



Project Summary

Characterization of Air Emissions from the Simulated Open Combustion of Fiberglass Materials

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The exposure of persons to fiberglass combustion emissions from structural fires, fires at waste landfills, and fires at demolition sites has become an issue of increasing concern. This study identifies and quantifies a broad range of pollutants that are discharged during the small-scale, simulated, open combustion of fiberglass and reports these emissions relative to the mass of fiberglass material combusted. Two types of fiberglass materials (representing the boating and building materials industries) were combusted in a controlled outbuilding designed for the simulation of open burning. Volatile, semivolatile, and particulate-bound organics were collected and analyzed by gas chromatography/mass spectrometry. The emphasis of these analyses was on the quantification of hazardous air pollutants listed in Title III of the Clean Air Act Amendments of 1990, although further efforts were made to identify and quantify other major organic components. Additional sampling and analysis were done for hydrogen chloride, particulate-phase metals, and respirable fibers. Fixed combustion gases (carbon dioxide, carbon monoxide, nitric oxide, oxygen, and total hydrocarbons) were monitored continuously throughout the test period. Analytical results show substantial emissions of a large number of pollutants including arsenic, benzene, benzo(a)pyrene, carbon monoxide, dibenzofuran, lead, naphthalene, particulate, phenanthrene, phenol, styrene, and toluene.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Concerns over exposure to air emissions from the open burning of fiberglass in structural fires, and at waste disposal and demolition sites have been expressed to EPA's Control Technology Center by government entities including the state of Alaska. Though little previous research has been done specifically on combustion emissions from fiberglass, literature does exist relating to the composition of fiberglass, the combustion products of some components of commercial fiberglass materials, and the suspected health effects of fiberglass fibers. Fiberglass is principally composed of SiO_2 (approximately 50% by weight); additional major components are Al_2O_3 , Ba_2O_3 , CaO , and MgO (typically 3 to 20% each); and trace components include F, Fe_2O_3 , K_2O , Na_2O , SO_3 , and TiO_2 (less than 1% by weight each). Additionally, fiberglass materials may contain organics as sizings or binders. Organics-containing fiberglass materials can be classified as either epoxy- or polyester-based. The known combustion products of polyester-based materials have been reviewed and are known to include acetaldehyde, benzene, biphenyl, carbon monoxide, ethyl benzene, pentadiene, styrene, and toluene. Much of the available



information on these combustion products has been obtained in small-scale studies of materials that are likely to be less complex than the commercial materials found in practice. Therefore, larger scale tests of complex commercial materials under simulated open combustion conditions promise increased insight.

In addition to potential hazards of a chemical nature, the air emissions from open fiberglass combustion may include fibrous aerosols; the physical nature of fibrous aerosols may lead to additional health hazards. Epidemiological studies have shown significant increases in non-malignant respiratory disease in populations exposed to glass fibers. Glass fibers are apparently less harmful to health than asbestos fibers. The greatest hazard appears to be related to fibers less than 1.5 μm in diameter and longer than 8 μm . No measurements of fiberglass fiber emissions from combustion processes have been found in literature reviewed to date. An assessment of the concentration and size distribution of fibrous aerosols produced from fiberglass open combustion processes would be valuable.

In response, with the guidance of EPA's Air and Energy Engineering Research Laboratory (AEERL), a study was undertaken to measure emissions from the combustion of fiberglass samples from two industries that use fiberglass extensively. This study included replicate tests of fiberglass materials from the boating industry (polyester-based, some with and some without a gel coating—a colored sealant), and the building industry (vinylester-based). The study was designed to collect, identify, and quantify a wide range of air emissions and to report these emissions per mass of fiberglass material combusted. The emphasis of these analyses was on the quantification of air toxics compounds listed in Title III of the Clean Air Act Amendments of 1990 (CAAA), although further efforts were made to identify and semiquantify other major organic components.

