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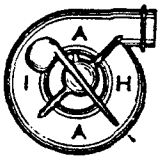

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Exposure of Insulation Workers to Airborne Fibrous Glass

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A study was undertaken to define the airborne concentrations of fibrous glass exposures of workers using prefabricated and other fibrous glass insulation materials. More than 100 fibrous glass products were examined and samples of airborne fibers were collected from various operations with such materials. Airborne concentrations ranged from 0.5 to 8 fibers/ml with mean fiber diameters from 2.2 to 8.4 micrometers. The mean diameter of fibers from the parent product were found not to be a reliable predictor of the mean diameter of the airborne fibers resulting from work with the products. The concentrations of airborne fibrous glass found in this study are not likely to be of long-term biological significance.

Introduction

THIS STUDY WAS UNDERTAKEN as part of our investigation of the work environment of insulating workers; and is a continuation of a previously reported study on the exposures of insulation workers to asbestos fibers and other environmental stresses.[1,2]

The stated objective of this part of our study was: "To define qualitatively and quantitatively the airborne concentration of fibrous glass in the breathing zones of workers engaged in the fabrication, application, finishing, and other operations involved in the installation of prefabricated and other fibrous glass insulation materials." To attain this objective: (a) over 100 samples of fibrous glass insulation products were examined; (b) the conditions of use of these materials were evaluated during visits to over 50 construction sites where the materials were being installed by members of the International Association of Heat and Frost Insulators and Asbestos Workers Local 16 (Northern California and Northern Nevada); and (c) the actual concentrations of airborne fibrous glass were determined during representative installation operations by taking and analyzing samples of the air in the breathing zones of those workers, and in areas surroundin operations.

The general work environment of insu workers has been described previously, ticularly in relation to asbestos exposur have been many of the chemical and ph properties of fibrous glass.[3] The use of fi glass insulation has increased markedly i cent years, and it is now probably the commonly used thermal and acoustica sulation material. As its uses have incre so have the variety of forms in which produced. It has found widest use in the of "batts" or "blankets" of light-density fi glass either with or without a backi protective and/or water impermeable terial such as foil, vinyl, or treated pape this form it is used by the insulation wo studied to thermally insulate ventilation work. Another important source of exp to the insulation worker is the handlin higher density "boards" of fibrous (which may be coated with Neoprene or substances) used for the thermal or acous insulation of walls, ceilings and other surfaces, particularly in mechanical r and ventilation plenums of large buildin third primary source of glass fiber exp is in the installation of fibrous glass

insulation, in which hal compressed fibrous glass a insulation. Fibrous glass used in insulation work thermal insulation of mec and are formed into speci sizes.

Because of the varying contractors, it is diffic "typical" exposure to fib probable that more than insulator's work experienc California and Nevada loc with fibrous glass insulatio However, usage varies a experience may be almost Further, the use of thes timing to increase.

The job classifications the description of work wi ing products do not ap work with fibrous glass man will ordinarily fab finish a single piece of fib Therefore, such classificat except where definite s tasks was observed.

Fibrous Glass Insulation M

Fifty-seven fibrous glass were supplied by manufa in the project. Additional ucts were collected in the were duplicates of those su product, a representative including portions of all material, and this sample w phase contrast microscopy mounting medium with below that of glass. The dividual fibers were estim with a Porton eyepiece r distribution of fibers in e mined. Although it is cu terize particle size distribu mean and geometric stand was not done for these da bution of fiber diameters the expected simple log-n

Although some of this normality was undoubted

nsulation, in which half-round sections of compressed fibrous glass are used for thermal insulation. Fibrous glass products are also used by insulation workers for acoustical/thermal insulation of mechanical equipment, and are formed into special shapes on the job sites.

Because of the varying emphases of local contractors, it is difficult to estimate a "typical" exposure to fibrous glass, but it is probable that more than half of an average insulator's work experience (in the Northern California and Nevada local union studied) is with fibrous glass insulation of various types. However, usage varies and some insulators' experience may be almost totally with glass. Further, the use of these materials is continuing to increase.

