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PUBLIC HEALTH REPORTS

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NO. 1

EFFECTS OF THE INHALATION OF ASBESTOS DUST ON THE LUNGS OF ASBESTOS WORKERS

A Preliminary Study

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INTRODUCTION

In 1929 the Metropolitan Life Insurance Co. was approached by officials representing the asbestos industry in the United States, who were desirous of ascertaining whether asbestos dust was an occupational hazard in their establishments and, if so, what was the nature of this hazard and what should be done to prevent or control it.

About this time several articles had appeared in English medical journals describing a pneumoconiosis due to asbestos dust. While in one or two isolated instances the occurrence of this type of pneumoconiosis had been described in American journals, the industry itself appeared to be quite uninformed of the existence of any such occupational disease.

The hazard of silica dust, with special reference to the lungs, has long been appreciated, and a great deal of study and research has been applied to the problem (in the metal mining and certain other industries) in Great Britain, the United States, the British Dominions, and in other countries. The nature of the effects of silica dust expressed in the term "silicosis", with the resultant extraordinary predisposition to pulmonary tuberculosis, is well known. These effects have been associated with the inhalation of dust containing free silica in varying amounts. The effects upon the pulmonary tissue of dusts containing combined silica—silicates—are still a fertile field for investigation, but evidence is accumulating that certain of these dusts produce pathological results quite distinct from true silicosis.

The name "asbestosis" has been applied to the pneumoconiosis caused by asbestos dust and it will be so used in this report. Chemically, the asbestos of commerce is a hydrated magnesium silicate consisting primarily of silica (combined silica) 44.1 percent, magnesium 43 percent, and water 12.9 percent, while ferrous iron and nickel are present in small quantities. This commercial variety of

asbestos most commonly encountered is designated as chrysotile and is one of the four varieties of the mineral serpentine, in which it usually occurs in seams.

It should be borne in mind that silicosis (and presumably asbestosis) develops very slowly, taking from 5 to 15 and even 20 or 25 years to become established. This rate of progress is influenced mainly by the dosage of silica which the lungs receive, and this dosage, in turn, depends upon three variables: the amount of silica in the dust, the quantity of dust in the air, and the length of exposure. Individual idiosyncrasy might be included as a fourth variable; however, little is known of the variations in susceptibility in those exposed to dust. It might well be assumed that similar variables would influence the occurrence of asbestosis.

In places where asbestos is mined or fabricated in North America there does not appear to be present the clear-cut clinical picture which is so unescapable in communities with a true silicosis hazard, such as hard-rock mining communities. It may be that some of the asbestos plants are of too recent origin for the typical effects of a silicate dust to become manifest, but this would not apply to the older mines or to all of the fabricating plants.

The industrial health service of the Metropolitan Life Insurance Co. undertook the following investigation during the period from October 1929 to January 1931, which included:

1. A study of dust conditions in asbestos mines and mills in Canada and in fabricating plants along the Atlantic Seaboard in the United States.
2. Physical examinations of asbestos workers, including X-ray films.
3. A study of dust exhaust systems designed to eliminate asbestos dust.

Data on the fabricating plants only are included in this study and are designated in the report as plants A, B, C, D, and E. This is a preliminary report. A more extensive study of the asbestos industry is now under way.

DUST STUDIES

Apparatus and methods of sampling.—Both the impinger (1) and the electric precipitator (2) were used for the collection of air samples for dusts at the breathing levels and in close proximity to the workmen. Both of these forms of apparatus are adapted for this work, as they are transportable, easily set up and adjusted for the taking of the air samples at the proper level, and are extremely efficient.

The impinger collects the dust by aspirating the air and then impinging it onto a flat surface covered by a liquid in a container. The liquid used was distilled water, containing 50 percent alcohol to

prevent the solution of some of the dusts, particularly any silica which might be present. The impinger was actuated by an electrically driven rotary pump and the rate of air sampled was measured by means of a resistance type of flow meter with an inclined manometer for measuring the pressure difference. Each sample represents the dust collected from a volume of 100 cubic feet of air.

The electric precipitator is designed upon the Cottrell precipitator principle used for recovering dusts and fumes commercially. This principle depends on electrifying the dust particles by making them pass through an electrostatic field and thus causing them to settle out upon a sheet of celluloid. The electrostatic field is set up by means of a transformer operating from the lighting lines on 120 volts, alternating current. Air is drawn through the apparatus by a small rotary fan, run by a motor, the quantity being measured by a flow meter.

Samples of dust brushed from beams and pipe lines near the ceiling also were secured for chemical analysis. All samples were shipped to the industrial hygiene laboratory of the Metropolitan Co., and the dust counts were made according to the methods accepted by the United States Bureau of Mines and the United States Public Health Service (1). Particles in size up to 360 microns in the greatest diameter were counted.

