BYSSINOSIS: Matter from Lint to Lungs

The authors are among the investigators who demonstrated how much of a hazard plant particles in lint, particularly cotton lint, are to textile workers. The risk is high and is higher for cigarette smokers than for non-smokers.

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Two symptoms define byssinosis—Monday morning chest tightness and shortness of breath in workers exposed to dusts of cotton, flax, and soft hemp. Symptoms are more obvious on the first day back after a rest from exposure.

The origins of the disorder probably date to the processing of cotton indoors in prehistoric Egypt. Despite a rich history with classic descriptions, this disease was denied in the United States by officials of the U.S. Department of Labor and the textile industry until studies during the past five years, carried out mostly in North Carolina.

Byssinosis has a worldwide distribution among cotton, flax, and hemp workers and has been reported from at least 16 countries. Prevalence in a given occupational group varies from a few percent to practically all workers. Workers in British cotton mills have shown a high prevalence of byssinosis since the early Nineteenth Century(1).

Careful studies of death rates from respiratory and cardiovascular-renal disease by Bradford Hill among cardroom workers (strippers and grinders), spinners, and weavers showed almost twice the expected mortality among cardroom workers with heavy dust exposure(2). Days of sickness with bronchitis also totaled more in this group than in less exposed spinners (cotton ringroom) and unexposed printers.

Byssinosis has been a compensable disease in England since 1941, but until recently, there were only sporadic reports of byssinosis in U.S. cotton workers. However, reports from the 1960's and 1970's of prevalence rates demonstrate the magnitude of health impairment related to cotton dust inhalation in cotton mill workers in the United States(3-10).

Cotton is a valuable textile fiber and cotton yarn production is several times larger than that of all other fibers combined, despite increased use of synthetic fibers. Although textile workers other than cotton workers are included, about 1 million people are engaged in textile work in the United States.

Symptoms and Signs

Chest tightness, dyspnea, frequent cough, and occasional wheezing cough are experienced on the first day of the work week. Symptoms disappear a few hours after leaving work, but may recur each Monday after a weekend of nonexposure. With continued exposure, the symptoms appear on Tuesday and may progress to other days of the week. Eventually, the development of a chronic productive cough signals the presence of chronic bronchitis.

Initially, it was thought in Great Britain that 20 or more years of dust exposure were required before airway obstruction caused serious functional impairment. This estimate was reduced to 10 years for the purposes of workmen's compensation in Great Britain. Recent studies suggest that irreversible airway disease occurs after a much shorter exposure, especially in cigarette smokers.

In many epidemiological surveys,

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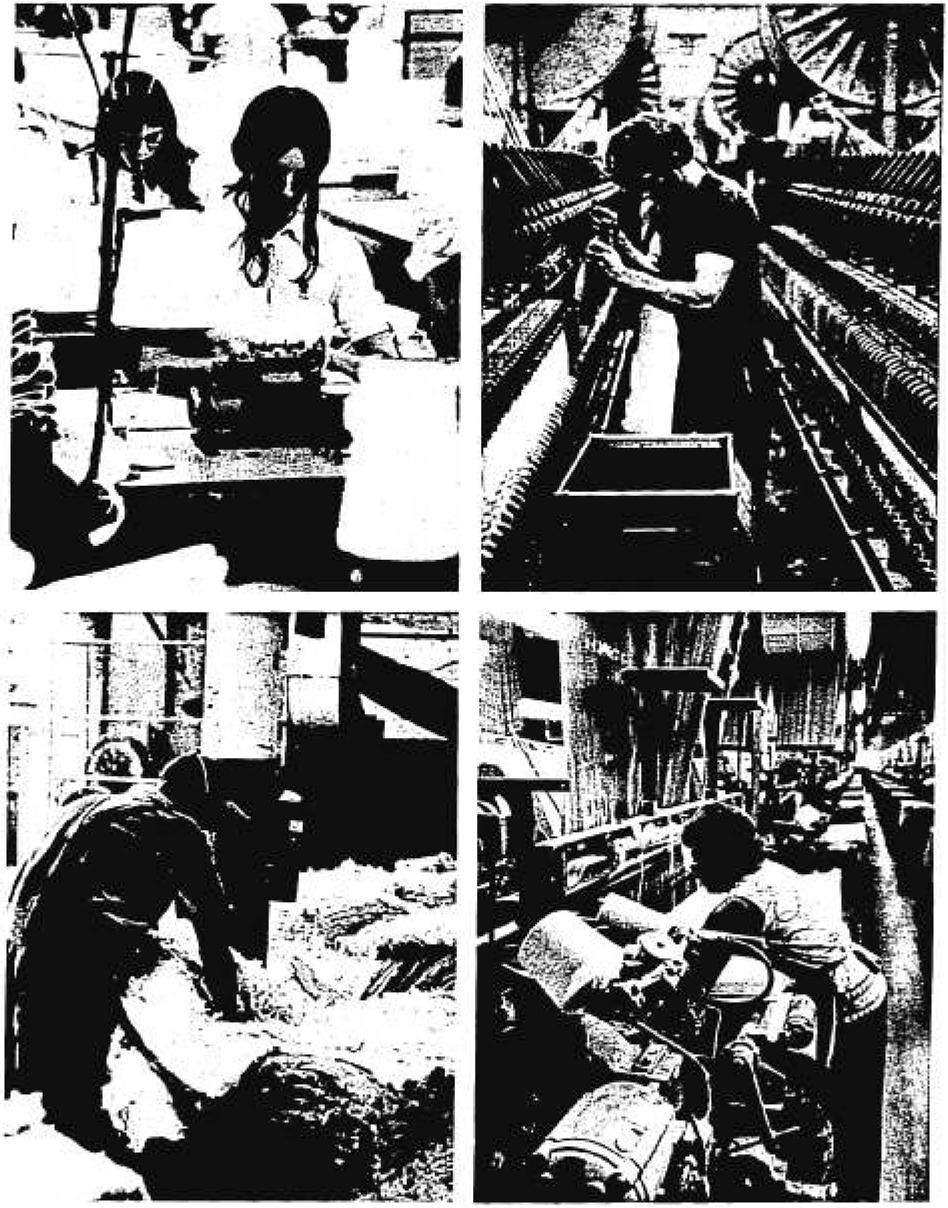


