Interstitial Lung Disease in A Nylon Flocking Plant: An Exposure Assessment

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Table of Contents

List of Figures

List of Tables

Abstract

The purpose of this study was to complete an exposure assessment for flock workers lung using data available from a flock manufacturing facility in an effort to explore associations between different exposure metrics and disease. Two different populations of workers from the facility were studied. The first population (study population A) included all workers for whom a detailed work history and symptom data were available (n = 152). The second population (study population B) included all workers in study population A who were evaluated at the MHRI and who have had a HRCT scan (n = 45). The case definition for the study population A, based on the responses to the NIOSH questionnaire or on medical evaluation was: any worker reporting cough and shortness of breath beginning after starting work at this facility and lasting for a period of 2 months or longer. The case definition for the study population B described above will be any worker with a finding of either diffuse ground glass opacity, micronodularity, or honeycombing on HRCT scan. Six exposure metrics were used in the epidemiologic analysis: duration of employment in production area, ever/never worked in each job category, ever/never having worked in a job category with peak exposures, duration in job categories with peak exposures, cumulative total dust, and cumulative respirable dust. This study showed that development of chronic respiratory symptoms among workers in a flock manufacturing plant and subsequent development of objectively diagnosed illness were not associated with duration of employment, work in particular job categories, or with a history of the potential for peak exposures. Symptoms of cough and shortness of breath were, however, shown to be associated with work in the production area of the plant and with cumulative respirable dust exposures while controlling for gender. Abnormal CT scans in symptomatic individuals were also associated with cumulative respirable dust exposures while controlling for gender.

Significant Findings

This study showed that development of chronic respiratory symptoms among workers in a flock manufacturing plant and subsequent development of objectively diagnosed illness were not associated with duration of employment, work in particular job categories, or with a history of the potential for peak exposures.

Symptoms of cough and shortness of breath were, however, shown to be associated with work in the production area of the plant and with cumulative respirable dust exposures while controlling for gender. Abnormal CT scans in symptomatic individuals were also associated with cumulative respirable dust exposures while controlling for gender.

Usefulness of Findings

These findings are useful in the development of a better understanding of the mechanism for flock worker's lung and in controlling future exposures in an attempt to prevent the occurrence of this newly recognized disease. Although there is still a great deal of work to be done in evaluating exposures in this industry and in isolating the etiologic agent in flock workers' lung, this study strongly suggests that the disease is a result of cumulative, rather than peak exposures. Control strategies and future sampling can now be approached with this in mind.

Introduction

The Original Outbreak Investigation

In November 1994, a patient was referred to a hospital-based occupational health clinic for investigation of possible hypersensitivity pneumonitis (HP). This patient had not had a biopsy to confirm his diagnosis and a visit to his workplace in early December revealed no obvious cause of HP. In February 1996, however, a second man from the same workplace was referred to the same occupational health clinic. This prompted an investigation of a potential outbreak of occupational illness in this plant manufacturing flock and flocked fabric. In the ensuing eight months, a total of eight cases of interstitial lung disease, pathologically unlike any previously recognized occupational illness, and subsequently named flock worker's lung, were revealed in this workplace. As of February 1999, the number of cases in this facility had reached 10 and 14 cases of flock worker's lung have been identified in workers at other facilities. Although there are a number of potential etiologic agents, the cause of disease is yet to be determined.

The Flocking Process

Flocked fabric is a form of imitation velvet and is produced by cutting textile fibers into tiny pieces (flock), applying an electrostatic charge to the flock and dropping it onto an adhesive-coated woven textile substrate. The flock manufactured and used in this facility is cut primarily from nylon tow using rotary precision cutters and has fiber diameters of approximately 10 - 20 μm and lengths ranging from approximately 250 μm to 2 mm. The flock fiber itself is not considered to be of respirable size and its toxicity had not been tested prior to the investigation of this facility. This facility produces some undyed flock as well as flock of a variety of colors. The substrate textile is a cotton/polyester blend and the adhesive is a formaldehyde-containing acrylic latex. The finish applied by the nylon manufacturer is routinely scoured off, and a new finish creating surface properties conducive to flocking is applied prior to cutting. This finish is comprised of an ammonium ether of potato starch, tannic acid, and a mixture of sulfonated alcohol derivatives. After flock application, the flocked fabric goes through a curing oven, is coated with fabric softeners and/or protectors, makes a second pass through the curing oven, and may then be finished by printing or embossing.

In this facility, there are three main production areas. One is devoted to the mixing of dyes, and another to cutting flock. The third is quite a large open space and the largest portion of it is devoted to the facility's two main coating lines (or ranges), which include adhesive application, flock application, and curing, as well as embossing and print ranges. This third area, however, also houses additional flock cutting lines, the compounding department where adhesive is mixed, an area for mixing finish, and a continuous dying unit for dying tow. There is spatial separation of these operations, but there is no obstruction of air movement between them, except for the screening area for the additional cutting lines, which was enclosed in December of 1995. The screening operation for the other cutting area is located in the basement of the building, apart from all other operations.

Available Data

Results of air sampling conducted in 1996 by both the National Institute for Occupational Safety and Health (NIOSH) and the Memorial Hospital of Rhode Island (MHRI) were available for this study. Additional information regarding the history of materials use and process changes provided by the company and historical information provided by production and engineering staff during on-site evaluations of the process were also available.

Job histories were obtained from the company for 196 production workers and supervisors who worked in the facility between June 1990 and June 1996. A database has been created, which includes start date, end date, job title, department, and building for each job held by each of the 196 workers.

There were 158 current production workers at the time of the NIOSH medical screening in May 1996. NIOSH completed questionnaire interviews for a total of 155 employees, including 138 production and 17 non-production workers. Two additional questionnaires were completed by phone. The questionnaires contain information regarding symptoms and illnesses as well as some important exposure information, such as history of exposure to certain high-exposure processes.

The investigators also had access to medical records for 50 workers who were medically evaluated by Dr. David Kern at the Memorial Hospital of RI Occupational Health Service, and to high resolution computerized tomography (HRCT) scan results for 46 of these workers.

Purpose

Due to the fact that Flock Worker's Lung is a previously unrecognized disease with unknown etiology, the objective data available for both exposure measurement and outcome measurement are limited. The disease occurring in this facility is unlike any other recognized occupational illness and the incidence of this disease in this facility appears to be quite high.[1,2] Twenty-eight of the fifty-seven companies that are members of the American Flock Association identify themselves as flockers.[3] There is also an international trade association (Verband der Flockindustrie e.V.) with additional member companies including some of the largest European flock manufacturers. If we account for the possibility of some facilities not belonging to trade associations, and if the investigated facility has an average number of employees for this industry, it is reasonable to estimate that there are several thousand workers involved in the manufacture of flock or flocked fabric worldwide. If the prevalence of disease in the industry is as high as it is in the current plant, then up to several hundred of these workers would be expected to have disease.

