

Brominated Flame Retardant End-User Survey – Phase 1**Final Report****Submitted To:**

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Brominated Flame Retardant Industry Panel
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Abstract

The first phase of a comprehensive assessment of occupational exposures to selected brominated flame retardants (BFRs) has been completed. The BFRs included in this assessment are decabromodiphenyl oxide (DBDPO), octabromodiphenyl oxide (OBDPO), pentabromo-diphenyl oxide (PeBDPO), hexabromocyclododecane (HBCD), and tetrabromobisphenol A (TBBPA). Phase I consisted of an evaluation of the extent to which existing data can be used to accurately characterize end-user exposures. An exposure questionnaire was designed and mailed to 276 customers of BFRIP member companies. A short one-page questionnaire was developed to be used, with follow-up phone calls of customers who did not respond to the mailed questionnaire. Eighteen customers that reported having exposure data were contacted and asked to share the data. Of these companies exposure data were received from nine.

Most companies do not routinely collect exposure data directly relevant to this study. Total dust samples are the most common type of exposure data collected. The mean and geometric mean dust concentration based on 52 personal samples provided by seven companies are 1.67 and 0.63 mg/m³, respectively. Interpretation of these results is limited, however, due to the lack of information on sample duration and purpose of sampling. Based on a limited amount of data provided primarily by a single company, antimony exposures may exceed the exposure standards and guidelines with mean and geometric means equal to 0.86 and 0.07 mg/m³ based on 41 samples, respectively. Three companies reported hydrogen bromide concentration; all were non-detectable.

No direct airborne BFR exposures were reported. One company provided information termed "% brominated product." These data were subsequently used to estimate airborne BFR levels in the absence of definitive data on the compounds of interest. The estimates indicate most (85%) airborne exposures are less than 1 mg/m³ and range from less than 0.001 mg/m³ to greater than 50 mg/m³.

The results of this survey indicate that the exposure data provided by end-users are of limited utility for risk-assessment purposes and suggest that a more detailed end-user exposure assessment is needed.

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I. Introduction

The purpose of this project is to evaluate occupational exposures to selected brominated flame retardants (BFRs) for the various industries that incorporate these substances into a polymer matrix (end-users). The BFRs included in this study are decabromodiphenyl oxide (DBDPO), octabromodiphenyl oxide (OBDPO), pentabromodiphenyl oxide (PeBDPO), hexabromocyclododecane (HBCD), and tetrabromobisphenol A (TBBPA). This research was supported by the Brominated Flame Retardant Industry Panel (BFRIP) of the Chemical Manufacturers Association.

Exposures to the five selected BFRs are being evaluated in a phased approach. Phase I consisted of an evaluation of the extent to which existing data can be used to accurately characterize end-user exposures. Subsequent phases may encompass a variety of activities including developing sampling and analytical methods, conducting a detailed exposure assessment, evaluating exposure surrogates, and developing biomarkers of BFR exposure. This report summarizes the results of the Phase I survey of existing end-user BFR exposure data. This survey was conducted from October 1999 to April 2000.

II. Background

Flame retardant chemicals are used in a wide range of commercial product applications including construction materials such as paints and adhesives, as well as plastics, textiles, fabrics, and other home furnishings.⁽¹⁾ In particular, BFRs are suitable for use in high performance thermoplastic resins used in electrical and high temperature applications.⁽²⁾ There is limited BFR exposure information in the published literature, particularly for end-users.⁽³⁾ One recent study reported quantitative exposure estimates of polybrominated diphenyl ethers in an electronics dismantling plant ranging from 0.08 to 200 ng/m³.⁽⁴⁾

Currently, the only occupational exposure standards or guidelines for BFRs other than DBDPO is the total nuisance dust Permissible Exposure Limit (PEL) set by the U.S. Occupational Safety and Health Administration (OSHA) at 15 mg/m³ and the Threshold Limit Value (TLV) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) at 10 mg/m³. The American Industrial Hygiene Association (AIHA) Worker Environmental Exposure Level (WEEL) for DBDPO is 5 mg/m³.⁽⁵⁾ A few exposure standards might indirectly affect people using BFRs such as the hydrogen bromide (HBr) and antimony standards. Hydrogen bromide gas is a byproduct of the combustion of BFRs, and some companies that use heat to process BFRs will test for HBr to ensure that their systems are not causing HBr off-gassing. The OSHA PEL for hydrogen bromide is 10 mg/m³, and the ACGIH Ceiling is 9.9 mg/m³. When added to polymers along with BFRs, antimony trioxide induces synergistic effects on flame retardancy. Companies using antimony trioxide may have dust samples analyzed for antimony content. The OSHA PEL and ACGIH TLV for antimony are both equal to 0.5 mg/m³.