The job classifications used by Balzer[1] for the description of work with asbestos-containing products do not appropriately describe work with fibrous glass products, since one man will ordinarily fabricate, apply, and finish a single piece of fibrous glass material. Therefore, such classifications are not used, except where definite separation of work tasks was observed.

Fibrous Glass Insulation Materials

Fifty-seven fibrous glass insulation products were supplied by manufacturers cooperating in the project. Additional samples of 50 products were collected in the field, some of which were duplicates of those supplied. From each product, a representative sample was taken, including portions of all apparent types of material, and this sample was examined under phase contrast microscopy at 430× using a mounting medium with a refractive index below that of glass. The diameters of 50 individual fibers were estimated by comparison with a Porton eyepiece reticle, and the size distribution of fibers in each product determined. Although it is customary to characterize particle size distributions by geometric mean and geometric standard deviation, this was not done for these data, since the distribution of fiber diameters did not exactly fit the expected simple log-normal distribution.

Although some of this deviation from log-normality was undoubtedly due to sampling variation, which was then magnified in effect by our relatively small samples, much of the deviation is "real," and was confirmed for several products by sizing 400 to 500 fibers. There was "smoothing" of the size distribution curves, and extension of the range of sizes encountered in larger samples; but the basic conclusions were not changed.

To permit comparison among materials, accumulated data on product fiber diameters are summarized in Table I.

Exposures of Insulation Workers

The exposures of insulation workers to fibrous glass, like their exposures to other environmental contaminants, cannot be described by time-weighted average exposures because of the nature of the trade. An insulation worker will be exposed, during a working day, to a series of "peak exposures" to the material which he is handling. One man will ordinarily cut, apply, and finish a single piece of glass fiber insulation material. This differs from the situation usually found in a production plant, or in some applications of asbestos-containing products, where a worker may repeat a single operation for most of his working day, so that environmental contamination tends to fluctuate less widely. The insulation worker moves about frequently, and may work on several floors of a large building in a single working shift, with a consequent variety of exposure to environmental contaminants. Further, the worker who today is installing calcium silicate insulation in an enclosed boiler room, with extremely high concentrations of airborne asbestos fibers, may

TABLE I
Diameters of Fibers of Various Fibrous Glass Products

Material	No. of Samples	Range of arithmetic Means (μm)	Mean of Means (μm)
Duct liner	23	4.4–17.0	6.7
Duct wrap	11	4.1– 9.4	5.4
Industrial Wall insulation	18	4.4–10.7	8.1
Pipe insulation	8	4.4– 9.0	7.0
Prefabricated duct	11	5.7–11.5	8.0
Basic fiber	6	5.0–11.5	8.8
Acoustical tile	5	4.0–11.4	9.1
Miscellaneous	6	4.0– 7.6	5.5
Packing wool	4	7.0– 9.0	8.0
Building insulation	14	4.9–11.5	8.2

TABLE II
Concentrations and Dimensions of Airborne Fibers from Various Operations Using Fibrous Glass Insulation

Operation	Site #	Parent Material: mean fiber diameter (μm)	Air Samples: Breathing Zone: fibers/ml	Breathing Zone: mean fiber diameter (μm)	Breathing Zone: Length % <78μm	Breathing Zone: Length % >78μm	Air Samples: Area: fibers/ml	Area: mean fiber diameter (μm)	Area: Length % <78μm	Area: Length % >78μm
Duct Wrapping	1	5.3 6.3 6.4	1.26 0.90	4.7 4.0	24 40	76 60	0.09	4.0	43	—
	2	4.0	0.51 0.79	3.4 3.6	46 36	54 64	0.02	5.5	40	
	3	4.1	1.40 1.33	2.6 2.3	62 60	38 40	0.03	3.7	78	
	5-IV	7.5	0.80	2.5	83	17				
	8	5.8 5.5	1.20 2.34	6.2 5.0	37 42	63 58	0.07 0.03	3.7 4.5	62 54	
Wall & Plenum Insulation	4	7.2	0.53	7.4	30	70	<0.01 0.09	— 6.2	— 50	
	5-I	10.2	3.26	8.4	47	53	0.08	7.9	49	
	7-I	8.1 7.6	4.18	3.5	59	41	0.47	2.8	55	
	7-II	7.8 8.1	8.08	3.8	60	40	0.34	2.2	60	
Pipe Insulation	5-III	8.5	0.93 0.48	3.1 4.1	71 40	29 60	0.05	2.3	86	
	6	6.7 6.0 6.0 5.6	0.57	3.4	50	50	0.05 0.03 0.02 0.09 0.09	2.6 2.6 3.1 3.5 2.9	88 86 66 66 65	
Fan Housing Insulation	5 II	6.9	1.57	3.5	88	12	0.20	3.4	82	