Chemical analyses were made for total (free and combined) silica according to the accepted standard method of Hillebrand (3).

In the first plant studied (A) only particles 10 microns and under in size were counted. It has been demonstrated repeatedly that no silica particles exceeding 10 microns (a micron equals one-millionth part of a meter or one-thousandth part of a millimeter) in greatest diameter enter the lung tissue; for this reason, the larger particles usually are not considered when determining dust counts. Later, as it appeared from some of the published articles (4) (English) that asbestos particles much larger in size were found in lung tissue, it was decided to count all particles and make differential counts of all those 10 microns and under.¹

Total particles per cubic foot and the corresponding weight of the dust in milligrams were obtained. Since no relationship between the dust counts and the corresponding weights was found, the weights are not included in the tabulations in this report.

Table 1 shows by plants and by departments the maximum and minimum dust counts in million particles per cubic foot of air. Although the counts in plant A are of particles 10 microns and under,

¹ Samples collected by both the impinger and the electric precipitator were counted. In addition, microphotographs of these dust particles were enlarged by being projected upon a screen with a lantern-slide projector, the enlarged particles being measured with a ruler. Knowing the entire enlargement (by actual measurement), it was easy to calculate the original particle size (2). By the use of Hansen's 60 logarithmic probability paper, the logarithms of the fractions to be measured (on this case microns) are plotted as ordinates against the probability of occurrence as abscissas.

and in the other plants are for all particles, direct comparison is possible, as in no sample taken were the number of particles 10 microns and under less than 94 percent of the whole.

TABLE 1.—Maximum and minimum dust counts in million particles per cubic foot of air, by plant and department

Department	Plant A		Plant B		Plant C		Plant D		Plant E	
	Number of samples taken	Million particles under 10 microns per cubic foot of air	Number of samples taken	Million particles per cubic foot of air	Number of samples taken	Million particles per cubic foot of air	Number of samples taken	Million particles per cubic foot of air	Number of samples taken	Million particles per cubic foot of air
Preparation.....	3	14-154	8	14-8	2	2-43			3	20-82
Card room.....	3	14-154	2	14-434	8	314-1544			2	26-76
Ring frame spinning room.....	2	14-34								
Mule spinning.....	2	14-214	8	14-1	2	111-414			3	214-10
Twisting.....	20	14-144	(7)	(7)	8	11-214			2	414-7
Weaving.....	4	14-2	4	14-14	8	214-10	18	1-7	3	1014-1044
Roll departments.....	6	14-414								
Sheet insulating.....	2	14-4								
Molded brake band and clutch.....							2	14-14		

¹ Included in spinning.

² Includes broad loom weaving.

Whereas the dust in the preparation room is practically all due to asbestos, the contrary is the case in the other departments. In the carding, spinning, and weaving rooms asbestos comprises about 25 percent of the material used. On special jobs the percentage of asbestos may be higher, but in general the figure quoted is approximately correct, the other material consisting principally of cotton. In the insulating departments of plant A, asbestos is but 5 percent of the total material used. In the molded brake-lining and clutch division of plant D, asbestos comprises about 25 percent of the total material. The actual exposure to asbestos dust, therefore, is considerably less than is indicated in the dust counts in table 1.

CONDITIONS IN THE PLANTS

The processes in these plants were very similar to those in cotton mills in general. For illustration, the process in the preparation room of plant B is here detailed at length:

Asbestos is received in bags. These are emptied upon the floor and the asbestos is shoveled into pug mills and run for about 5 minutes in order to crush and open the fibers. From there the asbestos is shoveled into trucks and wheeled to hoppers with either horizontal or vertical openers, similar to those used in textile mills. After passing through the opener, the material is discharged into trucks. Waste manufacturing material is first run through a garnet machine and

discharged into trucks, which are wheeled to the openers, and the material is fed into these in the same manner as is the new material. After being discharged from the opener, the material is put onto a vibrating or shaking screen, where the long fibers are picked off by a suction hood and blown into a bin to be used again in textiles. The short fibers falling through the screen are either sold as such or used in making an asbestos cement.

The cotton is received in bales, opened, and also run through vertical openers. It is discharged into trucks. The filled trucks from the vertical and horizontal openers containing either the asbestos fiber, the cotton, or the waste material are taken to separate storage bins. As needed, these materials are weighed and dumped onto the floor in proportion to the mixture desired, and the resulting mixed materials are then passed through a mixing picker. As this mixture is discharged from the picker, it is sprayed with a light mineral oil. The material is then taken by a mechanical conveyor to the storage bin in the card room. Two of these mixing pickers discharge onto this conveyor system, while a third machine is equipped with a suction device which conveys the material to a storage bin in the card room. The object of the two systems is to facilitate the handling of two grades of material at the same time. The third machine is not equipped with an oil spray. The object of the oil spray is primarily to entrap the small asbestos fibers and hold them enmeshed in the cotton fiber throughout the processes of carding, spinning, and weaving. Incidentally, it is apparent that it also diminishes the amount of dust. The material is saturated with about 4 percent of oil at this point; but by the time it reaches the looms, the oil had diminished to less than 1 percent.

