this way a group of 18 cases showing marked fibrosis was defined in men who had not worked in any other dusty industry and whose only significant dust exposure, therefore, had been to talc.

Signs and symptoms. Fifteen of the men showing fibrosis worked in the talc mills; 3 were miners. The proportion of mill workers to miners in the entire group, however, was approximately 2.3 to 1, showing that fibrosis was relatively more prevalent among millers than miners. With one exception, the men with fibrosis were all 40 years of age or older and had been exposed to talc dust, as noted above, for at least 10 years.

Thirteen of the 18 had one or more symptoms referable to the lungs. Ten complained of dyspnea, 7 of chronic cough, and 3 of pain in the chest. In addition, 5 complained of excessive fatigue.

On physical examination, all 18 showed limited chest expansion. Thirteen showed abnormal lung signs and 13 showed curving of the nails or clubbed fingers. In one case cardiac hypertrophy was observed, and in one there was auricular fibrillation.

The general appearance of the group struck the examiners as being distinctly different from the appearance of the usual group of first and second stage silicotics who are still able to work. The latter usually present a robust appearance. A substantial number of individuals in such a group are likely to be overweight. This was not the case with the talc workers who showed fibrosis. None of them was overweight, but on the contrary they tended to present an undernourished and drawn appearance. It was the impression of the examiners, also, that dyspnea was unusually pronounced in relation to the extent of the fibrosis seen in the roentgenograms.

Roentgenographic characteristics. The type of fibrosis seen in these roentgenograms is very fine and diffuse, showing in many cases an appearance of soft haziness to which the term "ground glass," used in describing certain cases of asbestosis, can very well be applied. In a number of cases there is, in addition, a distinctly granular appearance, and in some a nodulation which might be confused with silicosis. In certain films soft conglomerations also occur.

The fibrosis in these cases tends to be somewhat more marked on the right side, and in the mid-lung fields and bases. The hilar nodes show a slight or moderate increase in density. Evidence of obliterative pleuritis

and emphysema occurs in some cases. In a few instances a blurring or "shagginess" of the cardiac outline is noticeable.

Tuberculosis. In the total group of 221 talc workers there were 29 cases (13.1 per cent) of primary healed tuberculosis; 6 (2.7 per cent) of healed re-infection type tuberculosis; and 5 (2.2 per cent) which were considered, on the basis of the roentgen appearances alone, to show clinically significant tuberculosis.

The incidence of healed primary and re-infection type lesions is not remarkable in any way, being similar to that found, in general, in other industrial groups. The incidence of clinically significant tuberculosis (2.2 per cent) is slightly higher than is found in most industrial groups, the average rate found for this condition being about 1.2 per cent. Among the 5 individuals with clinically significant tuberculosis, 3 between the ages of 30 and 50, showed minimal lesions; one, 45 years of age, showed moderately advanced lesions and one, 64 years of age, showed what was interpreted to be far advanced atypical tuberculosis. Among the 18 cases of fibrosis in men exposed only to talc, clinically significant tuberculosis appeared to be a complicating feature in 3 cases (16.6 per cent).

Talc plaques. A most interesting finding in this group of talc workers—interesting because, to these investigators, it was new—was the presence of 14 instances (6.3 per cent of the 221 talc workers originally roentgenographed) of what appeared to be deposits of opaque material on various pleural surfaces. These deposits, or plaques, are seen on the visceral pleura, including the region of the diaphragm, and occasionally the pericardium. Lateral and oblique views indicate that their location is definitely at the periphery of the lung, not involving the parenchyma.

In size the plaques vary from a single, linear-appearing deposit of a few centimeters in length in the region of the diaphragm to massive deposits bizarre in shape, extending over a large part of the lung fields. They are characterized not only by irregularity of shape, but by marked irregularities in degree of density also, and by the sharpness of their borders. In this series of films the development of these plaques can be traced from small, light, scarcely noticeable deposits to the extensive opacities described.

It should be noted that roentgen appearances similar to the plaques herein described were apparently seen in Case 1 where mention is made of areas of increased density resembling lipiodol or calcific deposits in

mid-lung fields. Similar appearances have also been noted in another group of workers who were exposed to talc dust in the making of material for electrical insulation.

So far as can be ascertained, these deposits bear no relation to any history of previous infection, since they occur both with and without such a history. Nor are they necessarily associated with other pulmonary pathology. The underlying lung tissue may or may not show fibrosis. There is no associated enlargement of the hilar nodes in cases showing plaques without fibrosis.