*78 μm is the equivalent length of the major division of the Perton reticle with our optical system.

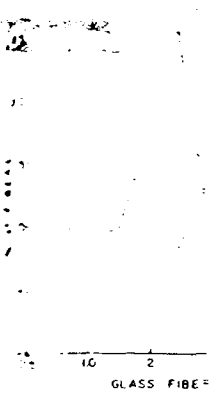
tomorrow be wrapping ducts with fibrous glass in a relatively open area of the same building, with natural ventilation from open windows serving to remove airborne glass fibers from his vicinity nearly as soon as they are produced. Exposures, then, cannot be accurately characterized as though they were constant, but must be related to the work being performed at the time of the exposure. Short term sampling periods are required in order to assess the environmental exposure.

Concentrations of Glass Fibers in Air

In Table II are shown the mean fiber diameters of the fibrous glass materials used, and concentrations and sizes of the airborne glass fibers found during installation of fibrous glass insulation at the construction sites from which air samples were taken.

Sampling techniques used in this study have been described previously.[2] Briefly, air for breathing zone samples was drawn through 0.8 μm (mean pore size) Milli membrane filters by MSA Monitaire p at flow rates of 2 to 3 liters per minute. samples were taken in the same way, pumps with flow rates of 25 to 30 liters minute. The filter holders for the samples were about 5 to 6 feet above level and 10 to 20 feet away from the tions of the installation operations. Samp periods were 20 to 60 minutes.

It will be noted that none of these re are expressed "gravimetrically" (*e.g.* glass/m³ air). The air at construction sites is notoriously dusty, and any attemp relate a total gravimetric sample to the centration of fibrous glass is impractical misleading. Secondly, the tentative Thr old Limit Value (American Conferenc Governmental Industrial Hygienists) o mg/m³ for fibrous glass only applies to fi with diameters less than "5 to 7 micrometer Our experimental work has shown that th



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Discussion

The exposures
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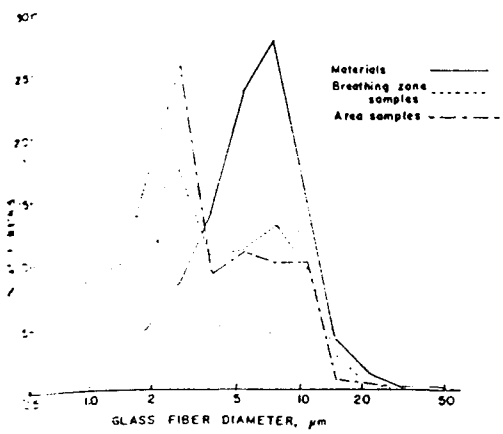

FIGURE 1. Accumulated percentage distribution of fiber diameters from all sampling sites.