III. Methods

Phase 1 included the following steps:

- A preliminary list of end-user companies, their addresses, and points of contact was obtained from BFR manufacturing companies;
- A detailed exposure questionnaire (referred to as the long questionnaire) was developed and mailed to end-user companies in order to catalogue the extent to which exposure data are available (Appendix A);

- Companies that did not respond to the long questionnaire were called and administered a short questionnaire over the telephone (Appendix B);
- Companies that reported having exposure data were asked to share the data in order to develop an exposure information profile for the industry; and
- The exposure data were statistically summarized.

The long questionnaire that was mailed to all potential BFR end-users had five parts: 1) company identification; 2) company description, including the types of BFRs used and the manner in which they are handled; 3) workforce demographics; 4) personal protective equipment used while working with BFRs; and 5) exposure information including the amount and types of dust samples taken and whether they were analyzed for BFR content or for BFR additives (e.g., antimony trioxide). This questionnaire was mailed with a cover letter from BFRIP explaining the purpose of the study and encouraging companies to participate in the survey. To facilitate return, a return-address envelope was included in each mailing. Standard follow-up procedures, e.g., phone call reminders, emails, and faxes, were used to achieve as high a response rate as possible in the time allotted.

Due to time constraints and concern about the amount of effort needed to complete the long questionnaire, a short questionnaire that could be administered over the telephone during follow-up calls was developed. The short questionnaire asked what types of BFRs were used and how they were used; what products were being made with the BFRs, whether exposure samples were taken and, if so, how many; and whether the company would be willing to share the exposure data with us. The long questionnaire did not ask for the exposure data, but any company that reported having exposure data was contacted and asked if they would be willing to send the data. Appendix C contains a flow chart of the methods used to survey end-user companies.

Lists of companies in North America who purchase BFRs were provided by three BFR manufacturers: Great Lakes Chemical Corporation, Albemarle Corporation, and Ameribrom, Inc. The three lists were compiled, and companies with duplicate addresses were removed. Detailed questionnaires were mailed to all of the contact addresses, of which fifteen were Canadian, one was Mexican and the rest had U.S. addresses. Over the course of the survey a few companies were uncontactable due to incorrect addresses; they were removed from the database (note that correct addresses were sought through internet and phonebook searches) giving a final end-user database that included 276 companies. The final list of companies has been kept confidential and has not been shared with any BFRIP member companies.

IV. Results

Table 1 summarizes the results of survey response information. Twenty-seven and 68 companies responded to the long and short questionnaires, respectively. Of these 95 companies (34% response rate), 18 reported having exposure data and nine provided exposure data for analysis. Twenty-nine of the responding companies did not provide information either because they did not have any exposure data, or for various other reasons including confidentiality issues, not using BFRs, and not enough time or staff available to complete the questionnaires. Many company addresses in the original database did not include a phone number. Attempts were made to locate telephone numbers using phone directory and internet searches. All companies for which a phone number or email address was available were contacted at least once and, in some cases, several times. Of the remaining companies 140 were contacted at least once (many were contacted multiple times) and 41 companies could not be reached.

Nine companies supplied exposure data including total dust, antimony trioxide, hydrogen bromide, and (in one case) "brominated product." A summary of company characteristics for these nine companies is presented in Table 2. Detailed company characteristics are available only for those companies that completed the long questionnaire.

Airborne total dust samples represent the most common exposure data collected, with seven of the nine companies reporting results. Table 3 summarizes total dust samples by company number and whether they were personal or area samples. These results are presented without regard to sample time. Detailed information on each sample is contained in Appendix D, which indicates that the sample times are highly variable. Some of the results were based on full-shift samples, some were for a relatively short duration, and some results were provided with no sample time information. A number of the results provided without sample times were referred to as "TWA" samples without any other descriptor. Table 3 contains the results of 16 and 52 area and personal total dust samples, respectively. The personal total dust samples averaged 1.67 mg/m^3 and ranged from less than 0.12 to 15.4 mg/m^3 . The area total dust samples averaged 1.81 mg/m^3 and ranged from less than 0.18 to 4.09 mg/m^3 . The highest personal exposure estimate, 15.4 mg/m^3 , was collected by Company 4 without reference to sample time. The next highest sample, 8.9 mg/m^3 , was collected on an operator at a hopper feed tank and is described by Company 6 as having been collected over a short (unspecified) sampling time. Table 4 summarizes total dust sampling results by BFR type. Most of the air sampling was conducted during DBDPO handling.

Antimony sample results are summarized in Table 5, with 42 samples from four companies (one area, the rest personal) presented. Personal exposures to antimony ranged from 0.003 to 22 mg/m^3 . Company 8 reported the results of 34 personal samples, averaging 0.97 mg/m^3 . No descriptive information was presented with any of the samples reported by Company 8. Company 8 sample results, which dominate the results presented in Table 4 (see Appendix D), were reported in terms of antimony concentration along with the percent antimony in each sample. The percent antimony in these samples was highly variable and ranged from 1 to 37%.