The purpose of this study was to complete an exposure assessment for the index facility in an effort to explore associations between different exposure metrics and disease with the hope of gaining a better understanding of the mechanism of disease and how to prevent it.

Methods

Study Populations

Two different populations of workers from a flock manufacturing facility were studied. Different measurements of disease outcome were available for each of these populations, and a different case definition was used for each population. Available data used to select the study populations is shown graphically in Figure 1.

The first population (study population A) included all workers for whom a detailed work history and symptom data were available. For non-production workers, the job history information from a NIOSH questionnaire administered during a health hazard evaluation at the facility was considered sufficiently detailed assuming that they were never employed in the production area and could be assigned no exposure. Detailed job histories from personnel files or from medical records were required for production workers to be included in this study population. Symptom data from either the NIOSH questionnaire or from medical evaluation was considered to be acceptable.

Two of the 17 production workers were not included because they were known to have exposure in the plant, yet the exposure history was unknown. Four others had plant exposure, but detailed job histories were available, so these workers were included for a total of 15 non-production workers. Of the 196 production workers for whom job histories were provided by the company, 130 completed NIOSH questionnaires. Another four workers with job history data who did not participate in the NIOSH screening were evaluated at MHRI and symptom data is available in their medical records. One worker completed the NIOSH questionnaire, but the company did not provide a job history. This worker was evaluated medically, and the self-reported job history in his medical record was used. There were three more workers without a company-provided job history or a NIOSH questionnaire, but who had a medical evaluation. Sufficiently detailed job histories are available in the medical records for two of them, and they were also be included. Thus, the total number of workers in study population A is 152.

The second population (study population B) included all workers in study population A, who were evaluated at the MHRI and who have had a HRCT scan (n = 45). This group is clearly a unique population since they have self-selected themselves by seeking medical attention. For the most part, the workers who came to the clinic were those who were either 1) symptomatic, 2) concerned about the health risk, or 3) urged to be seen as a result of the NIOSH screening results. Although there may be other workers in the cohort who sought medical attention elsewhere, or who were afraid to come to the clinic in spite of symptoms, this population is probably more likely to have disease than those who were not evaluated at the MHRI clinic. This does not, however, introduce a selection bias since this population will be considered to be a specific sub-population rather than a representative sample of the cohort. All analyses conducted on this group will be used to investigate whether there is a dose-response relationship between any of the six exposure metrics and objectively diagnosed disease *among workers with respiratory symptoms sufficient for them to seek medical attention.*

Case Definitions

The case definition for the study population A, based on the responses to the NIOSH questionnaire or on medical evaluation was: any worker reporting cough and shortness of breath beginning after starting work at this facility and lasting for a period of 2 months or longer. This case definition is quite broad and is expected to be quite sensitive, but not necessarily specific.

The case definition for the study population B described above will be any worker with a finding of either diffuse ground glass opacity, micronodularity, or honeycombing on HRCT scan. This case definition will be much more specific for interstitial lung disease than the case definition for population A and will serve to distinguish those with symptoms from those with objective disease.

Exposure Assessment

Exposure Metrics

Six exposure metrics were used in the epidemiologic analysis. Two of these metrics were based solely on work history (i.e. duration of employment in production area and ever/never worked in each job category). Two other metrics (ever/never having worked in a job category with peak exposures and duration in job categories with peak exposures) were based on job categories and the potential for workers in those job categories to have high peak exposures.

Cumulative total dust and cumulative respirable dust were also calculated for each individual in the study population.

Development of Job Categories

The first step in the exposure assessment was to combine the 70 job titles from employee job histories into job categories with similar exposures. In addition, each category was assigned a 1 or a zero for potential peak exposures. Peak exposure for this purpose was defined as exposure to blowdown of the module or screening equipment, or other extremely high dust exposure such as machine maintenance activities. The first category includes all maintenance workers as these workers are expected to roam throughout the plant and would have very different exposures from workers who remain in one area all day. Category 2 includes workers in the finished goods department and in shipping, who primarily work in the warehouse or on the loading dock handling finished product. Category 3 includes the shipping department worker and the quality control technician, who move around the entire plant, but are not involved in high exposure activities like the maintenance workers. Category 4 is the truck drivers, who have very little exposure inside the plant. Category 5 includes workers in compounding, who have direct exposures to chemicals in the adhesives and finishes, and some indirect, yet sometimes quite high, exposure to airborne flock due to their location in the plant. The dye house workers make up all of Category 6. Since they are in a separate area of the plant from the flock cutting and flock application processes, they are expected to have virtually no exposure to flock in spite of their exposure to chemical dyes. Category 7 is the cutting department, whose exposures are limited to dusts of flock and its finishes. They sometimes have very high peak exposures due to the need to clean the screening equipment. Category 8 includes all of the production supervisors and managers, who spend most of their time in the office with very little exposure to production processes, and Category 9 includes the non-production workers expected to have no exposure. The coating department workers are distributed in Categories 11 – 23 with between one and three job titles in each category because of the unique exposures expected for each job title in this department. A listing of job categories with associated job titles and peak exposure assignments is given in Table 1.

Detailed job histories were then used to assign exposure estimates for the two most basic exposure metrics (ever/never in a job category and duration of employment in the production area) to each individual. The job categories were also used to assign estimates for the metrics relating to peak exposure. Any individual whose job history indicated that the worker spent any time in a job category that had potential exposure to blow downs of the module or the screening equipment, or to dusty maintenance tasks was assigned a 1 for having had the potential for peak exposure. Others were assigned a 0. Duration in all job categories with potential for peaks was also calculated for each subject in the study population.

Development of an area-exposure matrix

Next, in order to calculate cumulative exposures to total and respirable dust, a matrix of estimated average concentrations of total and respirable dust in each of 14 areas and two high exposure tasks for each of six defined time periods was constructed. Time periods were defined by the timing of specific changes in the production process or controls. Exposure estimates for 1996 were based primarily on the available air sampling data from the 1996 investigations. In most cases, the average of all measurements made in a given area was used to fill in the 1996 estimate.

