Applied Occupational and Environmental Hygiene
Volume 17(4): 276–285, 2002

1047-322X/02 $12.00 + .00

A Synthetic Vitreous Fiber (SVF) Occupational Exposure Database: Implementing the SVF Health and Safety Partnership Program

Gary E. Marchant,[1] Michael A. Amen,[2] Christopher H. Bullock,[3] Charles M. Carter,[4] Kathleen A. Johnson,[5] Janis W. Reynolds,[6] Francis R. Connelly,[1] and Angus E. Crane[7]

[1] College of Law, Arizona State University, Tempe, Arizona; [2] Evanite Fiber Corporation, Corvallis, Oregon; [3] Rock Wool Manufacturing Company, Leeds, Alabama; [4] Johns Manville, Littleton, Colorado; [5] Owens Corning, Toledo, Ohio; [6] CertainTeed Corporation, Valley Forge, Pennsylvania; [7] North American Insulation Manufacturers Association, Alexandria, Virginia

The Health and Safety Partnership Program is a voluntary workplace safety program for workers involved in the manufacture, fabrication, installation, and removal of glass wool and mineral wool products. This article describes one element of this Partnership Program, the development of an occupational exposure database that characterizes exposures by fiber type, industry sector, product type, and job description. Approximately 6000 exposure samples are included in the database, most of which were collected over the past decade, making it the most extensive and recent exposure data set on record for glass wool and mineral wool. The development of this database, as well as the initial results for exposure measurements segmented by product type and/or job description, are described. The current database shows that most applications and uses of glass wool and mineral wool involve exposures below the voluntary 1 f/cc permissible exposure limit, although some specific product types and job descriptions involve average exposures approaching the 1 f/cc limit.

Keywords Synthetic Vitreous Fibers, Glass Wool, Mineral Wool, Fiberglass, Insulation, OSHA, Occupational Exposure, Exposure Database

Synthetic vitreous fibers (SVFs) are a class of inorganic fibrous materials that include glass wool, mineral wool (also known as rock and slag wool), textile glass fibers, and refractory ceramic fibers. Historically, this class of fibers has also been described as man-made mineral fibers (MMVFs), man-made vitreous fibers (MMVFs), and manufactured vitreous fibers (MVFs). These fibers are used primarily in a variety of thermal and acoustical insulation products, but also have numerous filtration, fireproofing, and other applications. Human exposure to SVFs occurs almost exclusively in the occupational context, as the installed products normally do not result in airborne fiber levels that can produce significant consumer exposures.[1,2]

The Occupational Safety and Health Administration (OSHA) has not adopted specific occupational exposure standards or other regulations for SVFs. In 1989, the agency proposed a 1 fiber per cubic centimeter (f/cc) occupational exposure standard for glass wool and mineral wool, but this proposal was withdrawn and never finalized. OSHA's published regulations treat these fibers as a nuisance dust using a gravimetric standard (permissible exposure limit of 15 mg/m^3 total dust and 5 mg/m^3 respirable dust).

In 1995, OSHA identified SVFs as one of 18 priorities in its Priority Planning Process, based on the number of potential workers exposed to SVFs.[3] This OSHA planning process was undertaken for the purpose of prioritizing potential occupational safety and health hazards for formal rule-making or other agency action. Five of the 18 priorities were designated for formal rule-making and added to OSHA's regulatory calendar. SVFs were not included in this rulemaking category, but, instead, were identified by OSHA, along with 12 other substances or categories, as candidates for voluntary or cooperative efforts to encourage worker protection without developing new regulations.

In response to this development, the North American Insulation Manufacturers Association (NAIMA), a trade association of manufacturers of glass wool and mineral wool, began discussions with OSHA to develop a voluntary occupational safety

Please direct requests for further information to Angus E. Crane.

program for workers involved in the manufacture, fabrication, installation, and removal of glass wool and mineral wool products. These negotiations culminated in a 1999 agreement involving OSHA, NAIMA, and two trade associations representing insulation installers (the National Insulation Association [NIA] and the Insulation Contractors Association of America [ICAA]), to establish a voluntary Health and Safety Partnership Program (HSPP).[4] Refractory ceramic fiber manufacturers are not included in the HSPP, but have developed their own exposure monitoring program as part of a consent agreement with the U.S. Environmental Protection Agency (EPA), which is described in Maxim et al. (1997).[5] Textile glass fibers are also not included in the HSPP because they are generally nonrespirable (nominal fiber diameter of 6–15 μm).[6]

The HSPP is a comprehensive and voluntary workplace safety partnership being implemented by the SVF industry under OSHA's oversight to promote the safe manufacture and handling of glass wool and mineral wool products. The program is being phased in over a three-year implementation period that commenced in May 1999. This implementation period will be followed by an initial five-year compliance period from 2002–2007. OSHA's administrator praised this voluntary program as "creative" and "innovat[ive]," and an "important step towards further improving worker protection." He also identified the program as "a possible model for future collaborative efforts of this type."[7]

The centerpiece of the HSPP is the establishment of a voluntary 8-hour, time-weighted average (TWA) permissible exposure limit (PEL) of 1 f/cc for respirable SVF. Achievement of this voluntary PEL is to be attained through the use of product design, engineering controls, work practices, respiratory protection, or a combination thereof. The voluntary 1 f/cc PEL is consistent with the exposure standards recently adopted by the American Conference of Governmental Industrial Hygienists (ACGIH®) and numerous other countries.

