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Hazardous Occupational Exposure and Lung Disease Among Nylon Flock Workers

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INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) has been involved in investigations initiated by recognition of a cluster of work-related interstitial lung disease (ILD) among workers at a plant in Rhode Island that produces nylon flock and nylon-flocked upholstery fabric [Kern et al., 1997, 1998]. Following the request for NIOSH assistance, additional cases were diagnosed among workers at this plant–bringing the total to 8 cases diagnosed from 1992 through 1996, plus one other case identified retrospectively in a former worker diagnosed in 1985. Common major symptoms were cough and shortness of breath. Systemic symptoms (fevers and generalized aches) were also reported by some, and were prominent in an affected worker whose flock-cutting work area had been enclosed in plastic sheeting several weeks before becoming ill. Most cases had restrictive lung function and half had low lung diffusing capacity. Chest radiographs were abnormal in some, and high resolution computerized tomography revealed abnormalities in nearly all. Of the 9 cases, 7 were confirmed by lung biopsy. In the other two cases, who were not biopsied, bronchoalveolar lavage fluid (BALF) abnormalities were consistent with an active alveolitis.

At the plant, nylon flock is made by cutting bundles of continuous nylon filaments (tow) into very short segments. Flock finish (which imparts desired electrostatic properties) is applied before cutting; dye may also be applied. Nylon-flocked fabric is made in a roll-to-roll process by applying finely screened flock to adhesive-coated backing fabric in an electrical field, which aligns the flock fibers perpendicular to the fabric as they imbed end-on into the adhesive. After heat curing, the flocked fabric is optionally printed, embossed, or otherwise finished.

METHODS

NIOSH industrial hygienists carried out area air sampling throughout the plant to characterize potential exposures to dust, bioaerosols, gases, and metals. Several personal breathing zone samples were collected on workers performing specific operations. Limited real-time sampling of particulate concentrations was done during these same operations. Airborne dust and flock were examined microscopically. A NIOSH medical team surveyed current employees with a standardized questionnaire, chest X-ray, spirometry, and lung diffusing capacity tests. NIOSH investigators also carried out in vivo toxicological studies to evaluate the respiratory toxicity of dust from this plant. These controlled experimental studies involved intratracheal (IT) instillations of dust in rats, followed by assessments of breathing rate, BALF, and lung tissue histopathology at 1 day and 29 days post-IT. Finally, NIOSH convened a workshop to review all known cases from this, and other nylon flock plants.

RESULTS

Endotoxin concentrations ranged from 0.7 to 138 endotoxin units per cubic meter (EU/m^3) based on area respirable dust samples. Viable bacteria concentrations ranged from 140 to 6080 colony forming units per cubic meter (CFU/m^3). Concentrations of viable fungi ranged

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from 129 to 1201 CFU/m^3. Formaldehyde concentrations were measured up to 0.44 parts per million (ppm). Concentrations of metals were unremarkable.

Given the physical diameter of nylon tow processed at this plant (approximately 10–15 microns), flock fibers themselves are not respirable. However, respirable dust is generated during processing. Respirable dust concentrations were particularly high in the screening rooms (as high as 5.02 mg/m^3) and in the flocking rooms (as high as 39.9 mg/m^3). Use of compressed air for "blowdowns" to remove loose flock from equipment between process runs resulted in extremely high dust concentrations. Microscopic examination of the airborne dust samples revealed respirable fibers that were visually similar to the nylon flock in terms of birefringence, color, and surface stippling. Additionally, the melting point of these elongated respirable particles was consistent with that of nylon. Scanning electron microscopy examination of cut ends of flock fiber showed evidence of nylon shredding.

Questionnaires were completed by 151 (89%) of the current employees, 17% of whom worked 7 days per week and 14% of whom worked at least 65 hrs per week. Prevalence of frequent respiratory or systemic symptoms was significantly associated with working on the flocking ranges and with performing blowdowns, but not with smoking. These symptoms were also significantly associated with number of days worked per week and with number of hours worked per week, both with highly significant exposure-related trends ($P < 0.001$). All 14 workers who reported a recent diagnosis of pneumonia, as well as 12 of the 15 workers with physician-diagnosed asthma, worked in the cutting/screening, flocking, and maintenance departments.

None of the 143 technically acceptable chest X-rays were classified as abnormal. Consistent with a restrictive interstitial process, lung function test results showed lower mean percent predicted values for both forced vital capacity (FVC) ($P = 0.07$) and diffusing capacity (DL_{CO}) ($P = 0.02$), but not for FEV_1/FVC ratio ($P = 0.86$), among workers with frequent respiratory or systemic symptoms compared to asymptomatic workers. Even among the subgroup of ever smokers, in which this same pattern of lung function results was most apparent, increased symptom prevalence was significantly associated with days and hours worked per week, work on the flocking ranges, and blowdown exposure.

In the toxicology studies, airborne dust sampled from the plant caused marked acute lung inflammation in rats. Acute lung injury at 1 day post-IT, but not at day 29 post-IT, was evidenced by statistically significant increases in several indicators, including rat breathing rates, yield of polymorphonuclear neutrophils from bronchoalveolar lavage, matrix metalloprotease activity and albumin in BALF, and alveolar macrophage chemiluminescence. The water-soluble fraction of airborne dust also demonstrated some inflammatory potency, but water-washed airborne dust and fine nylon particulate (without flock finish) generated by milling nylon tow in the laboratory were each highly inflammatory.

NIOSH also convened a workshop to review all 20 human cases of work-related interstitial lung disease known to have been diagnosed by January 1998 among nylon flock workers, including 9 from the study plant, 9 from a similar plant in Canada, and two sporadic cases from other plants in the U.S. Based on review of all available lung biopsies (15 cases from four plants), expert pulmonary pathologists noted a characteristic lesion–a lymphocytic bronchiolitis and peribronchiolitis with lymphoid hyperplasia–that was distinctive in these cases compared to other lung conditions.

CONCLUSIONS

A health hazard exists from exposure to flock-associated dust at this plant [NIOSH, 1998], and a potential hazard exists in other nylon flock processing plants. Respirable nylon shreds are of particular concern, but flock finish may contribute to toxicity of the dust. Reduction of worker exposures to airborne dust by means of process changes, engineering and administrative controls, and personal respiratory protection, together with implementation of a medical screening and surveillance program, is recommended to protect the health of workers at this plant. Manuscripts providing details concerning the NIOSH flock-related investigations have been published [Burkhart et al., 1999; Porter et al., 1999; Eschenbacher et al., 1999].

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