Because it is not possible to tell from the job histories in which cutting line, screening area, or coating line a worker spent time, these measurements were also averaged. For example, the estimate for cutting is an average of results from all samples collected in both cutting areas. Because the majority of the samples collected by NIOSH in the modules were heavily overloaded, these measurements were not used. Instead, the result of a short-term total dust sample (27 mg/m^3) collected by MHRI in Module 1 was used as the total dust concentration for the modules during normal operations. This measurement seemed fairly consistent with the average of the NIOSH measurements for the modules, which was 41 mg/m^3 (1.3 – 241 mg/m^3) for primarily full shift samples, which likely included some blow down operations.

For the screening area, measurements from the basement screening area were averaged and then that average was averaged with a measurement from the second screening area. The area with the continuous dye unit was not sampled, but concentrations were estimated to be the same as in compounding due to the proximity of the two areas, neither of which had a source of airborne dust. Concentrations in the maintenance area, which was not sampled, were estimated to be minimal since background concentrations were minimal and dust masks were used for very dusty repairs. The respirable dust concentration for the modules, near the modules, and blow down tasks were estimated using the average ratio of total to respirable dust (4.8) from the NIOSH samples that were not as heavily overloaded (<10 mg total dust per filter).

Estimates of average total and respirable dust concentrations for other time periods were adjusted as follows for various changes in the production process and controls. Two of the cutting lines had screeners upstairs, rather than in the basement and prior to 1996, these were open to the rest of the plant. When they were enclosed in 1996, the average exposure in the screening area increased slightly and exposures to other operations decreased significantly. So, going back in time, the screening area concentration is multiplied by a factor of 0.9 and screener blow down is multiplied by a factor of .9, accounting for the fact that there would have been no change in the basement screening area. Coating, near the module, Scotchguard®,, printing, embossing, compounding, and CDU area concentrations were multiplied by a factor of 1.25. Cutting area concentrations were multiplied by a factor of 1.1 since the cutting lines in the other area of the plant were unaffected. In 1995, new gas-fired air make-up units were installed affecting the coating lines, printing, embossing, Scotchguard®, compounding, and CDU, and two cutting lines. This make-up unit markedly improved air quality in these areas, so prior to 1995, concentrations were multiplied by 1.5, except in cutting and screening, where a factor of 1.2 was used to account for no affect in the second cutting area. In 1991, the air make-up that had been used since 1978 was disconnected. Therefore, before 1991, the air quality in all of the same areas affected by the installation of the new unit in 1995, was somewhat better than it was between 1991 and 1995 when there was no make-up air. It is not likely that the old unit was quite as efficient as the new one, so concentrations were multiplied by 0.95 in cutting and screening and by 0.8 in all of the other affected areas. In 1981, a cutting line was added, increasing the average exposure for one of the cutting and screening areas. Thus, before 1982, the average concentrations in these areas are multiplied by a factor of 0.8. Because there was no make-up air prior to 1978, the multiplication done for the disconnection of that unit was reversed so that cutting and screening concentrations were divided by 0.95 and concentrations in the other affected areas were divided by 0.8. The resulting area-concentration matrices are shown in Tables 2 and 3.

Development of a Job-Exposure Matrix

Because the quantitative exposure data were associated with areas of the plant rather than jobs, the relationship between job exposures and area dust measurements had to be defined in order to calculate cumulative exposures. This was achieved by having two industrial hygienists familiar with the plant and a worker from the plant independently construct a matrix assigning percentages of time in each of 14 areas and 2 high exposure tasks to each job title. Where only one estimate was available, that estimate was used in a combined matrix. Wherever two estimates were available, the average was used in the combined matrix.

This matrix was then combined with the quantitative area exposure data to develop a matrix of quantitative data by job title. Finally, the flock man and the coating department auxiliary sometimes wore a respirator with an assigned protection factor of 10. These respirators were not, however, always used or always used properly, so we assumed a workplace protection factor of 3 and adjusted exposures for these two jobs accordingly. This final job-exposure matrix was then used to calculate cumulative exposures for each individual. In the three cases where workers worked at the plant for twenty or thirty years, but only had detailed job history information beginning in the 1980s, they were assigned the average exposure of all other jobs in their department during the time periods worked.

Statistical Analysis

Within each population, cases were compared with controls for all relevant characteristics including each exposure metric. Univariate analyses were completed initially for each exposure metric in an effort to eliminate those of least importance to the model. Multiple logistic was conducted with case status as the outcome, and including age, sex, and smoking status as potential confounders. Regression coefficients for each exposure metric were used to calculate odds ratios associated with exposure, or with a unit increase in continuous exposure metrics. These odds ratios were ranked so that recommendations could be made regarding relevant measures of exposure in this industry.

Results

Study population A was comprised of 135 (89%) men and 17 (11%) women. The average age was 40 with a range from 18 to 77. There were 45 non-smokers, 58 ex-smokers, and 49 current smokers. Table 6 shows the distribution of smoking status over age categories by gender for cases and controls.

Seventy-two percent of population A had had peak exposures while working at the plant. Summary statistics for each of the continuous exposure variables are given in Table 7. It is clear from these tables that the workers who sought medical attention had shorter work experiences with lower cumulative exposure. It is also evident that the distributions of cumulative exposure measurements are quite skewed, so these values were log transformed for the remainder of the analysis. The 15 zero values for the non-production workers were assigned a value of 1 for the log transformation, so that the log cumulative values became zero.

Univariate analyses for each individual job category (ever/never) adjusted for age, sex, and smoking status revealed no significant association between any given job category and case status in either study population with the exception of category 9, which included only non-production workers. Because of some problems with collinearity for category 9, the analyses were repeated using an indicator variable for production or non-production work, and a highly significant association between production work in population A and case status was estimated (OR=16.0, 95% CI: 1.5-132.1). This is expected since only one production worker met the case definition in population A and all of them had little or no history of exposure. This exposure metric was not used in any population B analyses since there were no non-production workers in population B.

Results of univariate analyses for the other five exposure metrics are given in Tables 9 and 10. Given the very clear lack of association between either duration of exposure or duration of exposure to peaks, these two variables were not included in the multivariate analysis. Because total and respirable dust are roughly proportional to one another, and respirable dust exposure was the more biologically plausible cause of disease, the log cumulative total dust was also left out of the multivariate analysis.