Methods

Combustion testing for this study occurred in EPA's Open Burning Simulation facility. This facility consists of a 2.7 by 3.4 m outbuilding equipped with a platform scale, air handles, and sampling equipment used for combustion studies. The boating industry fiberglass samples (a total of 8-10 kg per test) were placed in the facility and ignited using a brief application of a hand-held propane torch which was removed before sampling began. A "hut blank" test, in which the propane torch

was briefly introduced into the facility but no fiberglass was combusted, was conducted for comparison. In order to allow adequate time for all necessary samples to be obtained, three separate charges of fiberglass were combusted during each test. Combustion of one charge was allowed to go to apparent completion (as signified by constant weight and near background concentrations of combustion gases) before another charge was introduced. Attempts to test the building industry fiberglass sample in like manner were unsuccessful because of the high concentration of flame retardant in this sample. Therefore, the combustion of the building industry material (a total of 4 to 6 kg per test) was supported by a continuous liquid propane (LP) gas flame during sampling. This study design was intended to simulate the behavior of this flame-retarded fiberglass material in the presence of other non-flame-retarded combustibles. A "combustion blank" test, in which the LP flame was operated but no fiberglass was present, was conducted for comparison. In addition, various field and laboratory blank samples were collected for each sampling train. In order to allow adequate time for all necessary samples to be obtained, two separate charges of fiberglass were combusted during each test. Combustion of one charge was allowed to go to apparent completion, as was done for the boating industry samples, before another charge was introduced.

An elemental analysis of the fiberglass samples was performed before testing. Fixed combustion gases [carbon dioxide (CO_2), carbon monoxide (CO), nitric oxide (NO), oxygen (O_2), and total hydrocarbons (THC)] were monitored continuously throughout the test period through the sampling manifold. Temperatures at relevant locations in and around the test facility and the mass of fiberglass material were monitored throughout the test period.

Volatile organics were collected from the sample manifold on sorbent tubes (VOST train) and analyzed by gas chromatography/mass spectrometry (GC/MS). Since extremely high levels of volatile organic compounds were observed during early tests of the building industry fiberglass, an additional volatile sampling method was implemented. Samples were collected in Tedlar[®] bags and analyzed by GC/MS. Samples for semivolatile and particulate-bound organics and metal aerosol analysis were collected through separate medium volume PM_{10} samplers in the burn hut. The sample for metal aerosol was collected on a 142-mm-diameter quartz fiber filter and analyzed by inductively

coupled plasma-atomic emission spectrometry. The semivolatile and particulate-phase organic sample was collected with a 142-mm-diameter, Teflon[®]-impregnated, glass fiber filter and XAD-2[®] resin sorbent. The filter and resin were then extracted in methylene chloride, and the pooled extract was analyzed by GC/MS. A real-time photoelectric analyzer, designed to quantify total polycyclic aromatic hydrocarbons (PAHs) on submicron particulate, was also operated using a sample stream withdrawn through the sampling manifold. A sample probe for vapor-phase hydrogen chloride was also located in the burn hut. These samples were analyzed by ion chromatography.

The sampling train used to sample for fiber size and morphology analysis consisted of a 37-mm mixed cellulose ester filter cassette followed by a low volume sampling pump and dry gas meter. The filter was operated in an inverted position, parallel to the facility floor during sampling to minimize the collection of particulate matter through gravitational settling. Analysis was performed by phase contrast light microscopy (PCM) and transmission electron microscopy (TEM). For these analyses, a fiber was defined as a particle with an aspect ratio of greater than 3:1. These sampling and analysis methodologies were based on NIOSH methods for asbestos fibers.

After the completion of the chemical and microscopic analyses, analyte concentration data were coupled with sample volume, facility air flow, and combustible material mass loss data to derive estimated emissions (expressed as mass of analyte produced per mass of fiberglass material consumed in the combustion process).

Results and Discussion

The elemental analysis of the fiberglass materials before combustion (Table 1) indicates that the organic matter content of the boating industry fiberglass is higher than that of building industry material. The substantial halogen concentration found in the building industry material tends to confirm the manufacturer's statement that the material contained a brominated fire retardant. The vast majority of the combustion of each charge of boating industry material was completed in a 20-40 minute period, while the majority of the building industry material in each charge appeared to be consumed in 30-60 minutes. Table 2 summarizes the estimated emissions derived from real-time measurements of CO , CO_2 , THC, and total PAH bound to submicron particulate. The substantial CO

emissions observed, which are probably underestimated in this data set, are a concern since CO is believed to be the most important cause of death of fire victims. Substantial emissions of particulate matter were also observed (average values were 117 g/kg for the boating industry material and 607 g/kg for the building industry material). This is a concern since most previous studies of combustion products of various polymers have paid little attention to the composition of the particulate phase.