While mineral oil was used in the preparation room of plant C, it apparently was not as efficacious as in plant B. In plant E oil was not used, nor was there any attempt at humidification or any system of dust exhausting. Carding machines were fed by hand. In plant A there was a humidifying, ventilating, and heating system, while plant B depended on natural humidity. In plant E the carding machines were equipped with a dust-exhaust system, but it was not efficiently used. In plant C carding was done in 2 buildings, 1 of which was equipped with an air-conditioning system, and in both buildings the machines had exhaust equipment.

Two plants, B and C, had artificial humidity installations in their spinning rooms. In the former the temperature was 76° F., relative humidity 78 percent. One plant, C, had a humidification system in the twisting department and also in the weaving department, where the relative humidity was 76 percent with a dry-bulb temperature of 69° F., as compared with a relative humidity of 44 percent in the weaving room of plant A.

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Aside from plant E, it would appear that the dust hazard was not excessive except in the preparation rooms of plants B and C. The dust counts are interesting, too, when considered in the light of the permissible standard for granite dust, established by the United States Public Health Service (7), namely, about 10 million particles (10 microns and under) per cubic foot. However, we are not justified in assuming that because available information suggests that asbestosis is a milder disease clinically than silicosis, the threshold of permissible dust counts is higher. Asbestosis appears to be pathologically different from silicosis, and the experience so far does not warrant an attempt to define a standard of dustiness for asbestos dust.

DUST CONTROL

Various measures, such as oiling, humidification, and local exhausts, tended to reduce the dust. Nevertheless, it was evident that they were only partly successful. If it is expected to control dustiness in these plants, final reliance must rest upon properly constructed exhaust equipment. In plant C in one department an experimental installation was set up. In spite of some obvious faults, this equipment, on the basis of comparative dust counts, reduced the dust by 50 percent and with further alterations will probably be 75 percent effective. In this case such a reduction seemed quite satisfactory. It is neither practicable nor economically desirable to install such equipment as will make the air entirely dust free. The normal defensive mechanism of the body takes care of a fair amount of atmospheric pollution. It is when the body is exposed to an excessive amount of dust that this defense mechanism breaks down.

The application of exhaust equipment to textile machinery involves considerable difficulty, especially where the construction of the plant is such that it is not possible to apply down-draft suction to the looms.

It is desirable to install exhaust apparatus in any plant on an experimental basis first, and then check its efficiency by dust counts. This practice will result in saving a needless expenditure of money.

PHYSICAL EXAMINATIONS

X-ray films were made of 126 persons (108 men, 18 women) working in asbestos plants in the United States. All but five of these were given physical examination. The cases were selected more or less at random from among those having more than 3 years of employment in the industry. It was soon obvious that the early diagnosis of asbestosis must rest to a large extent on X-ray pictures of the chest. As in the early stages of silicosis, the clinical symptoms of the asbestos workers were usually indefinite and inconclusive. The interpretations of these films are based on the readings of one competent roentgenologist, but they have been reviewed by several

others experienced in this field. The differences of opinion were of a minor nature, and there was general agreement as to interpretation. The films were read conservatively, taking into account the physical examination and the age of the individual, and were classed as positive only when there was no major disagreement. All examiners were guided by their experience in silicosis and other types of pneumoconiosis. The films classed as negative for asbestosis were further subdivided into doubtful and negative. Only time can tell whether the individuals classed as doubtful are progressing toward a definite asbestosis. Particular attention was focussed on the presence or absence of indications of tuberculosis, and in this respect all the reviewers of the films were in accord. With the unhappy experience of silicosis in mind, it was felt that a great deal of care should be devoted to ascertaining, if possible, whether or not asbestosis predisposes to tuberculous infection.

The cases of asbestosis were divided into two classes, first stage and second stage. The first stage embraces those who show by X-ray examination definite lung pathology sufficient in extent to warrant a diagnosis of pneumoconiosis, but who have no definite symptoms. The second-stage cases exhibit more extensive lung pathology and also definite symptoms.

All these individuals¹ were actively engaged in factory work, and it was not practicable to make any distinction on the basis of working ability or disability. Had any individuals been found who exhibited extensive pulmonary involvement and marked physical disability or total disability, they would have been classified as third stage, but no such cases were found.

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.

There is a definite increase in the percentage diagnosed as positive in relation to the years of exposure, as shown in table 2. Small numbers make it impossible to determine how far the factor of age enters into this increase.