The HSPP goes beyond simply setting a voluntary permissible exposure limit, and recognizes that the SVF industry involves a diverse array of product types and job functions with different exposure potentials. The program also recognizes that many employers in the industry, especially those in the installation sector, are small businesses that cannot afford to undertake expensive compliance activities such as exposure monitoring. The HSPP therefore includes numerous voluntary compliance assistance measures. These measures include the development of comprehensive work practice recommendations for the proper and safe handling of SVF products that provide detailed safety guidelines for specific product types and job functions. NAIMA and its member companies will also sponsor training seminars and workshops for employers and their workers, and NAIMA will prepare literature, brochures, videotapes, and posters to communicate the work practices and other elements of the HSPP. The HSPP also includes specific reporting requirements under which NAIMA will regularly collect and annually report information on the implementation of the HSPP to OSHA.

EXISTING SVF EXPOSURE DATA

While individual companies have collected extensive exposure data to support their own industrial hygiene, risk assessment, and product stewardship programs, most of these exposure data have not previously been published in the open literature. Some governmental sampling of occupational SVF exposures has also been undertaken, but again most of those data have not been published. For example, in the United States, the National Institute of Occupational Safety and Health (NIOSH) has evaluated some individual job sites for SVF exposures in 1992 and 1993, finding very low exposure levels generally below 0.1 f/cc, although with relatively small sample sizes. These exposure data were presented in agency reports,[8,9] but have not been published in a peer-reviewed journal. In Australia, Worksafe Australia teamed with the SVF industry to collect occupational exposure samples in the manufacturing, installation, and demolition/removal job sectors. Of the 938 fiber count results reported in this study, 934 involved exposures below 0.5 f/cc.[10] These exposure data have also not been published.

A number of published studies have reported SVF occupational exposure levels in manufacturing or installation operations.[2,11–23] These studies show that occupational exposures are generally below 1 f/cc, although some of the published studies report maximum exposures above 1 f/cc, and in a few studies the reported mean values exceeded 1 f/cc.

The published data, however, suffer from several important limitations. Many of the published data are relatively old, in many cases collected in the 1960s, 1970s, or 1980s, and therefore may not be representative of current industry exposure levels. Some of the older studies also use outdated or modified sampling and fiber counting methods. In addition, the methodologies used in the various published studies are often inconsistent, limiting the ability to compare or combine data between studies. The sampling times in many of the earlier published studies are relatively short or not reported, and thus may not be representative of full-shift exposure. In several of the published studies, relevant information is missing from the published reports, including in some cases the number of samples collected and full specification of the sampling and analytical procedures.

Perhaps most importantly, the published exposure data do not adequately cover the full range of product types and job descriptions. In some cases, the data are aggregated over many product types or job functions, making it difficult to predict exposure levels for specific job/product scenarios. For other products or job functions, published data are limited or nonexistent. For example, while a substantial body of exposure data has been published for manufacturing operations, the available published data for many installation activities are limited. The National Research Council (NRC), in a recent scientific review of SVFs that endorsed a 1 f/cc occupational exposure standard for most glass wool and mineral wool fibers, recommended that additional published occupational exposure data were needed for workers handling these fibers in nonmanufacturing sectors (i.e., installation job functions).[24]

THE HSPP SVF EXPOSURE DATABASE

Given the limitations of the existing published exposure data for SVFs, an important component of the HSPP is the commitment of NAIMA to develop, with the assistance of its member companies, a database of representative exposure levels for the manufacturing and end-use applications of glass wool and mineral wool products. This exposure database includes exposure data collected from the individual companies and other sources, and will be updated with additional data collected as part of the HSPP. The HSPP commits industry to collect approximately 400 samples per year in the period from 2002 to 2007 to ensure that the database contains sufficient data to document current exposures for specific product types and job functions.

As part of this sampling program, the HSPP commits NAIMA to develop and begin implementing by 2001 a sampling strategy designed to target specific tasks with higher potential exposures and limited published exposure data. Ten such tasks identified in the HSPP are batt insulation installation, compressed air cleanup, fabrication with hand-held power cutting tools, loose fill insulation installation, mineral wool manufacturing, mineral wool ceiling tile installation, removal activities combined with demolition, removal of high temperature unjacketed insulation exposed to service temperatures above 177°C/350°F, tasks involving handling of special application fibers, and applications in tightly enclosed, poorly ventilated spaces. NAIMA has also committed in the HSPP to develop a sampling strategy designed to verify exposures during manufacture, fabrication, or use of products with traditionally low potential exposures, as well as to assess exposure levels of new products.

The SVF exposure database will serve several purposes. First, it will provide a comprehensive overview of exposure levels in the industry as well as exposure levels for specific product types or job functions. The database is constructed to permit a user to select exposure data for any specific combination of fiber type, industry sector (i.e., manufacturing, fabrication, installation), product type, and job description. The database will also permit tracking of significant changes or trends in exposure levels over time.

Second, the exposure database will be used to provide representative exposure estimates to installation contractors and other industry participants for specific product type/job function combinations. Most job functions and products are generally narrowly defined and standardized, producing relatively consistent exposure levels over time and between sites for the same product type and job function.[22] By collecting and making available exposure data for a particular job function and product type, the exposure database will provide a convenient service for contractors and other companies to ensure that their workers are within the voluntary 1 f/cc PEL without requiring those companies to undertake their own burdensome exposure monitoring program.