Multivariate logistic regression was completed for population A with case status as the outcome, the production indicator variable, log cumulative respirable dust and history of peak exposure as predictors, and age, sex, and smoking status as possible confounders. The results of this analysis are given in Table 11. Note that production or non-production work remains the most predictive of case status, while cumulative respirable dust also seems to have some association. Peak exposures do not seem to be relevant, and in fact, when removed from the model, estimates for the other variables remain stable while the overall p-value of the model is reduced to 0.02. Because age and smoking status were shown to have no significant association with disease in the univariate modeling, they were also removed from the model. This had little effect on the other estimates, and improved the overall significance of the model (p=0.007) demonstrating that these two variables are not confounders.

Results for multivariate analyses for population B are given in Table 12. Again, cumulative exposure seems to be the most relevant predictor after controlling for age, sex, and smoking status. Peak exposure history appears to be unimportant, and again, when this variable is removed from the model, all other estimates remain stable while the overall p-value of the model is reduced to 0.14. Removing age and smoking status from the model also improves the overall significance (p=0.05) without changing the estimates for dust and sex.

Conclusions

Based on this study, the most important predictor of developing disease as defined by symptoms of cough and shortness of breath is simply work in the production area of the studied facility. Disease also seems to be associated with cumulative dust exposures, although this association is not statistically significant in a univariate analysis. However, a multivariate model including both an indicator variable for work in the production area and the log cumulative respirable dust exposure as predictors of symptomatic disease, controlling for sex, is quite significant (p=0.007).

Among workers who have symptoms sufficient to seek medical attention, the most important predictor of objective disease measured by CT scan seems to be cumulative dust exposure as well. Again this association is not significant in univariate analysis. The multivariate model including log cumulative dust exposure as a predictor of disease and controlling for sex, however, is significant with p=0.05.

A history of having worked in any given job category within the production area of the plant was not predictive of either subjective disease in population A, or with objective disease in population B. Duration of work in the facility, a history of ever having worked in a job with peak exposures, and the duration of such work with peak exposures were also not associated with disease in either population.

Discussion and Recommendations

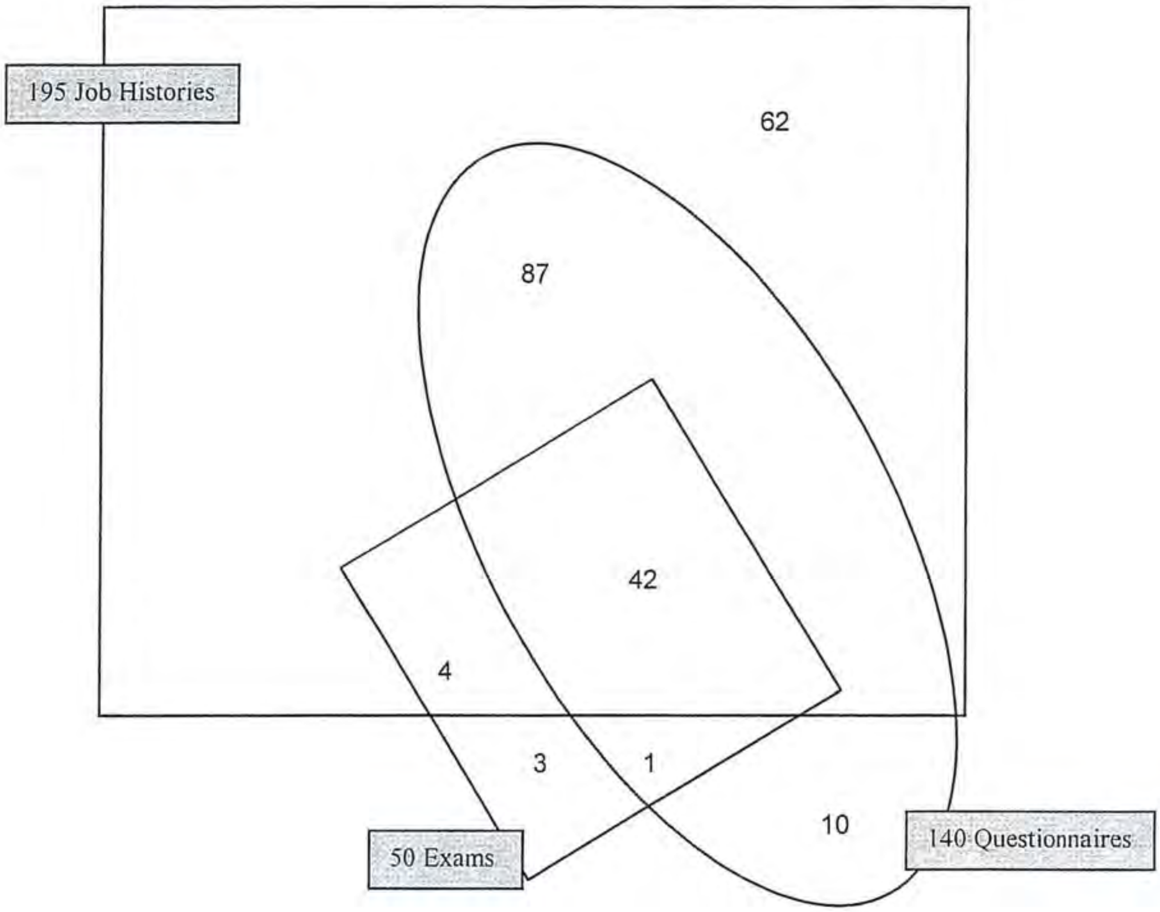
The greatest weakness in this study is the fact that the quantitative data was sparse. Given this weakness, the models built in this study seem clear about what measures of exposure are important in predicting flock workers lung. Clearly, having worked in the production area of the index plant is the most important risk factor in developing this disease. The dust exposures throughout this plant were extremely high and not well controlled when the initial outbreak of disease occurred. It had always been considered a possibility, therefore, that everyone in the plant might have some degree of abnormality resulting from work in the plant. The real question was whether clinical disease was more likely in individuals in certain jobs or locations, or whether the mechanism of the disease involved high peak exposures as opposed to long term cumulative exposure. This study would seem to indicate that it doesn't matter how long an individual works at the plant, or even what jobs they have had there. it doesn't matter how old they are or even whether or not they smoke. What does matter is their cumulative dust exposure. For example, based on the odds ratios calculated in this study, a male production worker who has a cumulative respirable dust exposure that is ten times that of another male production worker will be 1.14 times as likely to experience chronic cough and shortness of breath as the worker with the exposure ten times less than his. Then, among a group of workers who all have symptoms sufficient to seek medical attention, the ones with a cumulative respirable dust exposure ten times that of another will have a 1.47 times greater risk of having an abnormal CT scan. The ten-fold increase in cumulative exposure, however, could be a result of either duration in the plant or of intensity of exposure. Because it is difficult to control the duration of work in the plant, it will be extremely important to control exposure intensity throughout the plant in an effort to minimize the occurrence of this disease. Elimination of some of the peak exposures will help to some extent as high cumulative exposures will not be reached as quickly in workers performing these tasks. It will also be important, however, to reduce the overall background exposures for the long-term employees.