Three companies submitted hydrogen bromide exposure data. These companies were using heat in one or more processes and were concerned about possible thermal degradation of BFRs. None of the 20 sample results submitted were above the detection limits (<0.002 to $<0.2 \text{ ppm}$).

One company submitted 34 dust samples that had been analyzed for "brominated product" without reference to an analytical method. These results were expressed in terms of percent "brominated product" along with antimony concentration data (see discussion above for antimony results for Company 8). The percentages of "brominated product" in these 34 air samples ranged from 0 to 37.7%. By using the ratio of "% brominated compound" to the % antimony, the concentration of "brominated product" was estimated from the antimony concentration data (see Appendix D). Using this approach, the "brominated compound" concentrations for these 34 samples were highly variable and ranged from $0.7 \text{ } \mu\text{g/m}^3$ to 79.2 mg/m^3 . It was not possible to compute descriptive statistics for these 34 samples, because no information on the limit of detection was given for samples with no (0 %) brominated compound detected. Roughly one-third of these 34 samples had non-detectable brominated compound and 29 of the 34 results (85%) suggest BFR exposures were less than 1 mg/m^3 . Another important limitation of these data is the fact that no descriptive information was provided along with these results. We have no knowledge, for example, of the sample time.

V. Conclusions

The following can be concluded from this survey of BFR end-user companies:

- Most companies do not routinely collect exposure data directly relevant to BFR use.
- Total dust samples are the most common type of exposure data collected. Based on the limited total dust exposure data provided by seven companies, it can be preliminarily concluded that total dust exposures were typically well below the OSHA PEL and the ACGIH TLV, with a mean and geometric mean of 52 personal samples equal to 1.67 and 0.63 mg/m³, respectively. Interpretation of these results is limited, however, due to the lack of information on sample duration.
- Based on a limited amount of data provided primarily by a single company, the antimony exposures during BFR use can exceed the PEL and the TLV, with mean and geometric means equal to 0.86 and 0.07 mg/m³, respectively.
- Three companies reported hydrogen bromide exposures that were less than the limit of detection.
- No direct airborne BFR exposures were reported. One company provided information termed "% brominated product." This data was subsequently used to estimate airborne BFR levels in the absence of definitive data on the compounds of interest. The estimates indicate most (85%) airborne exposures are less than 1 mg/m³ and range from less than 0.001 mg/m³ to greater than 50 mg/m³.
- These results, by themselves, are of limited utility for risk-assessment purposes and suggest that a more detailed end-user exposure assessment is needed.

VI. References

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3. International Agency for Research on Cancer: *IARC Monograph - Some Flame Retardants and Textile Chemicals, and Exposures in the Textile Manufacturing Industry*, 48:73-85 (1990).
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Total number of end-user companies in database	276
Number of long questionnaires mailed	276
Number of companies responding to long questionnaire	27
Number of companies responding to short questionnaire	68
Total number of companies responding to either long and short questionnaire	95
Number of contacts with exposure data (reported on long or short questionnaire)	18
Number of contacts who have sent exposure data	9
Total number companies that have not responded or been contacted	181
Number of follow - up calls for 181 contacts that have not responded	140

Company Number	Location	Products	Processes	Number of Production Employees	Years in Business	Years using BFRs
1	Midwest	Compounded Engineering Products	Dry blending and extrusion	70	40	17
2	MidAtlantic	Fiberglass reinforced plastics	Pultrusion, batch mixing	300	70	30
3	Southwest	Polyester and vinyl ester resins	Reacting and blending	21	26	20
4	Southwest	Polypropylene resin compounding	Dry blending and extrusion	Not given	Not given	Not given
5	Southeast	Compounding	Dry blending and extrusion	200	10	5
6	Midwest	Plastics	Dry blending and extrusion	Not given	Not given	Not given
7	Southeast	Water-based dispersions	Wet blending	6	12	12
8	Midwest	Thermoplastic compounding	Dry blending	96	40	15
9	Northeast	Wire cable jacketing	Dry blending and extrusion	Not given	Not given	Not given

Table 1: Summary of Sample Results from BFR and User Companies without LOD or Sample Time

Company Number	Type of Sample ¹	N ²	Range (mg/m ³)	Mean (mg/m ³)	Std. Dev. ³ (mg/m ³)	GM ⁴ (mg/m ³)	GSD ⁵
1	A	5	<0.18 - <1.5	N/A**	N/A	N/A	N/A
1	P	9	<0.12 - 1.00	0.39	0.29	0.30	2.26
2	P	3	1.20 - 1.70	1.43	0.25	1.42	1.19
3	P	11	<0.13 - 1.77	0.66	0.61	0.42	2.81
4	P	14	0.18 - 15.40	3.09	4.98	1.04	4.35
5	A	1	4.09	N/A	N/A	N/A	N/A
5	P	10	<0.32 - 7.60	1.43	2.24	0.74	2.98
6	A	6	<5.0 - <5.0	N/A	N/A	N/A	N/A
6	P	1	8.90	N/A	N/A	N/A	N/A
7	A	4	0.03 - 0.46	0.30	0.19	0.21	3.63
7	P	4	0.08 - 4.80	1.30	2.33	0.31	6.46
Overall	A	16	<0.18 - 4.09	1.81	1.64	0.86	4.59
Overall	P	52	<0.12 - 15.4	1.67	3.12	0.63	3.69