Third, the exposure database will identify specific job tasks that involve exposures near or above the voluntary 1 f/cc PEL, and therefore may warrant additional exposure reduction or other worker protection. As part of the HSPP, NAIMA identified selected tasks where respirators will be recommended unless and until exposure data indicate occupational exposures are consistently below the voluntary 1 f/cc PEL. Specifically, under the HSPP, a worker must wear a NIOSH-certified dust respirator (N-95 series or better) in the following tasks: (1) blowing SVF insulation in an attic or for cavity fill; (2) in the immediate area of blowing SVF insulation in an attic or for cavity fill; (3) dumping or pouring unbonded, bulk, specialty filtration fiber products where engineering controls are absent; and (4) removing SVF products during significant repair or demolition activity. As mentioned above, the industry will also institute a program to measure worker exposures in other specified tasks with the potential for high fiber exposures, including workers in the manufacturing setting.

Finally, the SVF exposure database will provide additional benefits beyond the HSPP. For example, OSHA's 1998 respiratory protection standard requires employers to evaluate workplace exposures, typically through exposure monitoring, to determine appropriate respirator use for employees.[25] Such exposure monitoring can be very burdensome for small employers, such as many of the contractors that install SVF products. Recognizing this potential burden, OSHA in its preamble to the final respiratory protection standard (29 CFR § 1910.134) provided that appropriate industry-wide exposure surveys or databases could be used in lieu of company-specific exposure monitoring to estimate exposure levels for the purpose of determining respiratory protection requirements.[26] OSHA noted that such industry-wide surveys "must have obtained data under conditions closely resembling the processes, types of materials, control methods, work practices, and environmental conditions in the workplace to which it will be generalized, i.e., the employer's operation." Specifically referring to NAIMA's SVF exposure database, OSHA stated that, "It is clear that such programs can often assist employers to estimate workplace exposures reliably enough to make correct respirator choices without the need for employee monitoring."

The SVF exposure database developed by NAIMA and its members under the HSPP therefore represents an innovative and pioneering approach for enhancing worker protection while at the same time reducing compliance burdens, particularly for small businesses. As OSHA has noted, the HSPP including the SVF exposure database may serve as a model for other industries. This article describes the design and implementation of the SVF exposure database by NAIMA and its member companies. It also summarizes the exposure data collected to date, which consists of approximately 6000 TWA exposure samples mostly collected over the past decade, the vast majority of which were previously unpublished, making it the largest and most current occupational exposure data set reported for glass wool and mineral wool.

METHODS

Exposure Sample Collection

Although the large number of exposure samples in the SVF database were collected from many different locations by many different industrial hygienists over a period of many years, the SVF sampling procedure has been standardized, and is reinforced by the data acceptance criteria for the database (discussed below). The sampling locations were preferentially concentrated on the more common job tasks and tasks involving higher potential exposures.

The majority (> 90%) of the samples in the database were collected and analyzed following NIOSH Method 7400.[27] This method for analyzing fiber counts was first published in 1984. In 1985, the NIOSH 7400 method was revised to add the "B" counting rules (7400B). The NIOSH 7400B method has been the industry standard methodology for measuring ambient concentrations of synthetic vitreous fibers since 1989, and has also been accepted by government agencies.[28] This methodology is nonspecific for SVF fibers, in that it counts all fibers present in the workplace that meet the method's definition of fiber, and thus fiber counts will include other types of fibers (e.g., organic fibers) in addition to SVF fibers.

Some of the older samples in the database used other analytical methods, such as the World Health Organization (WHO) method (< 1% of all samples),[29] the 1977 NIOSH criteria method (∼ 8% of all samples),[30] and the P&CAM 239 method (∼ 1% of all samples),[31] which prescribe counting rules that differ slightly from the NIOSH 7400B method.

As described in the NIOSH 7400B method, personal samples were collected in the worker's breathing zone using constant flow pumps, with flow rates calibrated before and after monitoring using or linked to a primary calibration unit. Mixed cellulose ester (MCE) membrane filters (25 mm) were used. The 25-mm sample cassettes were fitted with conductive cowls (50 mm) with the outer face cap of the cassette removed (open-faced) for sampling. Samples were collected at a flow rate of 0.5–5.0 liters per minute.

All samples were analyzed by phase contrast optical microscopy (PCOM), in almost all cases by American Industrial Hygiene Association (AIHA)-accredited laboratories. The NIOSH 7400B counting rules specify that only fibers less than 3 μm in diameter and greater than 5 μm in length with aspect ratios (i.e., length-to-width ratios) of 5:1 or greater be counted using a Walton-Beckett graticule at a magnification of 400×. The rules further specify the counting of only fiber ends, with sufficient microscopic fields counted to yield at least 200 fiber ends or 100 fields. In addition, the counting of fibers in a minimum of 20 fields is required for statistical validity.

Construction of the SVF Exposure Database

The SVF exposure database contains recent historical SVF exposure data as well as new exposure data collected (as of September 8, 2000) as part of the ongoing HSPP implementation efforts. The historical data were contributed by NAIMA member companies or collected in NAIMA-sponsored studies. The data collection and construction of the exposure database was overseen by the Occupational Health and Safety Working Group of the NAIMA OSHA Initiative Task Force, consisting of health and safety professionals from NAIMA member companies and NAIMA staff and consultants. The database is maintained by a third-party independent consultant (GEM) at Arizona State University, who serves as the database manager.

To ensure consistency and quality control in the data collection and entry, the Occupational Health and Safety Working Group developed a database dictionary that provides criteria for data acceptance and data validation. The dictionary specifies that each sample entered into the database must include a sample identification number, the sample location and date, the sampling analytical method used, the type of SVF present in the workplace being sampled, the product type being handled, the type of operation or use from which the sample was collected, and the job description of the employee or job site being sampled.