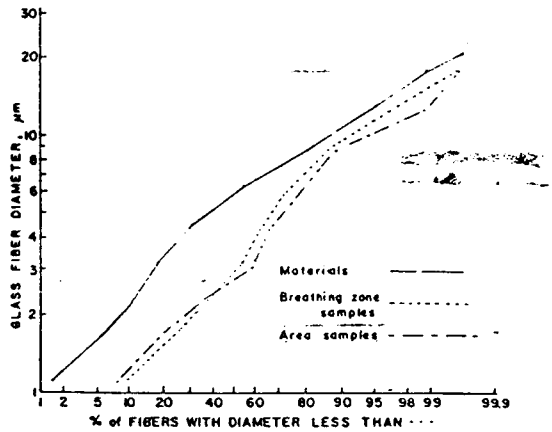

FIGURE 2. Cumulative distribution of fiber diameters from all samples.

is no size-selective sampler which will collect all fibers less than any specific diameter in this range and reject all larger fibers (or vice-versa). Thus, the only way to comply with the requirements of the TLV is to collect all airborne fibers, size them, and estimate the weights of individual fibers. Using this procedure, with many simplifying assumptions, we estimate that a concentration of 1 fiber/ml with a mean airborne fiber diameter of 4 micrometers and a mean airborne fiber length of 50 micrometers is equivalent to a gravimetric concentration of 1 to 1.5 mg/m³ of total fibrous glass. The estimated gravimetric concentration of fibers to which the TLV is applicable (less than 7 micrometers in diameter) is approximately 0.5-0.7 mg/m³ for a fiber concentration of 1 fiber/ml, although this of course varies with the fiber size distributions.

Discussion

The exposures of insulators to airborne fibrous glass during the application of fibrous glass insulation products ranged from 0.5 to 8 fibers/ml with a median of 1.26 and mean of 1.8 fibers/ml. This is significantly lower than their exposures to other fibrous materials.[2] The potential exposures of other construction trades to airborne glass fibers as a result of "fallout" from insulating operations were still lower, ranging from below 0.02 fiber/ml to 0.47 fiber/ml with a median of 0.07 fiber/ml and a mean of 0.1 fiber/ml, at a distance of 10 to 20 feet from the insulator during his application of fibrous glass materials.

The maximum levels were found in confined spaces, where there was little circulation of air, and where clean-up (including sweeping and packing of scraps of fibrous glass residue) had generated high concentrations of airborne dust of all kinds. Although, as stated previously, it is difficult to generalize about the occupational environment of the insulator, it is probable that exposures of this sort are relatively rare. It is most common for clean-up to take place only at the end of a work shift. Because of the bulkiness of fibrous glass insulation products, cutting is usually done in a relatively open area which affords the space necessary for layout and measurement.

One of the striking findings of the study, as shown in Figure 1, is that the mean fiber diameter of the parent products is not a reliable predictor of the mean diameter of the fibers in the aerosol generated from these products. Although the determinants of "respirability" of airborne fibers are not fully agreed upon, it is probable that respirability is diameter-dependent.[4] Timbrell's experiments, using the aerosol spectrometer, suggested that fibers with densities of less than 3.5 g/cm³ and large aspect ratios (length to width ratios) could be considered "respirable" if the fiber diameter was less than 3.5 micro-

meters. Fibrous glass (with a density of 2.4-2.6 g/cm³ fits his definition and thus glass fibers less than 3.5 microns in diameter will be defined as "respirable." As can be seen in Figure 2, about one half of the airborne glass fibers generated from the handling of fibrous glass insulation materials are below this upper limit. Thus, it would seem that the often encountered statement that the diameter of the majority of glass fibers is such that they will not penetrate to the lower respiratory tract is true of the parent materials, but generally not of the airborne fibers which are of primary concern in occupational health.

Although our observations might appear to be at variance with those of Johnson *et al.*,[5] who recently studied the airborne dust concentrations in glass fiber insulation and textile manufacturing plants, our conclusions are essentially the same as theirs; the concentrations of small diameter airborne fibers are very low.