¹ A= area sample, P= personal sample,

² N = number of samples,

³ Std. Dev. = standard deviation,

⁴ GM= geometric mean,

⁵ GSD = geometric standard deviation, N/A = not applicable

Note: For samples reported as less than the limit of detection (LOD), the LOD/√2 was substituted for all statistical calculations.

Table 2: Summary of Sample Results from BFR

Type of BFR ¹	Type of Sample ²	N ³	Range (mg/m ³)	Mean (mg/m ³)	Std. Dev. ⁴ (mg/m ³)	GM ⁵ (mg/m ³)	GSD ⁶
DBDPO	A	9	<0.18 - 0.46	0.43	0.38	0.29	2.99
DBDPO	P	30	<0.12 - 15.4	1.88	3.63	0.63	4.03
HBCD	A	6	<5.0 - <5.0	N/A	N/A	N/A	N/A
HBCD	P	1	8.9	N/A	N/A	N/A	N/A
TBBPA	P	11	<0.13 - 1.77	0.66	0.61	0.42	2.81
Unspecified	A	1	4.09	N/A	N/A	N/A	N/A
Unspecified	P	10	<0.32 - 7.6	1.43	2.24	0.74	2.98

¹ DBDPO = decabromodiphenyl oxide, HBCD = hexabromocyclododecane, TBBPA = tetrabromobisphenol A,

² A= area sample, P= personal sample,

³ N = number of samples,

⁴ Std. Dev. = standard deviation,

⁵ GM= geometric mean,

⁶ GSD = geometric standard deviation, N/A = not applicable

Note: For samples reported as less than the limit of detection (LOD), the LOD/√2 was substituted for all statistical calculations.

Company Number	Type of Sample ¹	N ²	Range (mg/m ³)	Mean (mg/m ³)	Std. Dev. ³ (mg/m ³)	GM ⁴ (mg/m ³)	GSD ⁵
2	P	3	0.052 - 0.100	0.07	0.03	0.07	1.4
4	P	3	0.58 - 0.99	0.73	0.22	0.71	1.33
8	P	34	0.003 - 22.0	0.97	3.82	0.06	9.59
9	A	1	<0.011	N/A	N/A	N/A	N/A
9	P	1	<0.011	N/A	N/A	N/A	N/A
Overall	A	1	<0.011	N/A	N/A	N/A	N/A
Overall	P	41	0.003 - 22.0	0.86	3.48	0.07	8.88

¹ A= area sample, P= personal sample,

² N = number of samples,

³ Std. Dev. = standard deviation,

⁴ GM= geometric mean,

⁵ GSD = geometric standard deviation, N/A = not applicable

E II

**Appendix A
Long Questionnaire**

**Brominated Flame Retardant
End-User Exposure Questionnaire**

**Johns Hopkins University
School of Hygiene and Public Health
615 N. Wolfe Street
Room W6010
Baltimore, MD 21205**

For More Information Contact:

**Patrick N. Breyse, PhD, CIH
Johns Hopkins University**

**pbreyse@jhsph.edu
410-955-3608**

or

**Wendy Sherman
Chemical Manufacturers Association
Brominated Flame Retardant Industrial Panel
Wendy_Sherman@cmhaq.com
703-741-5639**

Company: _____
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Johns Hopkins University
Flame Retardant Questionnaire

A. COMPANY IDENTIFICATION

Company Name: _____

Division: _____

Address: _____

City, State, Zip or Postal Code: _____

Person Completing Questionnaire:

Name: _____

Title: _____

Address (if different from above): _____

Phone: _____ Fax: _____

Please provide the name and phone number of a person at your facility who is responsible for or familiar with industrial hygiene and safety in your company. This person will be contacted if additional information is required.

Name: _____

Title: _____

Phone: _____ Fax: _____

Company _____
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Johns Hopkins University
Flame Retardant Questionnaire

B. COMPANY DESCRIPTION

Please describe the production process(es) and products manufactured at your plant that involve the use of brominated flame retardants (include attachment if necessary):

Is work conducted: (check all that apply) Indoors _____ Outdoors _____ Underground _____

Individual brominated flame retardants (BFR) that might be found at your plant: (check all that apply)

_____ Decabromodiphenyl oxide (DBDPO) -or- Saytex 102E, Saytex 102, DE-83, DE-83R, FR-1210

_____ Octabromodiphenyl oxide (OBDPO) -or- DE-79

_____ Hexabromocyclododecane (HBCD) -or- Saytex HBCD LM, Saytex HBCD HM, Saytex HBCD SF, CD 75, SP 75, SP 75C, FR-1206

_____ Tetrabromobisphenol A (TBBPA or TBBA) -or- Saytex RB100, BA-59P, FR-1524

_____ Pentabromodiphenyl oxide (PeBDPO) -or- DE-71, DE-60 F

Others:(please list) _____

How many years has your facility been operating _____, and how many years has it been using brominated flame retardants _____?

