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Respiratory Response to Domestic Fibrous Glass Exposure¹

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A domestic fibrous glass exposure from an air conditioning system occurred, in which members of a family experienced respiratory symptoms of such severity that they were forced to abandon their house. Elimination of glass fibers from the house could be accomplished only by turning off the air conditioner and disposing of all upholstered furniture, carpets, and draperies. Bronchial washings from a member of the family and autopsy lung specimens from their dog contained fibrous glass. In light of the carcinogen effect of fibrous glass of the diameters found in the bronchial washings, fibrous glass from air conditioning systems may be a serious domestic health hazard. The relationship of fibrous glass exposure to hemangiosarcoma in the dog's lung, that was responsible for its death, and a carcinoma in a member of the family can only be speculative.

INTRODUCTION

The respiratory system responds in a variety of ways to many types of dust inhaled. This response is dependent on many factors including: the nature of the dust, duration of exposure, concentration of dust, and particle size.

Fibrous glass from occupational exposure is a known irritant of the respiratory tract and the disorders it induces have been characterized as bronchitis, rhinitis, sinusitis, pharyngitis, laryngitis, asthmatic attacks, and nosebleeds (Milby and Wolf, 1969). Patients may complain of chest pain, troubled breathing, sore throat, pain in the nose, congested nasal passages and cough. The long-term pulmonary effects of fibrous glass exposure are difficult to assess. Gross *et al.* (1971) examined lung tissue of fiber glass workers with long-term exposure and found fibrous dust. Inasmuch as the glass fibers to which the workers had been exposed nominally ranged from 9 to 15 μm in diameter, with few fibers below 3 μm in diameter, the demonstration of fibrous dust with an average diameter of 2.3 μm suggested to the investigators that very little of the fibrous dust found in the lungs was glass. Stanton and Wrench (1972, 1974) have reported that in the rat, intrapleural fibrous glass ranging from 0.06 to 3 μm in diameter resulted in moderately high incidences of mesotheliomas, in the range of 12-18%.

We are reporting a domestic fibrous glass exposure in which members of a family experienced respiratory symptoms of such severity that they were forced to abandon their house for several months, until the source of the fibrous glass was eliminated. Bronchial washings were obtained from a member of the family who was incapacitated by fibrous glass induced asthmatic symptoms. Autopsy lung specimens were obtained from the family's dog, who, at the time of death, had a massive pulmonary hemorrhage as a result of hemangiosarcoma in the lung.

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Both bronchial washings and lung specimens contained fibrous glass. In light of the carcinogenic potential of fibrous glass of the diameters found in the bronchial washings, fibrous glass from air conditioning systems may be a serious domestic health hazard.

METHODS

Subjects

The subjects of this fibrous glass exposure include a family of four (father, mother, son and daughter), all of whom experienced respiratory symptoms with varied manifestations. In April of 1969, a central air conditioning system with an electrostatic filter was installed in their new house. The ducts used in the air conditioning system were lined with fibrous glass. The house was built in 1968, with a baseboard hot water heating system, with no forced air ventilation. About 6 months after the air conditioning system was installed, the mother noted progressive increased quantities of dust throughout the house on the furniture, walls, and floor. The problem progressed to the point that she was usually dusting and vacuuming at least once a day.

In May 1972, a private chemical firm analyzed the dust and on optical microscopy found glass fibers. They recommended a survey by a mechanical engineer, who confirmed glass fibers in the dust, which on microscopy appeared similar to the glass fibers of the air conditioner ductwork. The engineer stated that the ductwork was constricted at a number of places which acted like a venturi tube, increasing the air velocity at the points of constriction, thus entraining particles and carrying them into the rooms. He recommended that the ductwork be removed. In May 1972, because of the severe respiratory symptoms experienced by the family, they were forced to leave their house.