The sample results are reported as TWAs, with the sample duration and number of individual samples comprising the TWA also entered in the database in separate fields. A quantifier is also entered to indicate whether the sample TWA is an exact measurement or is below the level of detection (LOD), which is less than 0.01 f/cc for samples using the NIOSH 7400B method in atmospheres free of interference. If available, information is also entered on the use of personal protective equipment (e.g., NIOSH-approved air-purifying half-mask respirator) worn during the collection of personal samples. For most of the historical samples, information on respirator use is not available.

The company submitting the data enters the various data fields requested by the database, conducts a quality assurance/quality control review, and then submits the data to the database manager. The database manager performs a secondary QA/QC review and then adds the data to the database.

Presentation of Exposure Data

Various permutations of the exposure data outputs from the database are presented in the following section. All data included in these presentations involve TWA values from the database with a sampling duration of at least 240 minutes. The TWA values have not been adjusted to an 8-hour period, but represent actual sampling durations. For purposes of the presentations in this article, only personal samples using the NIOSH 7400B method were selected.

All samples in the database that are shown as being below the LOD (i.e., < 0.01 f/cc) were assumed to be at 0.01 f/cc for purposes of the analysis. For data segmented by product type or job description, only those categories that include at least 10 data points are listed individually in the relevant exposure tables. All other categories are grouped into an "other" category and identified in the applicable table.

The exposure data are presented using the following summary statistics: arithmetic mean, standard deviation (S.D.), median, and range (i.e., minimum and maximum). As is common for many occupational exposures, the SVF occupational exposure data reported here are highly skewed, with the vast majority of measurements well below 1 f/cc, but with occasional data points significantly higher. With such data sets that appear to be lognormally distributed, the EPA recommends presentation of both the arithmetic mean and either the median or the geometric mean.[32] The median and geometric mean are typically nearly equal for such distributions, and are substantially lower than the arithmetic mean. Accordingly, both the arithmetic mean and median are presented in the exposure data tables below.

RESULTS

The HSPP exposure database currently contains approximately 6000 TWA samples, of which 4260 are personal samples collected using the NIOSH 7400B method. The samples in the database were collected from over 175 different locations, including at least 50 different sites in each of the manufacturing, fabrication, and installation sectors. Most of the samples were collected in North America, but some European samples are also included in the database. The mean sampling time for all the personal samples in the database is 344 minutes. This database can be used to assess typical SVF exposure levels by fiber type, industry sector, product type, and/or job description. Some examples of such data categorizations are presented below.

Aggregate and Industrial Sector Exposure Levels

Aggregate exposure data for glass and mineral wool by industrial sector are presented in Table I. The 2473 available personal TWA samples (of at least 240 minutes) for glass fibers have an aggregate arithmetic mean exposure of 0.26 f/cc, and a median of 0.05 f/cc. For mineral wool, a total of 505 TWA samples resulted in an aggregate arithmetic mean exposure of 0.19 f/cc and a median of 0.14 f/cc. Table I also segments the aggregate data for both glass and mineral wool into the major industrial sectors of manufacturing, fabrication (relevant for glass wool only), installation, and retrofit/removal activities. For glass wool, the arithmetic mean exposure levels for the various sectors ranged from 0.23 f/cc for the manufacturing sector to 0.38 f/cc for glass wool installation. Arithmetic mean exposure levels ranged from 0.10 to 0.20 f/cc for the mineral wool manufacturing, installation, and retrofit/removal sectors. In all cases, arithmetic mean exposures for the aggregate categories are less than 0.40 f/cc, and the medians are less than 0.25 f/cc. The medians are consistently below the arithmetic means, suggesting that relatively rare outliers with elevated exposures are inflating the means. Every industry sector other than retrofit/removal for both glass wool and mineral wool, and mineral wool installation, includes some maximum exposure values over 1 f/cc, with the highest TWA exposure value recorded at 7.49 f/cc.

Exposure Levels by Product Type

The database can be sorted to provide exposure data for specific products. Product-specific exposure data are presented in Tables II–V for the glass wool manufacturing, glass wool installation, mineral wool manufacturing and installation, and glass wool fabrication sectors, respectively. Arithmetic mean and median exposure levels vary considerably by product type within industry sectors. For example, in the glass wool manufacturing sector, the category of separator and filtration media has an arithmetic mean exposure level of 0.80 f/cc, while all other product types have arithmetic mean exposure levels below 0.20 f/cc (Table II). Similarly, in the glass wool installation sector, workers installing blowing wool without a binder have arithmetic mean exposure levels of 0.79 f/cc, whereas the arithmetic mean exposure levels for installation of all other glass wool products and all mineral wool products are at or below 0.30 f/cc (Table III).