The volatile organic data set includes concentration measurements for 35 targeted (the majority of which are consistently non-detectable) and several dozen tentatively identified species; Table 3 presents average data on several selected compounds that were among those seen in the highest levels.

It appears that the relative ratios of these components are similar for both the boating and building industry materials but that the absolute emission rate is higher for the building industry material.

The semivolatile and particulate bound organics data set generated from this project includes concentration measurements for more than 90 targeted compounds (the majority of which were consistently non-detectable) and several dozen tentatively identified species. Average emission values for a selected set of detected, targeted semivolatile, and particulate bound organics are presented in Table 4. Average estimated emissions for these compounds are generally lower than for the volatile species discussed previously. As in previous measurements, the values obtained in the building industry fiberglass tests are generally higher than those in the boating industry tests. Preliminary calculations have shown that the estimated emissions calculated from the output of the real-time PAH analyzer (Table 2) agree at least within a factor of 10 with the sum of estimated emissions calculated from the Method 8270 analyses of PAHs that would be expected to be predominantly in the particulate phase.

Fibrous aerosols samples rarely showed significantly more fibers than were seen in blank samples, as shown in Table 5. However, detection limits were quite high for this analysis, since the maximum feasible loading of total particulate on these filters was reached after a very small volume (<20 L) was sampled, and it is feasible to conduct the microscopic examination only on a small representative portion of the filter surface area.

The particulate-phase metals samples were analyzed for 11 elements. Of these,

Table 1. Composition of Fiberglass Materials Tested (All Data as Percent Composition)

	Boating Industry Fiberglass - Without Gel Coat	Boating Industry Fiberglass - With Gel Coat	Building Industry Fiberglass
Carbon	52.97	55.06	25.33
Hydrogen	4.79	5.27	2.48
Oxygen	7.1	<0.5	10.06
Nitrogen	0.017	0.015	<0.5
Sulfur	<0.03	<0.03	<0.5
Total Halogen (as Cl)	<0.5	<0.5	1.9
Aluminum	0.28	0.081	2.2
Magnesium	<0.05	<0.05	0.12
Cadmium	<0.004	<0.004	<0.01
Chromium	0.0091	0.041	0.086
Moisture	2.06	1.19	0.52
Volatile Matter	63.11	56.24	35.29
Ash	34.83	39.57	60.23
Fixed Carbon	<0.1	3	3.96

Table 2. Combustion Gas and PAH Particulate Analyzer Concentrations and Estimated Emissions

Date	Test	CO as C Estimated Emissions (g/kg)	CO ₂ as C Estimated Emissions (g/kg)	THC as Methane Estimated Emissions (g/kg)	PAH Estimated Emissions (g/kg)
09/08/92	First Boating Industry Test	48.2*	980.8*	41.6*	1.48
09/17/92	Second Boating Industry Test	55.2*	953.4	40.5	0.85
10/13/92	First Building Industry Test	205.9*	NC	270.3*	0.97
10/30/92	Second Building Industry Test	141.4*	NC	202.3*	0.58
11/04/92	Third Building Industry Test	163.3*	NC	232.2*	0.59

Key: NC = Not calculated (estimated emissions were not calculated for CO₂ in the building industry test since the LP burner contributed a sizeable and somewhat variable percentage of the emissions).
* = Where some measured concentrations exceeded the concentration of the high calibration point before calculating the averages, the data were truncated to the high calibration point.

Table 3. Estimated Emissions of Selected Volatiles

Compound	Boating Industry VOST Samples, Average Estimated Emissions (g/kg)	Building Industry Tedlar® Bag Samples, Average Estimated Emissions (g/kg)
Benzene	5.9	34.8
Ethyl Benzene	0.7	9.3
Styrene	4.5	49.4
Toluene	3.6	18.0
m-p-Xylene	0.5	1.1

only lead, silver, and possibly cadmium were detected in the boating industry emissions and only arsenic and possibly chromium were detected in the building industry emissions. These results are summarized in Table 6.