An analysis of the group of 14 talc workers who showed these deposits revealed the following facts: Their ages ranged from 35 to 77 years and their exposure in the talc industry from 4 to 52 years. Ten were mill workers; 4 were miners. Only one individual gave a history of having had pleurisy. None had had empyema. In 5 instances no lung pathology other than the plaques was noted. A marked degree of fibrosis co-existed in 7 cases. Evidence of clinically significant tuberculosis was seen in one case and of primary healed tuberculosis in another case.

No symptoms or physical signs attributable to these deposits could be identified, since in the group studied symptoms and signs only occurred in those individuals in whom there was other lung pathology. Apparently the plaques themselves and the process responsible for producing them are symptomless.

Discussion

Fibrosis. The type of fibrosis found in this study was characterized, as already described, by a soft haziness and a *finely* granular or nodular appearance tending to be more marked in the mid-lung fields and bases. Dreessen[3] apparently found a condition somewhat similar to this in his study of tremolite talc workers in the same geographical area. However, the fibrosis here reported was more severe than that found by Dreessen, as indicated by the conspicuous presence of clinical symptoms, such as dyspnea, pain, and fatigue in these cases and also by the more frequent appearance of granulation and fine nodulation. It more closely resembled in severity the fibrosis later reported by Dreessen and DallaValle[4] among Georgia talc millers and miners. Here the talc was also of the tremolite variety. Analyses also failed to show the presence of free silica. These authors reported 8 cases with symptoms of dyspnea, cough and pain, abnormal chest signs, clubbed fingers, and a nodular or "nodular conglomerate" type of fibrosis.

The occurrence of a type of fibrosis giving a nodular roentgen appearance as a result of exposure to tremolite talc dust is a matter of considerable interest, since nodular fibrosis is traditionally associated only with dust containing free silica. Gardner[8] attributed fibrosis in tremolite talc workers to the contaminating presence of free silica, but inasmuch as the free silica content of the twelve samples of mineral from talc mills and mines analyzed in the present study was found to be practically negligible (less than 1 per cent) it seems reasonable to suppose that the fibrosis observed in these cases is primarily the result of the inhalation of the various silicate minerals present in the dust, namely, talc, tremolite, and anthophyllite.

Microscopic study has shown that this dust is largely fibrous in character, and it may well be that this particular physical characteristic is responsible for the pathology of tremolite talc fibrosis. The possibility of action analogous to that which occurs in asbestosis is suggested by several facts: first, the chemical and physical similarity between the minerals in this area and those found in asbestos; second, the fact that the disability in tremolite talc fibrosis, like that in asbestosis, tends to be greater than one would expect from the severity of the lesion as seen on roentgenological examination.

Because of these similarities, we have taken the opportunity to compare this series of films of tremolite talc workers with those of a group of workers showing early asbestosis.* They were impressed by the resemblances in the roentgen appearances in the two groups. The talc fibrosis resembled early asbestosis in its fineness and diffuseness, its hazy "ground glass" quality and, in addition, some in the series of asbestosis films showed a mottled or nodular appearance similar to that seen in the more advanced cases of talc fibrosis.†

Whatever the exact pathology may ultimately prove to be, the study here reported clearly indicates, from a practical standpoint, that the dust encountered in the tremolite talc industry is of a definitely injurious, fibrosis-producing type which requires control in order to prevent disabling occupational disease. Moreover, although the number of cases here presented is small, suggestive evidence has been found that

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† "Mottling" in asbestosis has been described by Merewether[1] and also by Gardner and Cummings.[9]

exposure to tremolite talc dust is associated with increased susceptibility to tuberculosis.

Talc plaques. In regard to "talc plaques," one possibility to consider is that they represent simply aggregations of actual talc dust which has remained in the periphery of the lung unable to be disposed of in any manner. This supposition makes it difficult, however, to account for the presence of these deposits in a few cases only, rather than in the majority of those exposed.

Since "talc plaques" closely resemble, in appearance, pleural calcifications resulting from traumatic pleuritis or empyema, the thought immediately suggests itself that they are, in fact, deposits of calcium. The dust of tremolite talc contains calcium—tremolite being a calcium magnesium silicate—but so also do other dusts such as cement and marble. Why does tremolite talc dust alone produce the opaque deposits described?