Exposure Levels by Job Description

Exposure data are classified by job description for the various SVF industry sectors in Tables VI–VIII. In glass wool and

TABLE I
Aggregate SVF exposure data by industrial sector

Industrial sector	Sample size	Exposure (f/cc)			
		Mean	S.D.	Median	Range
Glass wool manufacturing	1648	0.23	0.53	0.03	0.01–4.63
Glass wool fabrication	475	0.28	0.49	0.10	0.01–3.80
Glass wool installation	344	0.38	0.73	0.16	0.01–7.49
Glass wool retrofit/removal	6	0.26	0.26	0.21	0.03–0.74
All glass wool	2473	0.26	0.55	0.05	0.01–7.49
Mineral wool manufacturing	429	0.20	0.19	0.15	0.01–1.41
Mineral wool installation	74	0.15	0.17	0.09	0.02–0.82
Mineral wool retrofit/removal	2	0.10	0.01	0.10	0.10–0.11
All mineral wool	505	0.19	0.19	0.14	0.01–1.41

TABLE II
Glass wool manufacturing: Glass wool fiber exposures by product type

Product type	Sample size	Exposure (f/cc)			
		Mean	S.D.	Median	Range
Air handling products	12	0.03	0.03	0.02	0.01–0.13
Aircraft insulation	67	0.19	0.36	0.06	0.01–2.29
Appliance insulation	28	0.12	0.29	0.03	0.01–1.30
Automotive insulation	102	0.02	0.03	0.01	0.01–0.18
Separator and filtration media	376	0.80	0.84	0.51	0.01–4.63
Blowing wool with binder	71	0.04	0.03	0.03	0.01–0.02
Blowing wool without binder	53	0.11	0.12	0.08	0.01–0.49
High-density board	14	0.02	0.02	0.01	0.01–0.09
Pipe insulation	114	0.05	0.10	0.02	0.01–0.70
Insulation batts & blankets	472	0.05	0.09	0.02	0.01–0.97
Other[A]	339	0.07	0.18	0.02	0.01–2.30

[A]Includes acoustical panels and nonspecified industrial and commercial products.

TABLE III
Glass wool installation: Glass wool fiber exposures by product type

Product type	Sample size	Exposure (f/cc)			
		Mean	S.D.	Median	Range
Air handling products	11	0.28	0.34	0.23	0.02–1.23
Appliance insulation	31	0.08	0.16	0.02	0.01–0.06
Automotive insulation	17	0.02	0.02	0.01	0.01–0.05
Blowing wool with binder	19	0.30	0.30	0.24	0.04–1.13
Blowing wool without binder	133	0.79	1.02	0.50	0.01–7.49
Cavity loose fill insulation	12	0.15	0.12	0.11	0.04–0.47
Pipe insulation	28	0.05	0.05	0.03	0.01–0.19
Insulation batts & blankets	62	0.17	0.10	0.16	0.01–0.46
Other[A]	25	0.05	0.04	0.02	0.01–0.16

[A]Includes flex duct and nonspecified industrial and commercial products.

TABLE IV
Mineral wool manufacturing and installation: Mineral wool fiber exposures by product type

Product type	Sample size	Exposure (f/cc)			
		Mean	S.D.	Median	Range
Manufacturing					
Ceiling panel/tile	412	0.20	0.19	0.15	0.01–1.41
Other manufacturing[A]	17	0.06	0.04	0.05	0.01–0.15
Installation					
Ceiling panel/tile	33	0.23	0.21	0.17	0.02–0.82
Spray-on fireproofing	15	0.08	0.10	0.05	0.02–0.42
Insulation batt & blanket	12	0.09	0.04	0.08	0.04–0.16
Other installation[A]	14	0.11	0.11	0.06	0.02–0.40

[A]Includes air handling board, appliance insulation, blowing wool with binder, cavity loose fill insulation, pipe insulation, and safing blanket and board.

TABLE V
Glass wool fabrication: Glass wool fiber exposures by product type

Product type	Sample size	Exposure (f/cc)			
		Mean	S.D.	Median	Range
Acoustical panels	11	0.07	0.07	0.03	0.01–0.23
Air handling products	66	0.05	0.05	0.03	0.01–0.22
Appliance insulation	37	0.14	0.15	0.10	0.01–0.65
Automotive insulation	19	0.05	0.04	0.03	0.01–0.10
Battery separator media	122	0.55	0.77	0.20	0.01–3.80
Air & water filtration	146	0.32	0.41	0.15	0.01–1.90
Other[A]	74	0.10	0.10	0.09	0.01–0.64

[A]Includes aircraft insulation, pipe insulation, insulation batts, and blankets with binder and nonspecified industrial and commercial products.

mineral wool manufacturing, arithmetic mean exposure levels range from 0.01 to 0.35 f/cc (Tables VI and VIII). Median exposure levels by job description in these sectors are generally below 0.20 f/cc. In 11 of the 18 manufacturing job description categories, there are no measured TWA exposure levels above 1.0 f/cc.

All job categories in the glass wool and mineral wool installation sectors have arithmetic mean exposure levels below 0.50 f/cc, with median exposures at or below 0.20 f/cc (Tables VII and VIII). No TWA measurements above 1 f/cc have been recorded in the database for mineral wool installation, whereas both the feeder and installer categories for glass wool installation include TWA measurements above 1.0 f/cc.

Exposure Levels by Product Type and Job Description

Perhaps the greatest utility of the HSPP database will be to allow retrieval of representative exposure levels for specific product types *and* job descriptions. An example of such data is provided in Table IX, which shows exposure levels for specific product type/job function combinations such as blowing glass wool installation. This sector was chosen for presentation because of the relatively small number of product types and job functions involved. Other sectors involve many more potential product/job function combinations that make visual presentation difficult, but the database is constructed so that all available data for any specific product/job combination can be selected.

Table IX shows that there is a wide range of exposure potential for workers involved in the installation of blown-in glass wool insulation depending on product type and job description. The highest exposures are workers performing the installer job category for blowing wool without a binder, where the arithmetic mean exposure level is approximately 1 f/cc (0.99 f/cc). More intermediate exposures are found for the feeder job category for blowing wool without a binder (arithmetic mean = 0.44) and for the installer job category for blowing glass wool with a binder (arithmetic mean = 0.39 f/cc). The feeder of blowing wool with binder had an arithmetic mean exposure of only 0.09 f/cc.