Vapor-phase hydrochloric acid was not detected in any of the samples analyzed. Detection limits varied from 40 to 260 mg/

kg. No other acid gases were analyzed for.

Because of operational difficulties (i.e., sampling media overloading), the sampling periods for various trains varied widely. Thus, it is not possible to compute an accurate mass balance on this system since the rates of emission of various pollutants probably vary during various

Table 4. Estimated Emissions of Selected Semivolatiles

Compound	Boating Industry Average (mg/kg)	Building Industry Average (mg/kg)
Anthracene	353	202
Benzo(a)pyrene	86	72
Biphenyl	689	1,936
Chrysene	323	458
2-Methyl Phenol	125	400
Phenanthrene	902	2,156
Phenol	328	6,830

Table 5. Fibrous Aerosol Measurements

Sample No.	Test Date	Test	PCM Length >5 μ m Estimated Emissions (million S/kg)	ATEM Length >0.5 μ m Estimated Emissions (million S/kg)	ATEM Length >5 μ m Estimated Emissions (million S/kg)
7	09/17/92	Second Boating Industry	1710	490*#	420*#
8	09/17/92	Second Boating Industry	4846*	1902*#	1902*#
11	09/17/92	Second Boating Industry	504*	NFD*#	NFD*#
16	10/13/92	First Building Industry	1904*	395*	395*
17	10/13/92	First Building Industry	432*	89*#	89*#
19	10/30/92	Second Building Industry	231*#	120*#	120*#

Key: NFD = No fibers detected, detection limit cannot be stated accurately due to loading problems.
 PCM = Phase contrast microscopy.
 ATEM = Analytical transmission electron microscopy.
 * = Number of observed fibers not greater than 3 times larger than the applicable field and hut blank values.
 # = Air concentration of observed fibers not more than 3 times larger than the applicable hut or combustion blank value.
 S = Fibrous structures.

Table 6. Metals Estimated Emissions (mg/kg)

Test	Silver	Arsenic	Cadmium	Chromium	Lead
First Boating Industry	4.41	<0.52*#	0.06*#	1.57*#	21.00
Second Boating Industry	4.60	<0.6*#	0.29	0.48*#	38.72
Boating Industry Average	4.50	0.56	0.18	1.03	29.86
First Building Industry	13.38*	6.13*	<0.28*#	8.92	<2.79*#
Second Building Industry	14.45*	48.15	<0.80*	14.45*	<8.03*
Third Building Industry	6.76*#	13.05	<0.24*#	5.80*#	<2.42*#
Building Industry Average	11.53	22.44	0.44	9.72	4.41

Key: * = Mass of this sample not greater than 3 times the largest of the following: mass in field blank, mass in hut blank, or mass in combustion blank, as applicable.
 # = Sample hut air concentration not greater than 3 times the hut blank air concentration or the combustion blank air concentration, as applicable.

phases of the combustion process. In addition, since the rate of emissions from a small mass of combusted fiberglass was high enough to threaten overloading of the sampling media, it was necessary to sharply limit the amount of fiberglass combusted in each test phase. This may introduce a significant source of error into the data set because the resolution of the balance used to measure the weight of fiberglass lost to combustion was 0.09 kg (0.2 lb); (the average weight losses for the samples were as follows: organic semivolatile/particulate train 1.4 kg (3.0 lb), metals train 1.7 kg (3.8 lb), VOST train 0.4 kg (0.9 lb), Tedlar® bag train 0.91 kg (2.0 lb), CEM train 3.8 kg (8.3 lb), fiber train 0.45 kg (1 lb), and hydrochloric acid train 3.3 kg (7.2 lb)).

Conclusion

Despite the aforementioned experimental difficulties, this project did succeed in producing estimated emissions data for a broad range of atmospheric pollutants from simulated open fiberglass combustion. Substantial emissions of a large number of pollutants were observed, including arsenic, benzene, benzo(a)pyrene, carbon monoxide, dibenzofuran, lead, naphthalene, particulate, phenanthrene, phenol, styrene, and toluene.

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Paul M. Lemieux is the EPA Project Officer (see below).

The complete report, entitled "Characterization of Air Emissions from the Simulated Open Combustion of Fiberglass Materials," (Order No. PB94-136231; Cost: \$19.50; subject to change) will be available only from

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