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Exposure to Fibers in the Manufacture of Fibrous Glass

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As part of its study of health hazards associated with the manufacture and processing of fibrous materials, the Bureau of Occupational Safety and Health is conducting a cohort analysis of past workers in the fibrous glass industry. Environmental surveys to estimate the degree of exposure of fibrous glass workers to fibers that are respirable indicated that the exposure had been negligible. Present average concentrations of fibers in air are low, as is the total airborne glass concentration. Concentration ranges and averages in glass fiber insulation and glass textile fiber manufacturing are compared with those existing in other mineral industries for potential health implications.

Introduction

THE BUREAU OF OCCUPATIONAL SAFETY AND HEALTH of the U. S. Public Health Service is presently conducting a cohort analysis of past workers in the fibrous glass industry. The personnel records were obtained for the subject workers from five of the oldest plants in the United States that manufacture fibrous glass products. Mortality data will be developed for this group of workers from records of the Bureau of Retirement and Survivors Insurance, Social Security Administration. This records study is being undertaken in conjunction with the U. S. Public Health Service study of mortality rates in the asbestos product manufacturing industry. Since the two populations of industrial workers selected are exposed to two different fibrous materials, age-adjusted death rates by cause can be compared for possible relation to industrial dust exposures.

An environmental survey of the fibrous glass plants to estimate the exposure of workers to airborne fibers of respirable size was conducted when the personnel records were obtained. The sampling techniques and methods of characterizing exposures that had been developed for the asbestos study were used in this study also. This paper summarizes the concentrations of airborne dust and fibers in five fibrous glass factories, four manufacturing insulation, and one making textiles.

Background

Glass has been known to man for many centuries, but it has only been since the 1930's that glass has been produced in the fibrous form which is the basis for many unique and useful applications. Fibrous glass is classified into two groups: (1) wool fibers and (2) textile fibers. Wool fibers are used in the manufacturing of acoustical and thermal insulation, acoustical ceiling material, air filters, and similar products. Textile fibers are used in fabrics, insulating tapes, and reinforcements for plastics and other materials. The fibers differ in that the textile fibers are produced in a continuous filament and are generally smaller in diameter, ranging to

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a low of 4 microns (μ) in diameter. The wool fibers are produced in varying lengths and are usually about 5 to 14 μ in diameter, depending on the application.[1] The fiber diameters are varied to provide the desired characteristic for the particular application but are closely controlled for each application.

Concern about possible health hazards associated with fibrous glass has been increased by the evidence that links asbestos fibers with carcinoma of the lung. This asbestos experience contrasts with that for fibrous glass, where neither animal experiments nor human experience to date has demonstrated significant effects on the respiratory tract.

Gross *et al.*[2] investigated the biological effects of glass dust on the lungs of experimental animals. They found that inhalation exposure caused a pulmonary reaction no more severe than would be expected from fine kaolin dust and a nonfibrogenic reaction with no bronchial or bronchiolar disease. Schepers and Delahant,[3,4] studied the effects of glass fibers of different diameters in the lungs of rats and guinea pigs. They found that the larger-diameter fibers were relatively inert when administered by intratracheal injection, but that injected glass fibers 3 μ or less in diameter provoked bronchiolar damage without well-defined fibrosis. The latter condition was also reported from their inhalation studies with 6-μ-diameter fibers.

Human experience to date indicates that fibrous glass causes only upper respiratory irritation[5,6] Cardiac and pulmonary function studies revealed no functional impairment in workers who had been exposed for a number of years. In reported cases of lung disease associated with fibrous glass exposure, the disease has been acute, and infection has played a major role.[7] The consensus of the toxicological literature seems to be that fibrous glass is a biologically inert material.