TABLE VI
Glass wool manufacturing: Glass wool fiber exposures by job description

Job description	Sample size	Exposure (f/cc)			
		Mean	S.D.	Median	Range
Scrap baler/compactor	29	0.05	0.05	0.04	0.01–0.25
Batch/binder mixer	40	0.18	0.33	0.04	0.01–1.30
Cutting/hot press mold	109	0.04	0.12	0.01	0.01–0.88
Forming	289	0.11	0.23	0.02	0.01–2.30
General laborer/maintenance	62	0.11	0.33	0.02	0.01–2.29
Packaging	890	0.34	0.67	0.04	0.01–4.63
Quality control/research	75	0.18	0.23	0.09	0.01–1.20
Sewing/laminating/assembly	91	0.08	0.11	0.03	0.01–0.62
Shipping/receiving	53	0.01	0.01	0.01	0.01–0.06
Other[A]	10	0.11	0.20	0.05	0.01–0.66

[A]Includes administration and blowing wool chopper operator or nodulator.

TABLE VII
Glass wool installation and end-users: Glass wool fiber exposures by job description

Job description	Sample size	Exposure (f/cc)			
		Mean	S.D.	Median	Range
Assembly	34	0.04	0.06	0.02	0.01–0.35
Feeder	63	0.36	0.37	0.20	0.01–2.18
Installer	232	0.45	0.85	0.18	0.01–7.49
Other[A]	9	0.16	0.14	0.07	0.03–0.37

[A]Includes cutting/sawing with power tools and maintenance.

DISCUSSION

SVF Occupational Exposure Levels

The SVF exposure database provides the largest and most recent data set on record of occupational exposures to glass wool and mineral wool. The aggregate data indicate that overall exposure levels in both the manufacturing sector and end-use applications are generally below the voluntary 1 f/cc PEL. The results from the database are generally consistent with the previously published SVF occupational exposure data, but provide a much larger, more standardized, and more recent data set that permits a much more targeted and informative analysis of occupational exposures associated with specific SVF products and tasks.

One notable discrepancy between the current database and the older published data is the high average exposure levels reported in some studies published in the early 1980s for installation of SVF products. For example, while some of the older published studies reported average exposure levels for mineral wool installation over 1 f/cc,[16,20] the larger and more recent data set reported here show that arithmetic mean exposure levels in this sector are below 0.20 f/cc (Table VIII). It is not clear whether such changes reflect improvements in product design or work practices, or result from the shortcomings of the previously published data, which frequently involved small sample sizes, short sampling times, and nonstandardized analytical methodologies.

TABLE VIII
Mineral wool manufacturing and installation: Mineral wool fiber exposures by job description

Job description	Sample size	Exposure (f/cc)			
		Mean	S.D.	Median	Range
Manufacturing					
Supervisory	17	0.13	0.11	0.10	0.01–0.40
Forming	162	0.24	0.22	0.18	0.01–1.41
Maintenance	79	0.18	0.16	0.14	0.01–0.79
Packaging	62	0.25	0.20	0.23	0.01–1.00
Quality control	20	0.21	0.21	0.16	0.01–0.80
Shipping/receiving	55	0.14	0.14	0.08	0.01–0.57
Other manufacturing[A]	34	0.09	0.10	0.05	0.01–0.42
Installation					
Installers	65	0.16	0.17	0.10	0.02–0.82
Other installation[A]	9	0.09	0.12	0.05	0.02–0.40

[A]Includes assembly, cutting/sawing with power tools, vehicle driver production, warehousing, feeder, and general laborer.

At the aggregate level, the arithmetic mean exposure levels in the database for the manufacturing, fabrication (glass wool only), installation, and retrofit/removal sectors for both glass wool and mineral wool are all below 0.5 f/cc. The median exposure levels for the aggregate industry sectors are even lower, all at or below 0.16 f/cc. This difference between the median and arithmetic mean indicates that some outlier measurements are elevating the mean. Nevertheless, in every industry sector (with the exception of mineral wool retrofit/removal), there are some exposure samples above the 1 f/cc exposure limit, in some cases well above 1 f/cc. The aggregate data therefore indicate a pattern of low overall levels of exposure typically with occasional higher exposure incidents.

The nature of these occasional high exposure measurements is elucidated by further segmenting the exposure data by product type and/or job function. When the data are segmented by product type or job function within specific industry sectors (Tables II–VIII), a dichotomous pattern emerges. For most product types and job descriptions, exposures are very low, generally averaging below 0.25 f/cc, and in many cases never exceeding 1 f/cc. For some applications, however, average exposures are substantially higher, in some cases approaching 1 f/cc. Examples of such product types include separator and filtration media manufacturing (arithmetic mean = 0.80 f/cc) and installation of glass blowing wool without binder (arithmetic mean = 0.79 f/cc). The HSPP identifies these applications as potential high exposure applications for which respiratory protection is recommended.

When the data are segmented by job description, no job description in any industry sector had an arithmetic mean exposure level above 0.5 f/cc. The highest exposures are recorded for glass wool installation installers (arithmetic mean = 0.45 f/cc) and feeders (arithmetic mean = 0.36 f/cc). Many job categories, especially in the manufacturing sector, have arithmetic mean exposures below 0.2 f/cc, and in several cases below 0.1 f/cc.