In a textile mill, the risk of acquiring byssinosis varies with type of operation and type of fiber.

"Why does the Department of Labor delay? . . . Byssinosis and work-related chronic bronchitis can be prevented in cotton textile workers."

byssinosis is graded by a classification of Schilling and others(11):

Grade ½ The worker feels occasional chest tightness or coughs on the first day of the working week.

Grade 1 Chest tightness is experienced on every first day of the work week.

Grade 2 The worker feels chest tightness on the first and other days of the working week.

Grade 3 The worker has grade 2 symptoms and shows evidence of permanent ventilatory impairment.

Early in byssinosis, physical and chest roentgenogram findings are normal. When changes develop, they are those of chronic bronchitis. Few autopsy studies in byssinosis have been reported. Large roentgenographic surveys of textile workers have shown only one or two instances of diffuse pulmonary fibrosis, not an unexpected finding in a large cross section of adults. The source of widespread misinformation repeated in many textbooks that byssinosis produces diffuse pulmonary fibrosis is unknown. Reports of specific dust bodies in the lung are equally unfounded.

Most epidemiological investigations include measuring the forced expiratory volumes and flow volume curves(12). In byssinosis, expiratory flow and vital capacity usually are found to be reduced.

Study of Prevalence

A broad study of prevalence of byssinosis and its control was undertaken in February 1970 by our group at Duke University. The major research partner was the Occupational Health Section of the North Carolina State Board of Health directed by John Lumsden. Burlington Industries, with headquarters at Greensboro, North Carolina, provided an open door to their textile operations for study of workers and research and development of dust control.

Consultation with industrial hygienists, especially Jeremiah Lynch at the National Institute of Occupational Safety and Health, Cincinnati, led to the development of new dust-sampling methods adapted to the special conditions of vegetable dust, which has properties different from mineral dust. After visits to 21 textile plants, investigators chose eight for survey by human sampling and environmental sampling of dust particles small enough to be respirable. Five plants processed cotton that ranged from very dusty to cleaner, cotton-synthetic blends. Three that process only wool or synthetic fibers were chosen as controls.

Human sampling included interviewing 2,967 workers by a modified British Medical Research Council respiratory questionnaire; measuring forced expiratory volume in one second (FEV_1) and forced vital capacity on a simple spirometer (Jones Pulmonor, II) before and six hours after Monday's exposure; and taking postero-anterior and lateral chest roentgenograms to detect hyperinflation as an indicator of emphysema. Using the preferred dust sampler, the vertical elutriator developed by Lynch and Lumsden, several timed samples of dust were obtained in major work areas—preparation and carding, yarn production (spinning, winding, and twisting), and slashing and weaving. These data made it possible to compare the dose of respirable dust with the workers' responses as assessed by development of symptoms, and by decreases in expiratory flow and vital capacity during exposure. The measurements made after six hours at work on Monday were compared with those made before workers entered the plant, to obtain the change with exposure.