Additionally, the categorization of jobs was done in a very subjective manner, which simply relied on subjective impressions of homogeneous exposure. Poorly categorized job titles may have led to the lack of association between job and disease.

Another weakness in this study is the limited number of exposure metrics that was considered. Although some conclusions were drawn regarding peak versus cumulative exposures, there are many other considerations for future work in this area. The specific timing of exposure may be important. For example, workers who accumulated the greatest exposures during a specific time period in the history of the plant might be more likely to have developed disease. Particle size is likely to be extremely important, and it will be useful to look at size distributions of aerosols combined with the history of changes in the use of different fiber diameters. This could be evaluated in new studies, or as a means of refining the exposure matrix used in this study. It might also be useful to try to quantify a threshold cumulative exposure at which time symptoms and CT changes appear in an effort to better characterize flock workers' lung.

Figure 1. Worker Population

Production Workers



Non-Production Workers

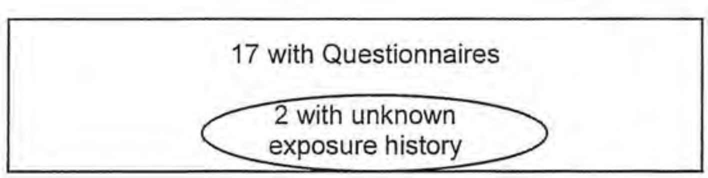


Table 1. Job Categories and Peak Exposures

Category	Department	Job Titles	Peaks (1) or no peaks (0)
1	Maintenance	Lead Man	1
		Janitor	
		Millwright	
		Master Millwright	
		Licensed Electrical Supervisor	
		Unlicensed Electrical Supervisor	
		Millwright Pipefitter 2nd	
		Millwright Pipefitter 1st	
		Electrician	
2	Shipping	Lead Man	0
		Baler	
		Material Handler	
		Working Foreman	
		Receiver	
	Finished Goods	Auxiliary	
		Inspector	
		Lead Man	
3	Shipping	Tow Motor Operator	0
	None	Quality Conrol Technician	
4	Shipping	Truck Driver	0
5	Compounding	Lead Man	0
		Compounder	
		Compounder Helper	
		Auxiliary	
6	Dye House	Extractor Operator	0
		Continuous Dye Unit Operator	
		Continuous Unit Helper	
		Drug Clerk	
		Dye Tank Operator	
		Ausiliary	
		Dye Tank Operator/Auxiliary	
		Screen Operator	
		Dryer Operator	
		Lead Man	

		Expanding Helper Expanding Operator ILMA Helper Fleissner Helper General Helper	
7	Cutting/Raycote	Machine Operator Auxiliary Bagger Lead Man Pre-Cut Operator	1
8	All	Supervisor Manager	0
9	Office	all non-production workers	0
10	Coating	Flock Man	1
11	Coating	Coater Operator	0
12	Coating	Reeler Inspector	1
13	Coating	Reeler Operator	1
14	Coating	Auxiliary	1
15	Coating	Reeler Inspector Print Range Printer Operator Auxiliary Print Range	0
16	Coating	Reeler Inspector Pilot Range Reeler Operator Pilot Range Auxiliary Pilot Range	0
17	Coating	Inspector Off-Line Embosser Operator off-Line Embosser	0
18	Coating	Machine Operator	0
19	Coating	Working Foreman	1
20	Coating	Coater Operator Pilot Range	0

21	Coating	Rewinder Operator Auxiliary	0
22	Coating	Mortamet Operator	0
23	Coating	Lead Man	1

Table 2. Area-Exposure Matrix for Total Dust

	1996	1995	1991-1994	1982-1990	1978-1981	before 1978
Cutting	0.3	0.3	0.4	0.4	0.3	0.4
Screening	2.8	2.5	3	2.9	2.3	3
Compounding	0.9	1.1	1.7	1.4	1.1	1.4
Pre-Coat	0.2	0.2	0.3	0.2	0.2	0.2
Coating	0.2	0.3	0.4	0.3	0.2	0.3
Module	27	27.0	27.0	27.0	27.0	27.0
Scotchguard	0.3	0.4	0.6	0.5	0.4	0.5
Embossing	0.4	0.5	0.8	0.6	0.5	0.6
Printing	0.3	0.4	0.6	0.5	0.4	0.5
Near Module	1	1.3	1.9	1.5	1.2	1.5
Module Blowdown	39	39	39	39	39	39
Screener Blowdown	16	14.4	14.4	14.4	14.4	14.4
Maintenance	0.1	0.1	0.1	0.1	0.1	0.1
Office	0	0.0	0.0	0.0	0.0	0.0
Continuous Dyer	0.9	1.1	1.7	1.4	1.1	1.4
Dye House	0	0.0	0.0	0.0	0.0	0.0

Table 3. Area-Exposure Matrix for Respirable Dust

	1996	1995	1991-1994	1982-1990	1978-1981	before 1978
Cutting	0.2	0.2	0.3	0.3	0.2	0.3
Screening	1.8	1.6	1.9	1.8	1.5	1.9
Compounding	0.5	0.6	0.9	0.8	0.6	0.8
Pre-Coat	0.2	0.2	0.3	0.2	0.2	0.2
Coating	0.2	0.3	0.4	0.3	0.2	0.3
Module	5.6	5.6	5.6	5.6	5.6	5.6
Scotchguard	0.2	0.3	0.4	0.3	0.2	0.3
Embossing	0.5	0.6	0.9	0.8	0.6	0.8
Printing	0.3	0.4	0.6	0.5	0.4	0.5
Near Module	0.2	0.3	0.4	0.3	0.2	0.3
Module Blowdown	8.1	8.1	8.1	8.1	8.1	8.1
Screener Blowdown	3.3	3.0	3.0	3.0	3.0	3.0
Maintenance	0.1	0.1	0.1	0.1	0.1	0.1
Office	0.0	0.0	0.0	0.0	0.0	0.0
Continuous Dyer	0.5	0.6	0.9	0.8	0.6	0.8
Dye House	0.0	0.0	0.0	0.0	0.0	0.0