TABLE I
Gross (Glass) Dust Concentrations by Plant and Operations
(milligrams/cubic meter)

Operations	Plant No.[a]	Mean	Range
Batch and Marble	1	N.R.[b]	N.R.
	2	N.R.	N.R.
	3	1.31	0.18– 5.96
	4	12.29	2.69–21.89
	1–4[c]	6.82	0.18–21.89
	5	0.12	0.12–
Forming	1	0.20	<0.01– 0.94
	2	0.44	0.04– 1.70
	3	0.18	<0.01– 0.66
	4	0.46	0.04– 1.74
	1–4	0.32	<0.01– 1.74
	5	0.06	0.04– 0.22
Spinning and Twisting	5	0.11	<0.01– 0.40
Waste Recovery	5	0.16	<0.01– 0.48

(a) Plants 1 through 4 are insulation plants; 5 is a textile plant.
(b) N.R.–no results
(c) Composite of results for plants 1 through 4.

TABLE II
Respirable (Glass) Dust Concentrations by Plant and Operations
(milligrams/cubic meter)

Operation	Plant No.[a]	Mean	Range
Batch and Marble	1	N.R.[b]	N.R.
	2	N.R.	N.R.
	3	0.15	<0.01– 0.31
	4	0.55	0.06– 1.03
	1–4[c]	0.35	<0.01– 1.03
	5	0.36	0.19– 0.52
Forming	1	0.03	<0.01– 0.24
	2	0.03	<0.01– 0.20
	3	0.07	<0.01– 0.45
	4	0.09	<0.01– 0.47
	1–4	0.06	<0.01– 0.47
	5	0.05	<0.01– 0.36
Spinning and Twisting	5	0.10	<0.01– 0.65
Waste Recovery	5	0.12	<0.01– 0.73

(a) Plants 1 through 4 are insulation plants; 5 is a textile plant.
(b) N.R.–no results
(c) Composite of results for plants 1 through 4.

Procedure

The environmental portion of the field study of the fibrous glass industry utilized some of the same sampling procedures employed in the study of the asbestos product industries.[8] The workers' exposures were characterized by a variety of sampling techniques to estimate the dust concentration in terms of the gross dust exposure, respirable dust exposure, gross fiber exposure and respirable fiber exposure. Membrane filter sampling, however, was selected as the principal method to be used in this study. The sampling medium used was Millipore Type AA membrane filter with a pore size of 0.8 μ. A 37-mm plastic filter holder was used for sampling at a flow rate of 1.7 liters per minute. Gross airborne samples were collected

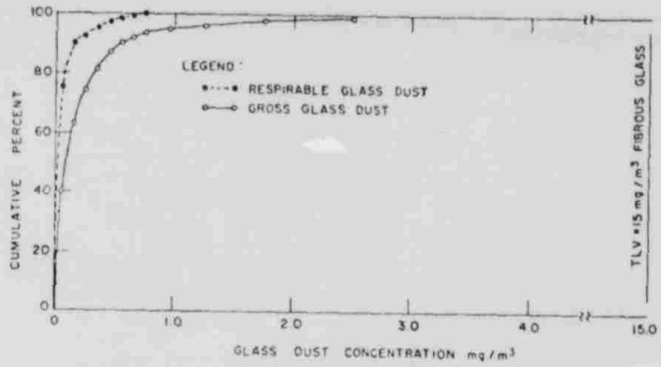


FIGURE 1. Cumulative frequency distribution of glass dust samples by plant.

with the holder open; for the respirable samples, the filter holder was fitted with a 10-mm nylon cyclone described by Lippmann and Harris[8] as meeting the "respirability" criterion suggested at a 1961 Los Alamos conference sponsored by the U. S. Atomic Energy Commission's Office of Health and Safety. Both personal and general air samples were collected with the 37-mm filters. Personal samples were collected for periods varying from 2 to 7 hours by means of battery-powered diaphragm pumps worn by the workers. Gross airborne and larger-volume "respirable" dust samples were collected with high-volume samplers operating at a rate of 35 cfm. An Aerotec-2 size selector was used prior to the filter for the collection of "respirable" samples.[10]

The samples were analyzed by two methods. A portion of each of the Millipore samples was rendered transparent and counted at 430× magnification by the procedure detailed by Edwards and Lynch.[11] Fibers, defined as elongated particles with a length-to-width ratio of 3 or greater, were counted in three size ranges: total fibers, fibers longer than 5 μ, and fibers longer than 10 μ. A Porton eyepiece reticle was used to define the counting field and as an aid in the sizing of the fibers. The other portion of the Millipore filters and the high-volume filters were analyzed for total silica by the Talvitie method.[12] On the basis of a composition of 50% total silica for fibrous glass, the dust concentrations were computed in terms of the amount of glass dust present in the atmosphere.