Please describe specifically how flame retardants are used and handled in your facility (include an attachment if needed):

Company: _____
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C. WORKFORCE DEMOGRAPHICS

How many production workers are currently employed in your plant? _____

How many non-production workers are currently employed in your plant? _____

*What is the age range of your workforce (i.e. youngest to oldest)? _____

*How many of your current workers have been employed at your facility for

less than 5 years? _____

5 - 10 years? _____

10 - 15 years? _____

more than 15 years? _____

*Of the total number of workers, roughly how many worked with flame retardant operations directly in the years

1990 - present? _____

1980 - 1989? _____

1970 - 1979? _____

D. PERSONAL PROTECTIVE EQUIPMENT USED WHILE WORKING WITH

Please check all that apply:

Processes Involving BFRs	Gloves	Dust Respirator	Supplied Air Respirator	Protective Clothing
Bulk Transport				
Milling/Grinding				
Mixing				
Maintenance Activities				

Company: _____
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Johns Hopkins University
Flame Retardant Questionnaire

E. EXPOSURE INFORMATION (This information applies to general dust sampling.)

Date	Sampling Method (check all methods used at your facility)	How often is sampling conducted for most of the workers who are monitored? (circle one)	How many total samples have you collected?	
			Avg/yr	Total/period
1990 to pres.	Personal air samples _____	Daily Weekly Monthly Annually Other	_____	_____
	Total dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Respirable dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Inhalable dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Area air samples _____	Daily Weekly Monthly Annually Other	_____	_____
	Total dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Respirable dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Inhalable dust _____	Daily Weekly Monthly Annually Other	_____	_____
Other (please describe): _____	Daily Weekly Monthly Annually Other	_____	_____	
1980 to 1989	Personal air samples _____	Daily Weekly Monthly Annually Other	_____	_____
	Total dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Respirable dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Inhalable dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Area air samples _____	Daily Weekly Monthly Annually Other	_____	_____
	Total dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Respirable dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Inhalable dust _____	Daily Weekly Monthly Annually Other	_____	_____
Other (please describe): _____	Daily Weekly Monthly Annually Other	_____	_____	
1970 to 1979	Personal air samples _____	Daily Weekly Monthly Annually Other	_____	_____
	Total dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Respirable dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Inhalable dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Area air samples _____	Daily Weekly Monthly Annually Other	_____	_____
	Total dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Respirable dust _____	Daily Weekly Monthly Annually Other	_____	_____
	Inhalable dust _____	Daily Weekly Monthly Annually Other	_____	_____
Other (please describe): _____	Daily Weekly Monthly Annually Other	_____	_____	

Company: _____
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Johns Hopkins University
Flame Retardant Questionnaire

Have you ever analyzed your dust samples for BFR content? Yes _____ No _____

If yes, what method was used: _____

How many samples were analyzed for BFR content:

From 1990-present? _____ Avg Annual Total? _____ Total for entire period? _____

From 1980-1989? _____ Avg Annual Total? _____ Total for entire period? _____

From 1970-1979? _____ Avg Annual Total? _____ Total for entire period? _____

Have you ever sampled and analyzed for antimony trioxide? Yes _____ No _____

If yes, when was the sampling done and how many samples were collected:

From 1990-present? Yes _____ No _____ Avg Annual Total? _____ Total for entire period? _____

From 1980-1989? Yes _____ No _____ Avg Annual Total? _____ Total for entire period? _____

From 1970-1979? Yes _____ No _____ Avg Annual Total? _____ Total for entire period? _____

Have you sampled for BFR additives other than antimony trioxide? Yes _____ No _____

If yes, please list these additives: _____

Have you collected any BFR surface contamination samples? Yes _____ No _____

If yes, please describe: _____

Have you determined size distribution of airborne dust? Yes _____ No _____

If yes, please describe your methods: _____

Please describe the format of most of your exposure data: (check one)

Paper records stored on site: _____

Paper records stored elsewhere: _____

Mainframe data sets: _____

PC-based data sets: _____

MAC-based data sets: _____

Other: (please describe) _____

Comments: _____

Company: _____
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Johns Hopkins University
Flame Retardant Questionnaire

Please list any other substances that are routinely monitored in your facility (for example, asbestos, silica, acid fumes, and organic compounds) and describe the sampling and analytical methods used for these substances:

F-05

**Appendix B
Short Questionnaire**

Brominated Flame Retardant End-Use Exposure Questionnaire

Date: _____

Company Name: _____

Address: _____

City, State, Zip or Postal Code: _____

Name & Title of person completing questionnaire: _____

Phone: _____

Fax: _____

1. What types of BFRs are used at your plant?

- Decabromodiphenyl oxide (DBDPO) -or- Saytex 102E, Saytex 102, DE-83, DE-83R, FR-1210,
 Octabromodiphenyl oxide (OBDDPO) -or- DE-79,
 Hexabromocyclododecane (HBCD) -or- Saytex HBCD LM, Saytex HBCD HM, Saytex HBCD SF,
 CD 75, SP 75, SP 75C, FR-1206,
 Tetrabromobisphenol A (TBBPA or TBBA) -or- Saytex RB100, BA-59P, FR-1524,
 Pentabromodiphenyl oxide (PeBDPO) -or- DE-71, DE-60 F
 Other type _____

2. Are BFRs used in _____ dry or _____ liquid form in your facility?

3. Are BFRs _____ mixed, _____ milled, or _____ ground with other products?

4. What types of products are BFRs used in? _____ Wire coatings? _____ Furniture?
 _____ Auto interiors? _____ Insulation? _____ Other, describe _____

5. Have you ever done personal or area air sampling for _____ total, _____ respirable,
 or _____ inhalable BFR dust? If so, roughly how many samples have you taken:

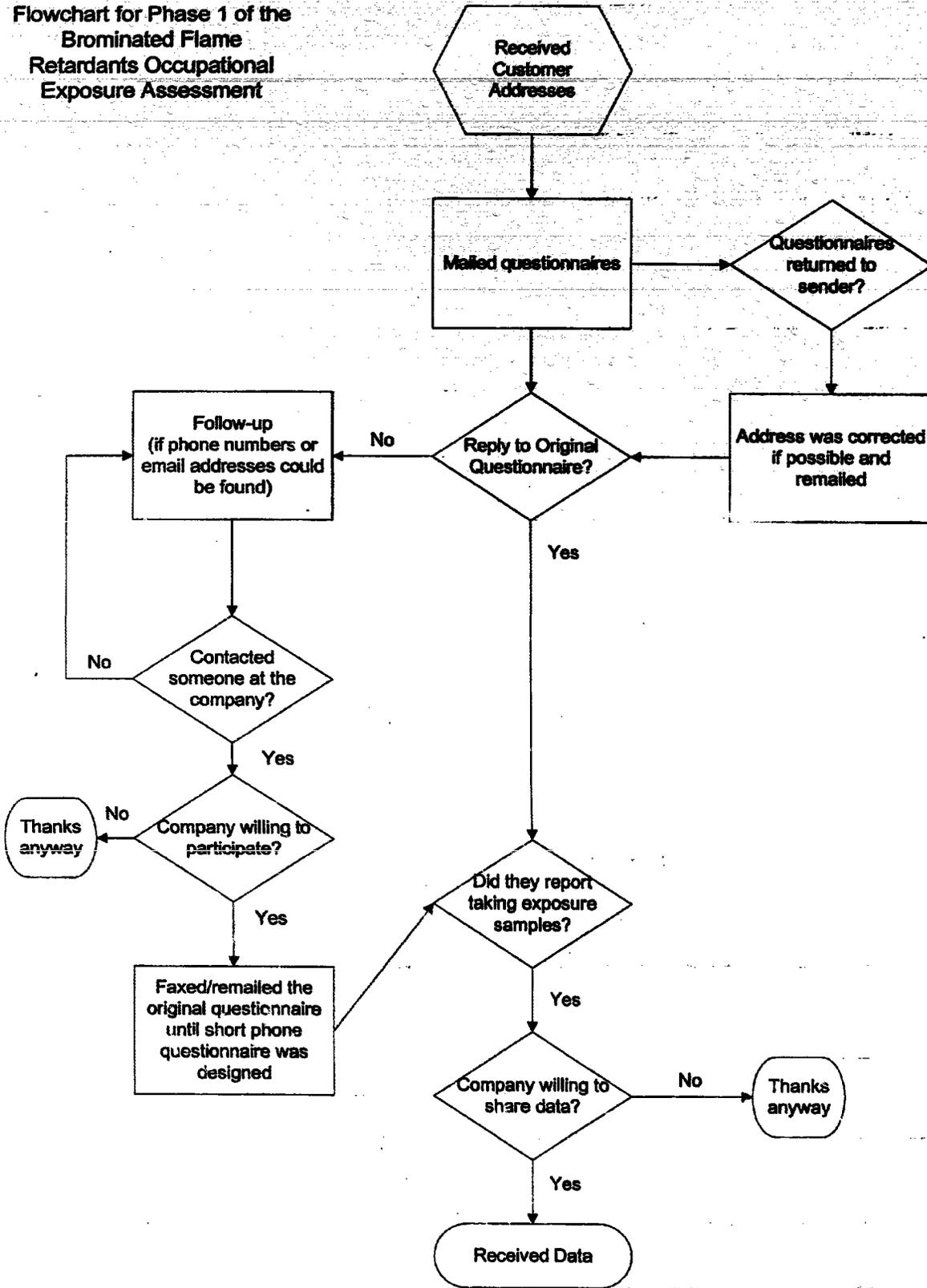
- 1-50,
 50-100,
 100-500,
 500-1000,
 More than 1000?