Table 4. Job-Exposure Matrix for Total Dust

Dept	Job Title	1996	1995	1991-1994	1982-1990	1978-1981	before 1978
Maintenance	Lead man	2.2	2.2	2.4	2.3	2.2	2.3
	Janitor	1.2	1.2	1.3	1.3	1.1	1.3
	Millwright 1st	1.3	1.3	1.5	1.4	1.3	1.4
	Master Millwright	2.2	2.2	2.3	2.3	2.2	2.3
	Lic Elec Sup	1.8	1.8	2.0	1.9	1.8	1.9
	Unlic Elec Sup	2.8	2.8	3.0	2.9	2.8	2.9
	Pipefitter 2nd	1.8	1.8	2.0	1.9	1.8	1.9
	Pipefitter 1st	1.8	1.8	2.0	1.9	1.8	1.9
	Electrician	2.8	2.8	3.0	2.9	2.8	2.9
	Supervisor	0.0	0.1	0.1	0.1	0.1	0.1
Shipping	Lead Man	0.9	0.9	1.0	1.0	0.9	1.0
	Baler	0.2	0.3	0.4	0.3	0.3	0.3
	Tow Motor Op Aux	1.6	1.6	1.8	1.7	1.6	1.7
	Truck Driver	0.0	0.0	0.0	0.0	0.0	0.0
	Material Handler	2.1	2.1	2.2	2.2	2.1	2.2
	Working Foreman	2.1	2.1	2.2	2.2	2.1	2.2
	Receiver	0.8	0.9	0.9	0.9	0.9	0.9
	Supervisor	0.8	0.9	0.9	0.9	0.9	0.9
Compounding	Lead Man	0.4	0.5	0.7	0.6	0.5	0.6
	Compounder	0.8	1.0	1.5	1.2	1.0	1.2
	Compounder Helper	0.8	1.0	1.5	1.3	1.0	1.3
	Auxiliary	0.6	0.8	1.2	1.0	0.8	1.0
	Supervisor	0.1	0.1	0.2	0.2	0.1	0.2

Dye House	Extractor Operator	0.0	0.0	0.0	0.0	0.0	0.0
	CDU Operator	0.8	1.0	1.5	1.2	1.0	1.2
	CDU Helper	0.8	1.0	1.5	1.2	1.0	1.2
	Drug Clerk	0.3	0.3	0.5	0.4	0.3	0.4
	Dye Tank Operator	0.0	0.0	0.0	0.0	0.0	0.0
	Auxiliary	0.0	0.0	0.0	0.0	0.0	0.0
	Dye Tank Op/Aux	0.0	0.0	0.0	0.0	0.0	0.0
	Screen Operator	1.1	1.0	1.0	1.0	1.0	1.0
	Dryer Operator	1.1	1.0	1.0	1.0	1.0	1.0
	Lead Man	0.0	0.0	0.0	0.0	0.0	0.0
	Expanding Helper	0.1	0.1	0.1	0.1	0.1	0.1
	Expanding Operator	0.1	0.1	0.1	0.1	0.1	0.1
	ILMA Helper	0.0	0.0	0.0	0.0	0.0	0.0
	Fleissner Helper	0.0	0.0	0.0	0.0	0.0	0.0
	General Helper	0.0	0.0	0.0	0.0	0.0	0.0
	Supervisor	0.0	0.0	0.0	0.0	0.0	0.0
Cutting	Machine Operator	0.9	0.8	0.9	0.9	0.8	0.9
	Auxiliary	0.8	0.7	0.9	0.8	0.7	0.9
	Bagger	0.3	0.3	0.3	0.3	0.3	0.3
	Lead Man	0.4	0.4	0.5	0.5	0.4	0.5
	Pre-Cut Operator	0.3	0.3	0.4	0.4	0.3	0.4
	Supervisor	0.6	0.6	0.7	0.7	0.6	0.7
Coating	Lead Man	6.1	6.1	6.3	6.2	6.1	6.2
	Coater Operator	0.4	0.5	0.6	0.5	0.4	0.5
	Flock Man	5.6	5.6	5.6	5.6	5.6	5.6
	Reeler Inspector	2.9	2.9	3.0	2.9	2.9	2.9
	Reeler Operator	2.9	3.0	3.1	3.0	2.9	3.0
	Auxiliary	3.2	3.2	3.2	3.2	3.2	3.2
	Reeler Insp Print	0.2	0.2	0.3	0.3	0.2	0.3

	Reeler Insp Pilot	2.4	2.5	2.7	2.6	2.4	2.6
	Aux Print Range	1.3	1.3	1.4	1.4	1.3	1.4
	Insp Offline Emboss	1.4	1.5	1.6	1.5	1.5	1.5
	Machine Operator	2.1	2.1	2.1	2.1	2.1	2.1
	Working Foreman	1.1	1.2	1.4	1.3	1.2	1.3
	Op Offline Emboss	0.3	0.4	0.6	0.5	0.4	0.5
	Coater Op Pilot	0.3	0.4	0.6	0.5	0.4	0.5
	Printer Operator	0.4	0.5	0.7	0.5	0.4	0.5
	Reeler Op Pilot	0.2	0.3	0.5	0.4	0.3	0.4
	Auxiliary Pilot	0.2	0.2	0.4	0.3	0.2	0.3
	Rewinder Op Aux	0.2	0.3	0.4	0.3	0.3	0.3
	Mortamet Operator	0.3	0.4	0.5	0.4	0.3	0.4
	Supervisor	1.5	1.5	1.6	1.6	1.5	1.6
Finished Goods	Auxiliary	0.1	0.2	0.3	0.2	0.2	0.2
	Inspector	0.1	0.2	0.3	0.2	0.2	0.2
	Lead Man	0.1	0.2	0.3	0.2	0.2	0.2
No Department	QC Technician	1.2	1.3	1.6	1.4	1.3	1.4
Assignment	Manager	0.1	0.1	0.2	0.2	0.1	0.2