Results

Means and ranges of concentrations of glass dust are presented in Tables I (gross) and II (respirable) by plant and principal operation. The batch and marble operations occur prior to the forming of the fibers; therefore, an exposure to fibers would not be anticipated. In operations where a fiber exposure would be expected, the airborne concentrations in all five plants were well below the 1969 threshold limit value (TLV) of 15 mg/m³ proposed by the American Conference of Governmental Industrial Hygienists.[13] Many of the raw materials used in the batch plant have a high percentage of free silica; the hazards from quartz exposure that may exist in some of the plants are generally recognized and will not be discussed in this paper.

Mean gross and respirable dust concentrations are shown in Figure 1. The line at the far right of the graph is the proposed TLV of 15 mg/m³. It can be seen that the concentrations found are well below the proposed TLV.

Table III (gross) and Table IV (respirable) present the means and ranges of fiber concentrations in total fibers, fibers longer than 5 μ, and fibers longer than 10 μ. The

TABLE III
Gross Fiber Concentrations by Plant and Operation
(fibers/cubic centimeter)

Operation	Plant No.[a]	Total fibers		Fibers greater than 5 μ		Fibers greater than 10 μ	
		Mean	Range	Mean	Range	Mean	Range
Batch and Marble	1	—	—	—	—	—	—
	2	1.14	1.14–	0.24	0.24–	0.12	0.12–
	3	0.18	0.18–	0.03	0.03–	0.	0. –
	4	0.20	0.08–0.32	0.05	0. –0.08	0.03	0. –0.05
	1–4[b]	0.51	0.08–1.14	0.11	0. –0.24	0.05	0. –0.12
	5	16.37	16.37–	0.91	0.91–	0.05	0.05–
Forming	1	0.0	0.0 –	0.0	0.0 –	0.0	0.0 –
	2	0.49	0.04–1.95	0.20	0. –1.01	0.15	0. –0.80
	3	0.30	0.07–0.73	0.11	0.02–0.29	0.08	0.02–0.23
	4	0.33	0.08–0.86	0.17	0. –0.69	0.13	0. –0.67
	1–4	0.37	0.04–1.95	0.16	0. –1.01	0.12	0. –0.80
	5	0.20	0.06–0.40	0.04	0. –0.15	0.02	0. –0.07
Spinning, Twisting and Waste Recovery	5	0.33	0.03–1.26	0.08	0. –0.38	0.05	0. –0.29

(a) Plants 1 through 4 are insulation plants; 5 is a textile plant.
(b) Composite of results for plants 1 through 4.

workers' exposures were evaluated in terms of the airborne fiber concentration to compare the exposure in the fibrous glass manufacturing industry to the exposures found by the same methods in the asbestos processing industry, although there is no evidence that glass fibers produce effects on the lung comparable to those of asbestos dust. One possible reason for this apparent difference would be the absence in the fibrous glass industry of exposure to fibers of a respirable size.

In Figure 2, the fiber concentrations in fibrous glass plants are compared with those in asbestos textile plants. The bar chart shows that mean concentrations of fibers found in the fibrous glass industry are well below those found in the asbestos textile industry. It should be pointed out that the asbestos textile plants have adopted dust control measures, and there may be little or no disease developing at the dust levels shown. In fact, the average asbestos concentration is less than half the 1969 proposed TLV for asbestos of 12 fibers per cubic centimeter over 5 μ in length.[13] In contrast, the fiber concentra-

TABLE IV
Respirable Fiber Concentrations by Plant and Operation
(fibers/cubic centimeter)