Calcific deposits ordinarily presuppose previous irritation or injury. This fact suggests that tremolite talc dust, therefore, has some unique ability to irritate or injure pleural surfaces, such injury being followed by the deposition of readily available calcium. It is known, for example, that the resolution of intrapleural hemorrhage is frequently followed by calcium deposition, and one is tempted to speculate as to whether the needle-like particles present in this dust may, by tissue penetration, cause multiple, minute, capillary hemorrhages whose resolution results in the appearances described.

The location of the deposits, as seen in lateral, oblique, and stereoscopic views, appears actually to be just beneath the pleural surface. This suggests that they may lie in the peripheral lymphatic network and opens up another speculative possibility. In this connection an illustrated article by Lommel[14] in the *Deutsche medizinische Wochenschrift* is of great interest. Discussing the familiar "egg-shell" appearance occasionally seen in hilar nodes, he reports, in certain cases of silicosis, large calcific deposits in the peripheral parts of the lung which, to judge by the illustrations, closely resemble "talc plaques." His suggested explanation is that calcium (lime) is laid down in inflamed fibrous tissue in the congested lymph spaces which form a network around the lobules of the lung.

The sharply demarcated, yet irregular, borders of the "talc plaques" do in fact suggest that the deposit of opaque material is definitely limited by the outlines of some irregularly shaped structure such as the walls

of lymphatic spaces. It is of interest in this connection that Gardner and Cummings,[9] working with asbestos, report well-marked hyperplasia and dilatation of lymphoid tissue in the periphery of the lung in guinea-pigs which they believe may be the result of pulmonary irritation. One may speculate as to whether tremolite talc may not produce a similar condition which is then followed by the deposition of calcium already present in the dust.

Another interesting feature of the cases showing talc plaques is that radiopaque material in these cases is not, apparently, deposited in the hilar nodes. This suggests that talc dust does not find its way to them in large amounts. If this be true, it would indicate a similarity in this respect to asbestos which, as Gardner and Cummings have shown, tends to be held in the periphery of the lungs.

Whatever the similarity in effect between asbestos and talc dust, however, one conspicuous dissimilarity is the absence of any change resembling "talc plaques" in the lungs of asbestos workers. In fact, as far as we are aware, with the single exception of the German reference[14] given above, such deposits have not heretofore been described in connection with any dust.

Summary

1. A study of the tremolite talc mining and milling industry in northern New York State is reported.

2. Talc in this region is of the asbestine variety, mingled with tremolite and anthophyllite. Analyses of material from both mines and mills gave consistently a free silica content of 1 per cent or less. Microscopic studies of dust showed the presence of fine, straight, needle-like fibers.

3. Dust counts in mining ranged from 6 to 5,000 million particles per cubic foot; in milling from 20 to 215 million particles per cubic foot.

4. In a group of 221 tremolite talc miners and millers, advanced fibrosis was found in 32 men, giving an incidence of 14.5 per cent.

5. All of the cases of fibrosis occurred among those men who had worked in tremolite talc for ten years or longer (107 men), giving an incidence for this group of 29.9 per cent.

6. The fibrosis found in this study was of a fine, diffuse type with a roentgenographic appearance of granulation or nodulation on a hazy background. It tended to be disabling in character and was frequently accompanied by dyspnea, cough, and fatigue.

7. There was also some evidence that this fibrosis was characterized by an increased susceptibility to tuberculosis. Clinically significant tuberculosis was diagnosed by roentgen examination in 3 of 18 cases of tremolite talc fibrosis where there had been no other dust exposure.

8. In addition to fibrosis, deposits of unidentified opaque material in the periphery of the lungs, including the region of the diaphragm and pericardium, designated as "talc plaques," were observed in 6.3 per cent of all tremolite talc workers examined. These deposits occurred independently of other lung pathology and could not be identified with any particular signs or symptoms.

Conclusions

This study identified tremolite talc as a silicate dust capable, like asbestos, of causing a disabling pneumoconiosis. It reveals distinctive pathological findings associated with exposure to tremolite talc dust which postulate a special etiology for the resulting disease. There is also evidence that tremolite talc fibrosis is associated with an increased susceptibility to tuberculosis.

In the light of these findings, exposure to tremolite talc dust must be considered to constitute a definite industrial hazard requiring control of dust by suitable engineering methods.

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