Table 5. Job-Exosure Matrix for Respirable Dust

Dept	Job Title	1996	1995	1991-1994	1982-1990	1978-1981	before 1978
Maintenance	Lead man	0.6	0.6	0.7	0.6	0.6	0.6
	Janitor	0.5	0.5	0.6	0.6	0.5	0.6
	Millwright 1st	0.5	0.5	0.6	0.6	0.5	0.6
	Master Millwright	0.6	0.6	0.7	0.7	0.6	0.7
	Lic Elec Sup	0.6	0.6	0.7	0.7	0.6	0.7
	Unlic Elec Sup	0.8	0.8	0.9	0.8	0.8	0.8
	Pipefitter 2nd	0.6	0.6	0.7	0.7	0.6	0.7
	Pipefitter 1st	0.6	0.6	0.7	0.7	0.6	0.7
	Electrician	0.8	0.8	0.9	0.8	0.8	0.8
	Supervisor	0.0	0.0	0.0	0.0	0.0	0.0
Shipping	Lead Man	0.3	0.3	0.4	0.3	0.3	0.3
	Baler	0.3	0.3	0.5	0.4	0.3	0.4
	Tow Motor Op Aux	0.5	0.5	0.6	0.6	0.5	0.6
	Truck Driver	0.0	0.0	0.0	0.0	0.0	0.0
	Material Handler	0.5	0.5	0.6	0.5	0.5	0.5
	Working Foreman	0.5	0.5	0.6	0.5	0.5	0.5
	Receiver	0.2	0.2	0.2	0.2	0.2	0.2
	Supervisor	0.2	0.2	0.2	0.2	0.2	0.2
Compounding	Lead Man	0.2	0.3	0.4	0.3	0.3	0.3
	Compounder	0.5	0.6	0.8	0.7	0.5	0.7
	Compounder Helper	0.5	0.6	0.8	0.7	0.6	0.7
	Auxiliary	0.4	0.4	0.7	0.6	0.4	0.6
	Supervisor	0.1	0.1	0.1	0.1	0.1	0.1
Dye House	Extractor Operator	0.0	0.0	0.0	0.0	0.0	0.0
	CDU Operator	0.4	0.5	0.8	0.7	0.5	0.7
	CDU Helper	0.4	0.5	0.8	0.7	0.5	0.7

	Drug Clerk	0.2	0.2	0.3	0.2	0.2	0.2
	Dye Tank Operator	0.0	0.0	0.0	0.0	0.0	0.0
	Auxiliary	0.0	0.0	0.0	0.0	0.0	0.0
	Dye Tank Op/Aux	0.0	0.0	0.0	0.0	0.0	0.0
	Screen Operator	0.2	0.2	0.2	0.2	0.2	0.2
	Dryer Operator	0.2	0.2	0.2	0.2	0.2	0.2
	Lead Man	0.0	0.0	0.0	0.0	0.0	0.0
	Expanding Helper	0.1	0.1	0.1	0.1	0.1	0.1
	Expanding Operator	0.1	0.1	0.1	0.1	0.1	0.1
	ILMA Helper	0.0	0.0	0.0	0.0	0.0	0.0
	Fleissner Helper	0.0	0.0	0.0	0.0	0.0	0.0
	General Helper	0.0	0.0	0.0	0.0	0.0	0.0
	Supervisor	0.0	0.0	0.0	0.0	0.0	0.0
Cutting	Machine Operator	0.4	0.4	0.5	0.5	0.4	0.5
	Auxiliary	0.4	0.4	0.4	0.4	0.3	0.4
	Bagger	0.2	0.2	0.2	0.2	0.2	0.2
	Lead Man	0.2	0.2	0.3	0.3	0.2	0.3
	Pre-Cut Operator	0.2	0.2	0.3	0.2	0.2	0.2
	Supervisor	0.3	0.3	0.3	0.3	0.3	0.3
Coating	Lead Man	1.4	1.4	1.5	1.5	1.4	1.5
	Coater Operator	0.2	0.2	0.3	0.2	0.2	0.2
	Flock Man	1.2	1.2	1.2	1.2	1.2	1.2
	Reeler Inspector	0.7	0.7	0.8	0.7	0.7	0.7
	Reeler Operator	0.7	0.8	0.8	0.8	0.7	0.8
	Auxiliary	0.7	0.7	0.7	0.7	0.7	0.7
	Reeler Insp Print	0.2	0.2	0.3	0.3	0.2	0.3
	Reeler Insp Pilot	0.6	0.6	0.7	0.7	0.6	0.7
	Aux Print Range	0.4	0.4	0.5	0.4	0.4	0.4
	Insp Offline Emboss	0.5	0.6	0.7	0.7	0.6	0.7
	Machine Operator	0.5	0.5	0.6	0.5	0.5	0.5
	Working Foreman	0.4	0.4	0.6	0.5	0.4	0.5

	Op Offline Emboss	0.4	0.5	0.7	0.6	0.4	0.6
	Coater Op Pilot	0.3	0.4	0.6	0.5	0.4	0.5
	Printer Operator	0.4	0.5	0.8	0.6	0.5	0.6
	Reeler Op Pilot	0.3	0.3	0.5	0.4	0.3	0.4
	Auxiliary Pilot	0.2	0.2	0.4	0.3	0.2	0.3
	Rewinder Op Aux	0.3	0.3	0.5	0.4	0.3	0.4
	Mortamet Operator	0.3	0.4	0.6	0.5	0.4	0.5
	Supervisor	0.4	0.4	0.5	0.5	0.4	0.5
Finished Goods	Auxiliary	0.2	0.2	0.3	0.3	0.2	0.3
	Inspector	0.2	0.2	0.3	0.3	0.2	0.3
	Lead Man	0.2	0.2	0.3	0.3	0.2	0.3
No Department Assigned	QC Technician	0.5	0.6	0.8	0.8	0.6	0.8
	Manager	0.1	0.2	0.2	0.2	0.2	0.2

Table 6. Age, Sex, and Smoking Status of Population A Cases and Controls

			Smoking Category			
			Current	Ex	Never	Total
Cases	Males	Age				
		18-29	1	1	3	5
		30-39	3	3	2	8
		40-49	4	4	1	9
		50-79	2	4	1	7
		Total	10	12	7	29
	Females					
		18-29	0	2	0	2
		30-39	1	0	0	1
		40-49	0	1	1	2
		50-79	0	1	0	1
		Total	1	4	1	6
	Total		11	16	8	35

			Smoking Category			
			Current	Ex	Never	Total
Controls	Males	Age				
		18-29	1	3	12	16
		30-39	19	12	11	42
		40-49	9	12	9	30
		50-79	1	13	4	18
		Total	30	40	36	106
	Females					
		18-29	0	2	0	2
		30-39	1	0	0	1
		40-49	0	1	1	2
		50-79	0	1	0	1
		Total	1	4	1	6
	Total		31	17	37	112

Table 7. Age, Sex, and Smoking Status of Population B Cases and Controls

			Smoking Category			
		Age	Current	Ex	Never	Total
Cases	Males					
		18-29	0	0	2	2
		30-39	1	1	1	3
		40-49	0	0	0	0
		50-79	2	3	0	5
		Total	3	4	3	10
	Females					
		18-29	0	1	0	1
		30-39	0	0	0	0
		40-49	1	1	1	3
		50-79	0	0	0	0
		Total	1	2	1	4
	Total		4	6	4	14

			Smoking Category			
		Age	Current	Ex	Never	Total
Controls	Males					
		18-29	1	2	2	5
		30-39	5	2	0	7
		40-49	3	6	3	12
		50-79	0	4	1	5
		Total	9	14	6	29
	Females					
		18-29	0	0	0	0
		30-39	2	0	0	2
		40-49	0	0	0	0
		50-79	0	1	0	1
		Total	2	1	0	3
	Total		11	15	6	32

Table 8. Summaries of work duration, peak duration, cumulative total dust and cumulative respirable dust for population A and B.