Workers in the preparation areas had the most symptoms and greatest decreases in expiratory flow. For example, 40 percent of preparation workers were judged byssinotic in one mill. Yarn production workers had approximately half the prevalence observed in preparation areas, and weavers were lowest, with 6 to 7 percent affected.

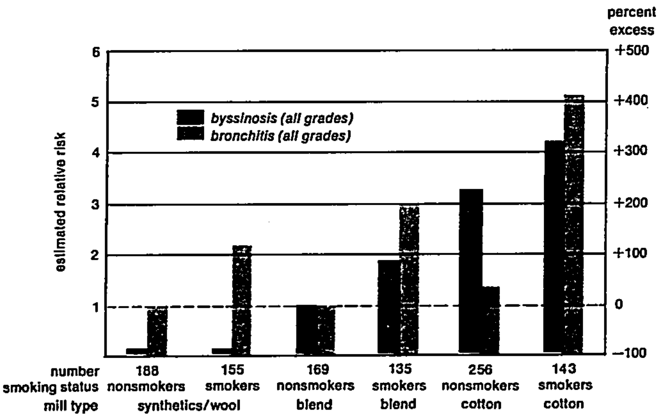
Such prevalence rates were useful, but comparison with dust levels provided more revealing data. There was a straight-line fit of the dust level and symptoms prevalence. Thus at 0.1 $mg./m.^3$, 6.5 percent of workers still had symptoms(13). Decreases in FEV_1 and dust levels exhibited a similar relationship. In keeping with our earlier studies, the prevalence of chronic bronchitis, judged from persistent cough and sputum production, also was highly dependent on dust levels.

An important positive interaction was discovered between cigarette smoking and cotton dust exposure, as reflected by the prevalence of chronic bronchitis. The data for 1,046 women demonstrated the lower prevalence of bronchitis among nonsmokers working in synthetics and in wool and blend mills (see graph at right). Nonsmoking cotton workers had a bronchitis prevalence of 8 percent, which was exceeded by the 13 percent in cigarette-smoking wool workers.

The combination of exposures to cotton and cigarette smoking raised the bronchitis rate to 28 percent, four times the rate in nonsmoking blend workers, which was more than additive. Thus, cigarette-smoking cotton workers have an appreciably greater risk of developing bronchitis than have nonsmokers and they are more likely to have byssinosis at any dust level(14).

Early data convinced the research team that byssinosis and chronic bronchitis were more prevalent in cotton textile workers than in wool-synthetic (control) workers. Over 120 of these cotton textile workers were hospitalized for cardiopulmo-

BYSSINOSIS AND BRONCHITIS: ESTIMATED RELATIVE RISK



Estimated relative risk (age adjusted) of contracting byssinosis and bronchitis among 1,046 women textile workers in N.C. in 1970-1971 by dust level. Dust levels were negligible with synthetics or wool, low with blends, and medium with cotton. Effects of cigarette smoking and cotton exposure on bronchitis were more than additive.

nary evaluation. They had various degrees of pulmonary insufficiency. Reduced expiratory flow was invariably associated with arterial hypoxemia, dyspnea on mild to moderate exercise, abnormal gas distribution in the lungs, and increased airway resistance. Most of these patients had byssinosis and chronic bronchitis; a few had pulmonary emphysema.

Protecting Workers

In 1971, the Workmen's Compensation Law in North Carolina was amended to cover diseases resulting from inhalation of a broad range of dusts, fumes, gasses, and smokes. This allows cotton textile workers with pulmonary insufficiency due to byssinosis to make claims. In the first year, 1971-1972, the North Carolina Industrial Commission settled 17 such claims although no cases were heard; and others are now pending. North Carolina is the only state that compensates workers disabled by byssinosis. Following this lead, other states have considered similar amendments but the slow progress may force federal legislation.

Meanwhile, the Occupational Safety and Health Act of 1970 places the responsibility for adequate standards and their enforcement on the U.S. Department of Labor. To date, however, the Department has failed to adopt a criteria document based on respirable-dust or to enforce the old standard based on earlier British studies.

The American Conference of Governmental Industrial Hygienists has recommended that a safe level for respirable, lint-free cotton dust should be 0.2 mg./m.^{3}. Many workers could be protected by the employment of better textile-mill-ventilation systems, high grades of cotton which contain less dust, more synthetic fiber, and better enclosures and air removal from opening, picking, and carding machines. The 10 percent or so of workers still exposed to high levels could be protected by respirators or air hoods. Medical surveillance can help by removing highly susceptible workers after initial exposure and monitoring changes in those who have little or no initial reaction.