In September of 1972, after the air conditioning system had been turned off for several months, a major attempt was made to clean the house of the fibrous glass. Conventional vacuum cleaners were of no help because the small glass fibers filtered through the collecting bag. A special Microstat vacuum cleaner (The Kent Co.) with a filter to remove particles as small as $0.3 \mu\text{m}$ was of some help in removing the fibrous glass. In September of 1972, after cleaning with the Microstat vacuum cleaner and with the air conditioning unit having been off for several months with all outlets sealed, the family moved back into their house. The quantity of fibrous glass in the house had been greatly reduced; however, the respiratory symptoms of the subjects again returned. Elimination of the fibrous glass from the house was accomplished only after turning off and sealing the air conditioner outlets, extensive vacuuming with the Microstat vacuum cleaner, and disposal of carpets, draperies, and upholstered furniture. With this, the family's respiratory symptoms have also disappeared.

Case Reports

Father. The patient is a 48-year-old Caucasian male whose respiratory symptoms included sinusitis with obstructed nasal passages, nosebleeds, and progressive shortness of breath. His sinus problem antedated the exposure to fibrous glass; however, it was much worse during the period of exposure. The problem was sufficiently severe that his physician treated him with nasal mucosal injec-

tions of steroids, with little relief. The patient was then scheduled for partial resection of his nasal mucosa. After moving out of his house, the sinus symptoms disappeared, and he became asymptomatic without medications or surgical intervention. Whenever he returned to the house, he would sneeze and his nasal passages would again become obstructed. The patient has smoked cigarettes for 33 years, and currently smokes two and one-half to three packs per day, with a cumulative exposure of about 54 pack-years. Physical examination of the chest was within normal limits. Chest roentgenograms were reported to be normal, while pulmonary function studies (lung volumes, flow rates, and diffusing capacity) revealed a mild obstructive defect.

Son.—The patient is an 11-year-old Caucasian male whose respiratory symptoms included coughing, sneezing, and shortness of breath. At 2 years of age, he developed symptoms of asthma which had been well controlled, with wheezing only at times of respiratory infections. In 1969, with the progressive increased quantities of fibrous glass dust in the house, the patient's respiratory symptoms progressively worsened. In 1971, his asthmatic symptoms became sufficiently severe that he was unable to participate in sports because of wheezing and shortness of breath. He also had repeated acute asthmatic attacks during the night with severe wheezing, shortness of breath, and dry nonproductive cough. He was treated with bronchodilators and steroids, but his symptoms continued. A chest roentgenogram in May, 1972, revealed a right upper lobe lesion and led to bronchoscopy which showed edematous erythematous tracheobronchial mucosa with marked tracheobronchitis. Bronchial washings contained fibrous glass. On moving out of the house, his respiratory symptoms decreased. On moving back into the house in September of 1972, his asthmatic symptoms again worsened. Physical examination revealed wheezes during forced expiration. Chest roentgenogram at present is within normal limits while pulmonary function studies show a mild obstructive defect with some improvement after aerosolized Isuprel.

Daughter. The patient is an 8-year-old Caucasian female whose respiratory symptom was mainly a severe dry nonproductive cough which persisted during the day as well as the night. Her classmates called her a seal, because of the barking quality of the cough. The cough was treated with steroids, with little improvement. On moving out of the house in May 1972, her cough went away, but reappeared when the family returned to the house in September 1972. Physical examination of the chest, chest roentgenograms, and pulmonary function studies were all within normal limits.

Mother. The patient is a 40-year-old Caucasian female whose respiratory symptoms included sinus and pharyngeal irritation and hoarseness. In January of 1975, abnormal uterine bleeding led to a hysterectomy and the finding of an adenocarcinoma. Because of local extension of the cancer, she received radiation therapy. Physical examination of the chest, chest roentgenograms, and pulmonary function studies were all within normal limits.

Dog. The dog was a 14-year-old mongrel which developed breathing difficulty which progressed to respiratory insufficiency. Because of the severity of his illness, the dog was sacrificed by a veterinarian. While dying, he had a massive pulmonary hemorrhage with blood flowing from his nose and mouth. Autopsy

showed a hemangiosarcoma, with dissemination in the lungs. Electron microscopy of the dog's lung revealed fibrous glass.