	Exposure Metric	Mean	Std.Dev.
Population A			
	Duration of Work in Production (days)	3297	2991
	Duration of Work with Peak Exposure (days)	1646	2222
	Cumulative Total Dust (mg/m3*days)	10216	66071
	Cumulative Respirable Dust (mg/m3*days)	3306	21329
Population B			
	Duration of Work in Production (days)	2797	3088
	Duration of Work with Peak Exposure (days)	1631	2090
	Cumulative Total Dust (mg/m3*days)	4772	5407
	Cumulative Respirable Dust (mg/m3*days)	1630	1630

Table 9. Results of Univariate Analysis of Association Between Exposure Metrics and Case Status in Population A Adjusted for Age, Sex, and Smoking Status

Variable	Estimated Odds Ratio	95% CI
Duration of Employment in Production	0.99	0.99-1.00
Peak Exposures (ever/never)	0.75	0.32-1.74
Duration of Peak Exposures	1.00	0.99-1.00
Cumulative Total Dust Exposure	1.15	0.96-1.37
Cumulative Respirable Dust Exposure	1.20	0.98-1.47

Table 10. Results of Univariate Analysis of Association Between Exposure Metrics and Case Status in Population B Adjusted for Age, Sex, and Smoking Status

Variable	Estimated Odds Ratio	95% CI
Duration of Employment in Production	1.00	0.99-1.00
Peak Exposures (ever/never)	0.70	0.18-2.69
Duration of Peak Exposures	1.00	1.00-1.00
Cumulative Total Dust Exposure	1.38	0.91-2.08
Cumulative Respirable Dust Exposure	1.48	0.92-2.38

Table 11. Multiple Logistic Regression in Population A

Overall p-value for original model = 0.05

Variable	Estimated Odds Ratio	95% CI
Sex	0.15	0.03-0.67
Age Category	1.13	0.75-1.71
Smoking Status	1.03	0.61-1.73
Production vs. Non-Production Work	11.17	1.15-108.25
Log Cumulative Respirable Dust Exposure	1.15	0.94-1.43
Peak Exposures (Ever/Never)	0.94	0.39-2.23

Overall p-value for final model = 0.007

Variable	Estimated Odds Ratio	95% CI
Sex	0.15	0.03-0.66
Production vs. Non-Production Work	11.47	1.21-108.72
Log Cumulative Respirable Dust Exposure	1.14	0.92-1.42

Table 12. Multiple Logistic Regression in Population B

Overall p-value for original model = 0.21

Variable	Estimated Odds Ratio	95% CI
Sex	0.08	0.01-0.80
Age Category	1.25	0.65-2.43
Smoking Status	0.69	0.26-1.83
Log Cumulative Respirable Dust Exposure	1.49	0.92-2.40
Peak Exposures (Ever/Never)	0.67	0.16-2.71

Overall p-value for final model = 0.05

Variable	Estimated Odds Ratio	95% CI
Sex	0.10	0.01-0.90
Log Cumulative Respirable Dust Exposure	1.47	0.93-2.32

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service
Centers for Disease Control
and Prevention (CDC)

Memorandum

Date: December 12, 2001

From: Michael J. Galvin, Jr., Ph.D., Lead Program Activity
Office of Extramural Programs, NIOSH, D30

Subject: Final Report Submitted for Entry into NTIS for Grant 1 R03 OH003678-01.

To: William D. Bennett
Data Systems Team, Information Resources Branch, EID, NIOSH, P03/C18

The attached final report has been received from the principal investigator on the subject NIOSH grant. If this document is forwarded to the National Technical Information Service, please let us know when a document number is known so that we can inform anyone who inquires about this final report.

Any publications that are included with this report are highlighted on the list below.

Attachment
cc: Sherri Diana, EID, P03/C13

List of Publications

Title: Occupational Lung Disease in a Flocking Plant
Investigator: Kate T.H. Durand
Affiliation: University of Washington
City & State: Seattle, WA
Telephone: (206) 616-2691
Award Number: 1 R03 OH003678-01
Start & End Date: 5/1/1999–6/30/2000
Total Project Cost: $37,821
Program Area: NORA
Key Words:

Abstract:
The purpose of this study was to complete an exposure assessment for flock workers lung using data available from a flock manufacturing facility in an effort to explore associations between different exposure metrics and disease. Two different populations of workers from the facility were studied. The first population (study population A) included all workers for whom a detailed work history and symptom data were available (n = 152). The second population (study population B) included all workers in study population A who were evaluated at the MHRI and who have had a HRCT scan (n = 45). The case definition for the study population A, based on the responses to the NIOSH questionnaire or on medical evaluation was: any worker reporting cough and shortness of breath beginning after starting work at this facility and lasting for a period of two months or longer. The case definition for the study population B described above will be any worker with a finding of either diffuse ground glass opacity, micronodularity, or honeycombing on HRCT scan. Six exposure metrics were used in the epidemiologic analysis.- duration of employment in production area, ever/never worked in each job category, ever/never having worked in a job category with peak exposures, duration in job categories with peak exposures, cumulative total dust, and cumulative respirable dust. This study showed that development of chronic respiratory symptoms among workers in a flock manufacturing plant and subsequent development of objectively diagnosed illness were not associated with duration of employment, work in particular job categories, or with a history of the potential for peak exposures. Symptoms of cough and shortness of breath were, however, shown to be associated with work in the production area of the plant and with cumulative respirable dust exposures while controlling for gender. Abnormal CT scans in symptomatic individuals were also associated with cumulative respirable dust exposures while controlling for gender.

Publications
No publications to date.