Because of the disappointing results in this country and Great Britain from appeals for better mill ventilation and for enclosing dust-producing operations, we have joined others in the search for additional approaches to removal or detoxification of cotton trash dust. To pursue this, a model cardroom or human exposure chamber was constructed in 1970 in a Burlington mill. It has its own air-treatment system to prevent leakage of dust from the work areas, dust-measuring equipment, and a carding engine to generate dust from cotton.

Twelve workers from the plant who react to cotton dust were the human subjects(15). The protocol for each trial in the model cardroom resembled the survey protocol: questionnaire and pulmonary function tests before and at two-hour intervals during six hours of exposure to dust. Biological response in the panel was validated by using untreated cotton of varying dustiness to match plant conditions. Negative controls consisted of no material being carded and rayon, which is a clean synthetic fiber. We demonstrated that cotton of higher grade picked with spindle pickers produced less dust, less decrease in FEV_1, and fewer symptoms.

Washing cotton with water alone or alkali followed by detergent and water totally removed the biological effect and lowered respirable dust levels to below 0.2 mg./m.^{3}. Unfortunately, such washed cotton could not easily be manufactured. Dry-heat treatment of cotton alone increased the toxic effect.

As an alternative, we tried steaming cotton and showed a 60 to 80 percent reduction in effect by five minutes of steaming or by autoclaving. Symptoms were also reduced, as were dust levels. Some dust was removed, but steaming may also fix small vegetable particles to the cotton fiber or aggregate them so they are not shaken free and dispersed into the air during cotton processing.

Now, efforts are directed at mastering the engineering problems of increasing the volume of cotton steamed in a continuous process, to test whether an entire cotton textile mill can manufacture cotton pretreated by steam.

Meanwhile, studies continue to identify and characterize the toxic agent or agents and determine how they produce symptoms. When agents extracted from cotton trash or dust by warm water are dispersed into chambers containing hamsters and guinea pigs, the animals' airways recruit white blood cells and their blood white counts decrease(16). Chemicals in the phenol family evaporated onto bland particles elicit this reaction; so we believe plant phenols may be responsible. Perfection of biological test systems, comparisons with human responses, and chemical isolation studies are continuing.

Medical Surveillance

Medical surveillance has four related objectives that are aimed at reducing exposure to susceptible workers. These are (*a*) byssinotic-reactor case finding among employed workers, (*b*) pre-employment reactor detection, (*c*) regular periodic follow-up studies, and (*d*) placing workers with disability in less dusty areas or retiring them with data to obtain workmen's compensation. Occupational health nurses can accomplish these four objectives in cotton textile plants in addition to other health conservation programs such as hearing conservation, accident prevention, and first aid.

For reactor case finding, the nurse administers the modified Medical Research Council questionnaire and measures expiratory flows before and after six hours of exposure in the plant. This questionnaire provides a constrained respiratory history, which is of maximal usefulness in determining the presence of byssinosis and chronic bronchitis as well as asthma. Workers who are negative for these disorders by questionnaire and do not show decreased flow (and are 80 to 100 percent of predicted) can be evaluated yearly. Those reactors with 60 to 80 percent of predicted function should be evaluated at six months, and those below 60 percent should be relocated whether they are reactors or not.

In evaluating new or prospective workers, the same technique is used. Asthma appears to be incompatible with cotton dust exposure, and so asthmatic persons should be counseled to seek other work. This would apply also to those with greater than 10 percent decreases in flow. Reactors should be monitored more frequently than nonreactors.

If changes in respiratory function or symptoms are found during periodic reexamination, workers require similar attention. Convincing a worker he should accept a new job or work area or discontinue smoking cigarettes is most difficult. Here the nurses' talents and patience will be sorely tested. Workers can be relocated, retrained, and rehabilitated.

The most difficult job may be that of telling a moderately disabled person that he should not continue working. A nurse should know how to help the worker apply for Workmen's Compensation, the settlement to be expected, the steps in the process, and the counterpart process of applying for disability retirement under Social Security. Frequently, the nurse can ease the worker's transition while he still has breath left.

A solution to discomfort during working and eventual disability appears to be within reach for cotton textile employees from a scientific and engineering view. Dust can be reduced by better exhaust ventilation of carding engines and of the cleaning operations of opening and picking.

To improve the workers' environment, a dust level with minimal toxicity for workers must be enforced by the U.S. Department of Labor. Either it should be temporarily the threshold limit value of 1 mg. of total dust per cubic meter of air, established by English studies in 1960 and adopted as part of the Occupational Safety and Health Act of 1970, or the logical new value of 0.1 to 0.2 mg. of *respirable* dust per cubic meter, sampled by vertical elutriation as proposed in November 1971(13). Why does the Department of Labor delay? Once a goal is set and enforced, byssinosis and work-related chronic bronchitis can be prevented in workers in the cotton textile industry.

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