6. Would you be willing to share the data with us? _____ Yes _____ No
 Personal identifiers would be hidden.

E-07

**Appendix C
Flowchart of Survey Methods**

Flowchart for Phase 1 of the Brominated Flame Retardants Occupational Exposure Assessment



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**Appendix D
Detailed Dust and Antimony Data**

Appendix D - Detailed Dust and Antimony Data

Description of Dust Data

Sample ID	Sample Type	Sample Location	Sample Date	Sample Time	Sample Duration	Sample Volume	Sample Weight	Sample Analysis	Sample Comment
1	1 A	Not given	Not given	<	0.18	DBDPO			
1	2 A	Not given	Not given	<	0.3	DBDPO			
1	3 A	Not given	Not given	<	0.33	DBDPO			
1	4 A	Not given	Not given	<	1.5	DBDPO			
1	5 A	Not given	Not given	<	1.5	DBDPO			
1	6 P	Not given	Not given		0.14	DBDPO	TWA		
1	7 P	Not given	Not given		0.26	DBDPO	TWA		
1	8 P	Not given	Not given		0.4	DBDPO	TWA		
1	9 P	Not given	Not given		0.5	DBDPO	TWA		
1	10 P	Not given	Not given		0.51	DBDPO			
1	11 P	Not given	Not given		0.52	DBDPO	TWA		
1	12 P	Not given	Not given		1	DBDPO			
1	13 P	Not given	Not given	<	0.12	DBDPO	TWA		
1	14 P	Not given	Not given	<	0.2	DBDPO	TWA		
2	1 P	161	322		1.2	DBDPO	Operator at catalyst mixer		
2	2 P	138	276		1.4	DBDPO	Operator at resin mixer		
2	3 P	157	314		1.7	DBDPO	Operator at resin mixer		
3	1 P	225	450		0.15	TBBPA	Operator at hook deck		
3	2 P	185	370		0.17	TBBPA	Operator at hook deck		
3	3 P	229	458		0.19	TBBPA	Operator in gel hook area		
3	4 P	263	Not given		0.28	TBBPA	Operator in resin area		
3	5 P	207	414		0.32	TBBPA	Operator at hook deck		
3	6 P	280	560		0.71	TBBPA	Operator at hook deck		
3	7 P	275	Not given		0.8	TBBPA	Operator at hook deck		
3	8 P	216	432		1.1	TBBPA	Operator in gelcoat area		
3	9 P	248	496		1.63	TBBPA	Operator in gelcoat area		
3	10 P	163	326		1.77	TBBPA	Operator in gel hook area		
3	11 P	266	Not given	<	0.13	TBBPA	Operator in gelcoat area		
4	1 P	Not given	Not given		0.18	DBDPO			
4	2 P	Not given	Not given		0.26	DBDPO			
4	3 P	Not given	Not given		0.29	DBDPO			

4	4P	Not given	Not given	0.37	DBDPO	
4	5P	Not given	Not given	0.48	DBDPO	
4	6P	Not given	Not given	0.49	DBDPO	
4	7P	Not given	Not given	0.5	DBDPO	
4	8P	Not given	Not given	0.56	DBDPO	
4	9P	Not given	Not given	1	DBDPO	
4	10P	Not given	Not given	1.2	DBDPO	
4	11P	Not given	Not given	4.7	DBDPO	
4	12P	Not given	Not given	4.9	DBDPO	
4	13P	Not given	Not given	13	DBDPO	
4	14P	Not given	Not given	15.4	DBDPO	
5	1A	97	Not given	4.09	Other	Crystalline poly area
5	2P	190	Not given	0.26	Other	Intern in R&D
5	3P	116	Not given	0.66	Other	Lab tech in polypropylene area
5	4P	175	Not given	1.74	Other	Lab tech in prod devel area
5	5P	125	Not given	7.6	Other	Lab tech in polypropylene area
5	6P	154	Not given	0.32	Other	Lab tech in elec mat R&D
5	7P	128	Not given	0.39	Other	Lab tech in elec mat R&D
5	8P	75	Not given	0.66	Other	Lab tech in crystalline poly area
5	9P	66	Not given	0.76	Other	Lab tech in prod devel area
5	10P	62	Not given	0.81	Other	Lab tech in crystalline poly area
5	11P	20	Not given	2.5	Other	Lab tech in crystalline poly area
6	1A	Not given	Not given	5	HBCD	TWA-Extruder mix panel -short sampling time
6	2A	Not given	Not given	5	HBCD	TWA-Color concentrate gaylord-short sampling time
6	3A	Not given	Not given	5	HBCD	TWA-Surger hopper tower-short sampling time
6	4A	Not given	Not given	5	HBCD	TWA-Weight augur-short sampling time
6	5A	Not given	Not given	5	HBCD	TWA-Control switches-short sampling time
6	6A	Not given	Not given	5	HBCD	TWA-Color concentrate hopper-short sampling time
6	7P	Not given	Not given	8.9	HBCD	TWA-Operator at hopper feed tank-short sampling
7	1A	Not given	Not given	0.03	DBDPO	TWA-Mix tank
7	2A	Not given	Not given	0.32	DBDPO	TWA-Drum off
7	3A	Not given	Not given	0.4	DBDPO	TWA-Drum off
7	4A	Not given	Not given	0.46	DBDPO	TWA-Mix tank
7	5P	Not given	Not given	0.08	DBDPO	TWA-Operator
7	6P	Not given	Not given	0.12	DBDPO	TWA-Operator
7	7P	Not given	Not given	0.2	DBDPO	TWA-Operator
7	8P	Not given	Not given	4.8	DBDPO	TWA-Operator