Given that occupational SVF exposures vary by both product type and job description, the most useful exposure data are those for specific product type and job description combinations. Adequate data with this specificity are only possible with an exposure database of the magnitude envisioned by the HSPP. The example presented showing exposure levels for specific product/job combinations in the blowing glass wool installation sector confirms that exposure levels vary by both product type and job description, and that consideration of both variables is necessary to accurately discern tasks with exposure levels that may approach or exceed the voluntary 1 f/cc PEL.

TABLE IX
Glass wool installation: Glass wool fiber exposures by product type and job description

Product type	Job description	Sample size	Exposure (f/cc)			
			Mean	S.D.	Median	Range
Blowing wool with binder	Feeder	6	0.09	0.06	0.06	0.04–0.19
	Installer	13	0.39	0.32	0.28	0.09–1.13
Blowing wool without binder	Feeder	49	0.44	0.39	0.35	0.01–2.18
	Installer	84	0.99	1.21	0.62	0.04–7.49

Several factors suggest that actual occupational exposure levels to SVFs are even lower than reported above. First, exposure sampling is not random, but tends to be focused on the areas and job functions where significant exposures exist. Second, the exposure data generally do not include information on whether the exposed worker wore a respirator. It has been the industry practice for many years to recommend that workers wear NIOSH-approved half-mask respirators when engaged in work practices or handling product types that tend to have elevated exposures. The HSPP likewise recommends mandatory respirator usage for specific job functions where exposures may exceed 1 f/cc. Thus, to the extent that the workers wore such respirators during the exposure measurements in the database, actual exposure levels for those particular workers would be considerably lower than reported in the database.

Utility and the Future of the SVF Exposure Database

The SVF exposure database already contains sufficient data to provide accurate estimates of exposure for many product type/job function combinations in the SVF industry. When the exposure data are segmented by both product type and job function, as was presented for the blowing glass wool installation sector, precise exposure estimates are produced with relatively small standard deviations, especially for those product/job combinations with lower exposures. This finding confirms previous reports that SVF workers can be categorized by product type and job function into relatively homogenous exposure groups.[22] Thus, as envisioned by the HSPP, the SVF database will provide a useful resource for insulation contractors and other industry participants, especially small businesses, to predict expected exposure levels, and therefore to institute appropriate work practices and respiratory protection where warranted, without requiring burdensome exposure monitoring.

For some product/job combinations, the existing database is insufficient to estimate representative exposure levels. The additional exposure data collections called for by the HSPP will help to fill in these gaps over the next few years. In addition, NAIMA will seek to add additional exposure data from published and unpublished sources, including international data collections, when adequate information and quality assurance for such data are available. As the database expands, it will become an even more useful tool for monitoring overall and specific product/job exposures in the SVF industry.

Of particular significance will be the entry of respiratory protection information for newly collected samples, critical information that is lacking for most of the historical data. Manufacturers' recommendations and the HSPP both call for the use of a NIOSH-certified dust respirator (such as N-95 series or higher) for tasks that could involve exposures exceeding 1 f/cc, and compliance with these and the other work practices in the HSPP should result in even lower SVF exposures than are reported in the current database. The database may also provide a means for tracking changes in exposure levels over time, and will also provide useful information on which additional tasks should or should not include recommendations for respiratory protection.

In conclusion, with approximately 6000 recent TWA samples collected from a broad range of product types and job descriptions in both the manufacturing and end-use sectors, the NAIMA HSPP exposure database provides the most comprehensive and current assessment available of occupational exposures to glass wool and mineral wool. It will also provide a useful tool for small businesses and other interested parties to reliably estimate exposure levels for specific product/job combinations, and based on such data, to select appropriate work practices and, when necessary, additional protective measures.

The current database shows that most applications and uses of SVFs involve exposures below the voluntary 1 f/cc exposure limit, although some specific product types and job descriptions involve average exposures approaching the 1 f/cc limit. Additional data are needed to better characterize some of these exposure levels, which will be collected as part of the expansion of the SVF exposure database pursuant to the Health and Safety Partnership Program.

ACKNOWLEDGMENTS

The North American Insulation Manufacturers Association (NAIMA) supported the preparation of this article. The authors thank all the health and safety professionals from the NAIMA member companies who assisted with this project. Additional information and future updates on the HSPP will be available on the NAIMA Web site at http://www.naima.org.