What do the concentrations of fibrous glass which were found mean in terms of potential hazard to health? The consensus of present opinion is that fibrous glass, although mechanically irritating to the skin and upper respiratory tract, is *per se* relatively inert and that it does not cause chronic pulmonary disease when inhaled.[6-9] Although Milby and Wolf have reported cases indicative of respiratory irritation in individuals who had removed insulation materials or otherwise been exposed to fibrous glass,[10] and Murphy in 1961 reported a case of hemorrhagic bronchiolitis after heavy exposure to dust during removal of glass insulation,[11] no documented cases of pneumoconiosis or other chronic pulmonary diseases due to fibrous glass are known to us. Intubation studies in lower animals have shown relatively little biologic activity.[12,13]

This is the basis upon which the American Conference of Governmental Industrial Hygienists, in 1969, set the tentative threshold limit value for fibrous glass at the same level as that for inert dusts, now 10 mg/m³ (for fibers under 5 to 7 micrometers in diameter). Although gravimetric determinations of glass are not feasible in the construction trade, the fiber counts that we observed have been calculated to represent amounts of glass far low the TLV. These were the concentrat during actual installation operations and time-weighted averages. The insulator's t weighted average would be much lower the figures given.

Because there are unquestionably respir fibers in most fibrous glass materials and t are many possible variations in coat binders, etc., prudence dictates that ther continued surveillance of the exposure various groups to fibrous glass as is being by the Public Health Service.[5] The assu absence of chronic effects should be che by appropriate long-term observation of t whose work involves frequent or daily halation of glass.

Conclusions

1. Insulation workers, during the ac application of fibrous glass insulation prod were exposed to airborne concentration glass fibers ranging from 0.5 to 8 fibers with a median of 1.3 fibers/ml and mea 1.8 fibers/ml.

2. The computed gravimetric concen tions of airborne glass fibers less than 7 in diameter did not exceed the tenta Threshold Limit Value of 10 mg/m³ du any peak period. The majority of these m surements were less than 1.0 mg/m³.

3. No time-weighted average could computed which would be representativ a work day exposure. In any case, it w be considerably less than the peak con trations measured.

4. Insulators work with fibrous glass taining materials from less than 10% to 1 of their time depending on employer and of construction site.

5. It is doubtful that the concentration airborne fibrous glass found in our study of long-term biological significance.

Acknowledgments

The technical assistance of Mr. J Murchio and microscopy of Mr. Arturo Leon are gratefully acknowledged. This search was supported in part by the Nati Insulation Manufacturers Association.

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Safety in the Laboratory

The Bureau of Occupational Safety and Health, U. S. Public Health Service, is presenting a course "Safety in the Laboratory" in Cincinnati, Ohio, March 29-April 2, 1971. This course is intended to train safety managers, laboratory staff, and related workers in the control of accidental injuries. The course provides an opportunity for staff members to be reapprised of the facilities and methods at their disposal to minimize injury in the laboratory. Administrative and organizational aspects as well as design and construction of laboratory equipment and facilities will be discussed. Methods of handling reagents, biological, pathological, radioactive, and other materials and specimens will be reviewed. Animal care and related facilities, protection from extreme temperatures, and waste storage and disposal are to be included. The trainee will have opportunity to investigate ventilation systems, clean rooms, diseases transferable to man, emergency aid, noise, and other pertinent subject matter.

Inquiries may be addressed to Training Branch, Bureau of Occupational Safety and Health, 1014 Broadway, Cincinnati, Ohio 45202 or inquires may be made by telephone to (513) 684-3287.

Measures for Industrial Noise Control

A five-day course on Measures for Industrial Noise Control will be co-sponsored by the University of California and the National Council on Noise Abatement in Berkeley, California on March 22-26, 1971. This course is directed towards the practical steps needed to meet the requirements of the noise amendment of the Federal Walsh-Healey Act. The course will deal with basic concepts of noise and noise measurement, prediction of noise-induced hearing impairment, the effect of noise on speech and work performance, and hearing conservation programs. Major emphasis will be placed on case histories of noise control measures and their effectiveness in various industries. Each enrollee will receive the 1967 guide on *Industrial Noise* issued by the U. S. Public Health Service and the 1966 *Industrial Noise Manual* of the American Industrial Hygiene Association.

Advanced enrollment is required and may be made by individuals or companies. The enrollment is $315. For further information please write to Continuing Education in Engineering, University Extension, University of California, 2223 Fulton Street, Berkeley, California 94720.