RESULTS

In August of 1972, when we examined the family (3 months after they moved out of their house), there were no objective signs that one could attribute to the fibrous glass exposure. The chest roentgenograms were within normal limits, and the pulmonary function studies revealed only a mild obstructive pattern in the father and son. We visited the house in September of 1972, and Fig. 1 shows a 3-week dust accumulation. The dust was analyzed by optical, polarizing light, and electron microscopy, as previously described (Pooley, 1972). The house dust contained large amounts of fibrous glass which ranged in diameter from 2 to 11 μm . The ductwork lining of the air conditioning system was composed of similar fibrous glass impregnated with a yellow resin, and having diameters with a range of 0.5 to 14 μm . Samples of dust contained additional delustered glass fibers of 1–6 μm in diameter. The lining material from the air handler was composed of similar delustered glass fibers with diameters of 1.5 to 15 μm . Thus, the dust contained glass fibers from two separate components of the air conditioning system. Electron and optical microscopic analysis of the dog's lung and the son's bronchial washings revealed glass fibers. The glass fibers from the latter had diameters ranging from 0.5 to 0.7 μm . Several other potential sources from the house were examined for glass fibers. However, only the ductwork and the air handler had glass fibers that were similar to those found in the house dust, the son's bronchial washings, and the dog's lung. Autopsy lung specimens from the dog showed disseminated hemangiosarcoma (Fig. 2).



FIG. 1. Three-week accumulation of dust from the air conditioner. The dust contained large amounts of fibrous glass similar to that of the air conditioner ductwork.

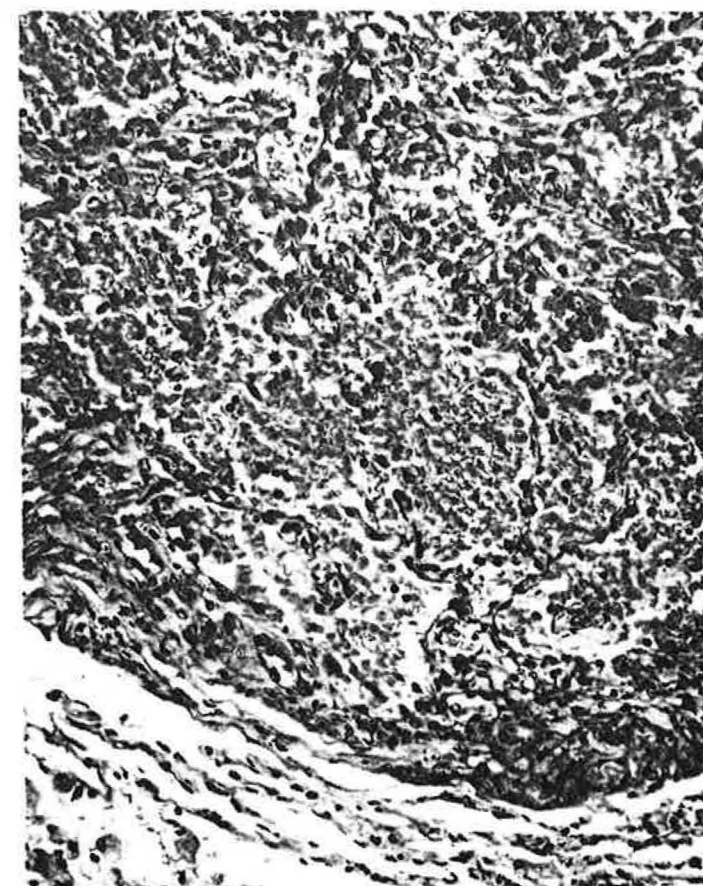


FIG. 2. Autopsy lung specimen from the dog showing hemangiosarcoma. There are hemangioendothelial cells, RBC extravasation, and numerous macrophages containing hemosiderin. $\times 200$.

DISCUSSION

The evidence indicates that the source of the fibrous glass was the air conditioning system. Glass fibers of similar dimensions and yellow resin binder were found in the ductwork and the glass fiber dust in the house. Moreover, the quantity of glass fiber dust increased when the air conditioner was operating and virtually disappeared when the air conditioner was turned off and the reservoirs of glass fibers (carpets, furniture, and draperies, etc.) removed.