REFERENCES

1. Carter, C.M.; Axten, C.W.; Byers, C.D.; et al.: Indoor Airborne Fiber Levels of MMVF in Residential and Commercial Buildings. Am Indus Hyg Assoc J 60:794–800 (1999).
2. Jacob, T.R.; Hadley, J.G.; Bender, J.R.; et al.: Airborne Glass Fiber Concentrations During Installation of Residential Insulation. Am Indus Hyg Assoc J 53:519–523 (1992).
3. Occupational Safety and Health Administration: OSHA Priority Planning Process: Announcement of the Results of the OSHA Priority Planning Process (Dec. 13, 1995).
4. North American Insulation Manufacturers Association: Letter to Adam Finkel, Director of Health Standards, Occupational Safety and Health Administration on Voluntary Health and Safety Partnership Program for Fiber Glass, Rock and Slag Wool Products from Kenneth D. Mentzer, Executive Vice President of NAIMA (May 18, 1999).
5. Maxim, L.D.; Allshouse, J.N.; Kelly, W.P.; et al.: A Multiyear Workplace-Monitoring Program for Refractory Ceramic Fibers: Findings and Conclusions. Regul Toxicol Pharmacol 26:156–171 (1997).
6. MRC Institute for Environment and Health: Fibrous Material in the Environment. Medical Research Council Institute for Environmental Health, Fibrous Material, Leicester, U.K. (1997).
7. Jeffress, C.N.: Letter to Kenneth Mentzer, Executive Vice President of NAIMA on Health and Safety Partnership Program from Charles N. Jeffress, Assistant Secretary of Labor for Occupational Safety and Health (May 18, 1999).
8. National Institute of Occupational Safety and Health: Health Hazard Evaluation Report (HETA 91-003-2232). Scoot Molders, Inc., Kent, OH (July 1992).
9. National Institute of Occupational Safety and Health: Health Hazard Evaluation Report (HETA 91-120-2286). U.S. Department of Veterans Affairs, Austin, TX (Feb. 1993).
10. Worksafe Australia: Australian Exposure Databank on Synthetic Mineral Fibres (Glasswool & Rockwool) in 1991–1992. Occupational Hygiene and Safety Engineering Unit, Worksafe Australia, Canberra, Australia (December 1994).
11. Johnson, D.; Healey, J.; Ayer, H.; et al.: Exposure to Fibers in the Manufacture of Fibrous Glass. Am Indus Hyg Assoc J 30:545–550 (1969).
12. Corn, M.; Sansone, E.B.: Determination of Total Suspended Particulate Matter and Airborne Fiber Concentrations at Three Fibrous Glass Manufacturing Facilities. Environ Res 8:37–52 (1974).
13. Dement, J.M.: Environmental Aspects of Fibrous Glass Production and Utilization. Environ Res 9:295–312 (1975).
14. Corn, M.; Hammad, Y.; Whittier, D.; et al.: Employee Exposure to Airborne Fiber and Total Particulate Matter in Two Mineral Wool Facilities. Environ Res 12:59–74 (1976).
15. Esmen, N.; Corn, M.; Hammad, Y.; et al.: Summary of Measurements of Employee Exposure to Airborne Dust and Fiber in Sixteen Facilities Producing Man-Made Mineral Fibers. Am Indus Hyg Assoc J 40:108–117 (1979).
16. Head, I.W.H.; Wagg, R.M.: A Survey of Occupational Exposure to Man-Made Mineral Fiber Dust. Ann Occup Hyg 23:235–258 (1980).
17. Cherrie, J.; Dodgson, J.; Groat, S.; et al.: Environmental Surveys in the European Man-Made Mineral Fiber Production Industry. Scand J Work Environ Health 12 (Supp 1):18–25 (1986).
18. Jacob, T.R.; Hadley, J.G.; Bender, J.R.; et al.: Airborne Glass Fiber Concentrations Involving Glass Wool Insulation. Am Indus Hyg Assoc J 54:320–326 (1993).
19. Fowler, D.P.; Balzer, J.L.; Clark, W.C.: Exposure of Insulation Workers to Airborne Fibrous Glass. Am Indus Hyg Assoc J 32: 86–91 (1971).
20. Esmen, N.A.; Sheehan, M.J.; Corn, M.; et al.: Exposure of Employees to Manmade Vitreous Fibers: Installation of Insulation Materials. Environ Res 28:386–398 (1982).
21. Perrault, G.; Dion, C.; Cloutier, Y.: Sampling and Analysis of Mineral Fibers on Construction Sites. Appl Occup Environ Hyg 7: 323–326 (1992).
22. Lees, P.S.J.; Breysse, P.N.; McArthur, B.R.; et al.: End User Exposures to Man-Made Vitreous Fibers: I. Installation of Residential Insulation Products. Appl Occup Environ Hyg 8:1022–1030 (1993).
23. Koenig, A.R.; Axten, C.W.: Exposures to Airborne Fiber and Free Crystalline Silica During Installation of Commercial and Industrial Mineral Wool Products. Am Indus Hyg Assoc J 56:1016–1022 (1995).
24. National Research Council: Review of the U.S. Navy's Exposure Standard for Manufactured Vitreous Fibers. National Academy Press, Washington, DC (2000).
25. Occupational Safety and Health Administration: Respiratory Protection Standard, 29 C.F.R. § 1910.134(d)(1)(iii) (1998).
26. Occupational Safety and Health Administration: Respiratory Protection, Final Rule. Federal Reg 63:1151–1300 (Jan. 8, 1998).
27. National Institute for Occupational Safety and Health: NIOSH Method 7400, Fibers, In: NIOSH Manual of Analytical Methods, 4th ed. 1987. NIOSH, Cincinnati, OH (1994).
28. Occupational Safety and Health Administration: Air Contaminants, Proposed Rule. Federal Reg 57:26002 (June 12, 1992).
29. World Health Organization: Reference Methods for Measuring Airborne Man-Made Mineral Fibers (MMMF), Environmental Health Report No. 4. WHO, Regional Office for Europe, Copenhagen, Denmark (1985).
30. National Institute for Occupational Safety and Health: NIOSH Criteria for a Recommended Standard: Occupational Exposure to Fibrous Glass, DHHS (NIOSH) Pub No. 77-152. NIOSH, Cincinnati, OH (1997).
31. National Institute for Occupational Safety and Health: Asbestos Fibers in Air. In: Manual of Analytical Methods. NIOSH, Cincinnati, OH (1977).
32. U.S. Environmental Protection Agency: Guidelines for Exposure Assessment. Federal Reg 57:22888–22938 (May 29, 1992).