Operation	Plant No.[a]	Total fibers		Fibers greater than 5 μ		Fibers greater than 10 μ	
		Mean	Range	Mean	Range	Mean	Range
Batch and Marble	1	—	—	—	—	—	—
	2	3.64	3.64–	0.97	0.97–	0.54	0.54–
	3	0.66	0.41– 1.03	0.16	0.10–0.26	0.08	0.02–0.16
	4	0.30	0.08– 0.67	0.10	0.02–0.25	0.04	0. –0.07
	1–4[b]	1.53	0.08– 3.64	0.41	0.02–0.97	0.22	0. –0.54
	5	0.09	0.09–	0.04	0.04–	0.	0. –
Forming	1	—	—	—	—	—	—
	2	0.41	0.04– 2.95	0.12	0. –0.36	0.08	0. –0.35
	3	0.15	0.02– 0.45	0.04	0. –0.14	0.02	0. –0.09
	4	0.19	0.02– 0.31	0.02	0.01–0.19	0.03	0. –0.06
	1–4	0.25	0.02– 2.95	0.08	0. –0.36	0.04	0. –0.35
	5	0.10	0. – 0.19	0.02	0. –0.04	0.01	0. –0.04
Spinning, Twisting and Waste Recovery	5	0.72	0.03–12.67	0.11	0. –1.97	0.01	0. –0.06

(a) Plants 1 through 4 are insulation plants; 5 is a textile plant.
(b) Composite of results for plants 1 through 4.

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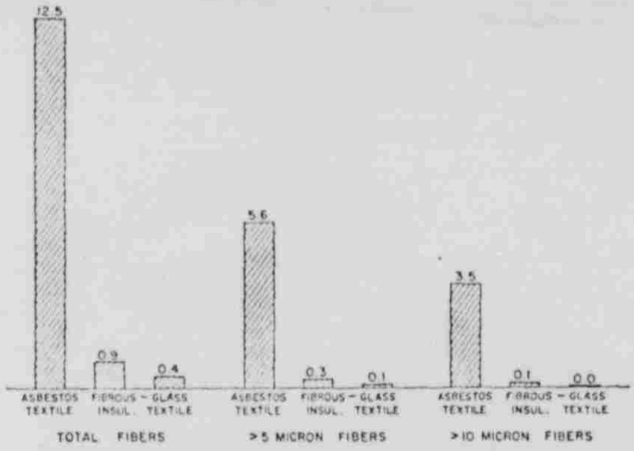


FIGURE 2. Comparison of mean fiber concentrations: asbestos textile versus fibrous glass industry (fibers per cubic centimeter).

tions found in the glass fiber industry were one-fortieth of the proposed asbestos TLV. No sample taken in the fibrous glass industry reached the concentration level of the proposed asbestos TLV. Our results confirm the findings of prior investigators that the fibers produced in these fibrous glass plants were too large to result in significant concentrations of respirable fibers.

In the plants surveyed, little or no local exhaust ventilation was being used at most operations. Therefore, it would seem unlikely that airborne fiber and dust concentrations higher than those found in our survey would be encountered unless the present process is changed.

Summary

In this paper the results of environmental studies of four plants manufacturing fibrous glass insulation and one plant manufacturing fibrous glass textile products are presented. The results in terms of airborne concentration of glass fibers and total dust would indicate that the workman's exposure to these materials is negligible. The airborne concentrations found in the fibrous glass industry are contrasted to those found in similar environmental samples taken in a study of the asbestos textile industry. Exposures in the asbestos textile industry to fibers are of the order of twenty times those in the fibrous glass industry.

Animal experiments and human experience reported in the literature seem to indicate that fibrous glass is a relatively inert material with no fibrogenic or other significant toxic properties.

From the environmental results found in this survey and data from the previous toxicologic and worker studies, there appears to be no reason to class the manufacture of fibrous glass products as a hazardous occupation.

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The Education Committee of the American Association of Poison Control Centers has prepared several visual aids that concern themselves with prevention of accidental poisoning. These include:

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