The acute respiratory symptoms experienced by the family are well known to result from respiratory tract irritation by fibrous glass (Milby and Wolf, 1969). The relationship of symptoms to exposure and the finding of fibrous glass in the boy's bronchi, leave little doubt that the respiratory symptoms experienced by the family were a result of exposure to fibrous glass. Respiratory tract irritation from occupational exposure to fibrous glass has been known for years (Murphy, 1961). However, it is not generally appreciated that fibrous glass exposure from air conditioner systems may be a serious domestic problem (Sacca, 1975). The

domestic exposure herein reported is not an isolated incident; we are aware of several similar exposures.

A serious difficulty is that once the glass fibers have entered the house and become entrenched in the carpets, rugs, draperies, upholstered furniture and mattresses, etc., our experience and that of others suggest that the only way of eliminating the glass fibers is to discard the contaminated materials. Our experience indicates that simply turning off the air conditioner may be inadequate to rid a house of glass fibers. The contamination may continue for longer periods with consequent hazard to sensitive individuals.

Fiberglass ductwork is extensively used in air conditioner systems. This domestic exposure to fibrous glass shows that large quantities of fibrous glass may be discharged into the environment by air conditioning systems so constructed. Some of the fine glass fibers may reach the lungs, as was shown in the lungs of the dog and boy. Of great concern is the fact that the diameters of the glass fibers found in the boy's bronchial washings (0.5 to 0.7 μm) were of the diameters reported by Stanton and Wrench (1972) to be highly carcinogenic when applied to the pleura of rats. Whether there is a relationship between fibrous glass exposure and the hemangiosarcoma that was responsible for the dog's death, or the mother's adenocarcinoma, is not known. Uterine carcinoma is a relatively common tumor of older women. However, one should not be lured into thinking that because a type of cancer is common at a given age, that its incidence may not be importantly influenced by cocarcinogenic factors. Lung cancer is the most common type of cancer causing death in men; of interest is the fact that in cigarette smokers, its incidence may be increased ten-fold by asbestos exposure (Selikoff *et al.*, 1968). Furthermore, exposures to other carcinogenic agents such as asbestos fibers (Selikoff *et al.*, 1968), vinyl chloride (Thomas *et al.*, 1975), and chloromethyl methyl ether (Figuerola *et al.*, 1973) are known to induce a variety of tumors including angiosarcomas, and adenocarcinomas of the lung and gastrointestinal tract.

The long-term effects of fibrous glass deposition in the lung have been difficult to assess. The industrial studies of fibrous glass exposure have so far given incomplete information, since data regarding the period of time from onset of exposure were not provided (Hill *et al.*, 1973; Wright, 1968). A recently reported epidemiological study by the National Institute for Occupational Safety and Health (NIOSH), of workers exposed to fine-diameter fibrous glass has suggested an association between exposure to fibrous glass and respiratory diseases in men (Mortality patterns among fibrous glass production workers, presented by David L. Bayliss (NIOSH) before the Conference on Occupational Carcinogenesis, New York City, March 24, 1975). Although the experience with the long-term effects on populations of fibrous glass exposure is limited, the experience with asbestos fibers has taught us that a latent period of 20–30 years may be required before the consequences of exposure become manifested (Selikoff *et al.*, 1968). The long-term effects of fine fibrous glass, as with asbestos, may not be manifested for 20–30 years.

Fibrous glass is not only irritating to the respiratory tract and demonstrably carcinogenic in animals, but it also induces leakage of red blood cells from capil-

laries in the lung, and causes alveolar macrophages to leak enzymes (Botham and Holt, 1973; Beck *et al.*, 1972). It was shown that guinea pig alveolar macrophages exposed *in vitro* to glass fibers of 0.25 to 1 μm in diameter have increased membrane permeability and leak enzymes into the supernatant fluid. Human alveolar macrophages exposed to glass fibers of similar diameters (as were seen in the boy's bronchial washings) may also release enzymes that could have proteolytic effects on the human lung.

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