TABLE 2.—Classification of cases by years of exposure

Years of exposure	Percentages positive	Number		
		Positive	Doubtful	Negative
Over 15 years	57	12	11	13
10 to 15 years	51	7	3	3
5 to 10 years	20	20	23	3
Under 5 years	43	17	18	12
Total examined		67	55	29

¹ Part time.

² Not continuous.

³ One asbestos worker (second stage) retired of his own accord, because of old age, 10 years previous to this study, but is still active about his garden.

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Of the 64 persons given physical examination and diagnosed as having positive asbestosis, only 8 were entirely free from symptoms, while 10 out of 37 with doubtful and 7 out of 20 with negative diagnoses were free from symptoms. Dyspnoea and cough were the symptoms most complained of, but none of these cases exhibited the urgent or evident type of "short wind" seen in true silicosis. Several of those classed as negative stated that they were "short winded" and were so recorded, but too much emphasis should not be placed on statements of subjective symptoms. During the progress of the study, physicians who were practicing in the communities where asbestos workers lived were questioned and stated that they did not find an unusual amount of tuberculosis among these workers. The contrast between this state of affairs and that found in a community with a silicosis hazard is noteworthy.

The incidence of tuberculosis (based upon X-ray films) is given in table 3; 40 of the 67 examined had less than 15 years of employment in the industry.

TABLE 3.—Incidence of tuberculosis

	Positive	Doubtful	Negative
Tuberculous (positive).....	7	1	2
Tuberculous (doubtful).....	11	6	1
Total examined.....	67	20	20

¹ This case was diagnosed as probably active on the X-ray findings.

Table 4 gives information as to physical signs of chest trouble.

TABLE 4.—Chest findings

	Positive	Doubtful	Negative
Physical signs of chest trouble.....	12	10	17
No physical signs.....	21	2	13
Not examined.....	3	1	6
Total.....	67	20	20

¹ At least 6 of these showed no evidence associated with asbestosis.

² 2 of these not associated with usual signs found with asbestosis.

³ 6 of these not associated with usual signs of asbestosis.

What significance, if any, can be attached to the presence of "asbestos corns" on the hands of workers appears doubtful, as 13 percent of the positives (12 out of 64) and 15 percent of the others (doubtful, 7 out of 37, negative, 2 out of 20) showed such corns.

Each roentgenologist who reviewed the X-ray films called attention to the fact that these films indicated a very unusual incidence of enlargement of the heart. It is probable that this is a compensatory enlargement due to the additional work put upon the heart in efforts

slight irritant effect on the mucous membranes, its presence may be suspected by means of smell. Perception of smell appears to diminish with prolonged exposure or high concentrations. The observations of Fairley indicate that concentrations of the order of 1 in 1,000 to 1 in 500 could readily be tolerated by workers for prolonged periods without any warning subjective symptoms. The fatal effects of exposure to dioxan in industry were clearly brought out in England seven years ago when five workers in an artificial silk factory died. Three stages have been described, the first being characterized by irritation of the naso-pharynx and of the eyes, but if the exposure is continued, the irritation may subside and thus give rise to a false sense of security. Symptoms of drowsiness, vertigo, and gastric disturbances may be present, but if a rest of twenty-four hours is taken at this stage, these tend to pass off quickly.

With further continued inhalation, the second stage is reached. The gastric symptoms become more severe and are associated with pain and tenderness in the abdomen and lumbar region. There may be enlargement of the liver. The third stage is characterized by acute hemorrhagic nephritis, leading to suppression of urine, uraemia, coma, and death.

Mention finally might be made of one more of the solvents, namely, furfural, which is the only aldehyde of importance as a pyroxylin solvent. It also has recently been used successfully as an ingredient in paint, varnish and lacquer removers. When condensed with phenol it gives resins analogous to bakelite. Its odor is disagreeable to most users and its vapors are irritating and may be damaging to the eyesight.

The measures at our disposal for preventing toxic concentrations of solvents escaping into the plant atmosphere fall within three special fields of endeavor, the safety, engineering and medical. Safety measures must be employed against accidents and irregularities in operation. Labels on cans and drums should indicate the hazardous nature of the substance and workmen should be instructed as to dangers. Personal protective devices, such as protective

clothing, goggles and respirators should be provided when necessary.

Good housekeeping and sanitary facilities are essential and include segregation of processes, care of spilled solutions, receptacles for soaked rags, ample general ventilation, and provisions for showers, lockers, lunch rooms, and drinking facilities.

A survey to determine the presence of low concentrations under normal operations may be indicated. This leads us into a field of detailed technical work which we will not discuss here. The results, however, give important information regarding the necessity of employing local exhaust ventilation or giving consideration to substitution or entirely enclosing the offending process.

Medical supervision to be effective presumes a knowledge of the physiological action of the solvents in use and sufficiently frequent physical examinations including special diagnostic methods for the detection of early intoxication or disease.