Description of Antimony Data

Company Number	Sample Time (mins)	Sample Vol (litres)	Sample No	Antimony (mg/m ³)	Type of BFR	Operator
2	1 P	161	322	0.052	DBDPO	Operator at the catalyst mixer
2	2 P	138	276	0.063	DBDPO	Operator at the resin mixer
2	3 P	157	314	0.1	DBDPO	Operator at the resin mixer
4	1 P	Not given	Not given	0.584	DBDPO	
4	2 P	Not given	Not given	0.618	DBDPO	
4	3 P	Not given	Not given	0.985	DBDPO	
8	1 P	Not given	Not given	0.103	DBDPO	
8	2 P	Not given	Not given	0.303	DBDPO	
8	3 P	Not given	Not given	0.003	DBDPO	
8	4 P	Not given	Not given	0.003	DBDPO	
8	5 P	Not given	Not given	0.003	DBDPO	
8	6 P	Not given	Not given	0.004	DBDPO	
8	7 P	Not given	Not given	0.006	DBDPO	
8	8 P	Not given	Not given	0.007	DBDPO	
8	9 P	Not given	Not given	0.008	DBDPO	
8	10 P	Not given	Not given	0.009	DBDPO	
8	11 P	Not given	Not given	0.014	DBDPO	
8	12 P	Not given	Not given	0.018	DBDPO	
8	13 P	Not given	Not given	0.023	DBDPO	
8	14 P	Not given	Not given	0.042	DBDPO	
8	15 P	Not given	Not given	0.042	DBDPO	
8	16 P	Not given	Not given	0.056	DBDPO	
8	17 P	Not given	Not given	0.062	DBDPO	
8	18 P	Not given	Not given	0.062	DBDPO	
8	19 P	Not given	Not given	0.068	DBDPO	
8	20 P	Not given	Not given	0.076	DBDPO	
8	21 P	Not given	Not given	0.085	DBDPO	
8	22 P	Not given	Not given	0.11	DBDPO	
8	23 P	Not given	Not given	0.15	DBDPO	
8	24 P	Not given	Not given	0.19	DBDPO	
8	25 P	Not given	Not given	0.21	DBDPO	
8	26 P	Not given	Not given	0.21	DBDPO	

TWA

Brominated Product Data from Company 8

Antimony (%)	Brominated Product (%)	Antimony (mg/m ³)	Brominated Product (estimated mg/m ³)
1.5	3.85	0.15	0.385
1.5	3.85	0.75	1.92
1.25	3.75	0.042	0.126
1	20	1.6	32
1.25	3.75	0.21	0.63
3.07	0.72	0.0029	0.0007
3.07	0.72	0.34	0.08
3.07	0.72	0.062	0.015
3.07	0.72	0.003	0.0007
3.07	0.72	0.0078	0.0018
28.04	0	0.018	0
3.18	0	0.062	0
3.18	0	0.0067	0
1.5	3.85	0.042	0.11
3.18	0	0.0057	0
1	3.25	0.056	0.18
2	6	0.023	0.069
2	6	0.0089	0.0267
2.36	5.64	0.0029	0.0069
1.25	4.5	0.19	0.0684
1.25	4.5	22	79.2
37.74	0	0.29	0
3.18	0	0.003	0
37.74	0	0.068	0
4.79	20	1.4	5.645
3.18	0	0.003	0
3.18	0	0.076	0
1.08	1.08	0.21	0.21
1.5	3.9	0.085	0.22
1.3	5	4.8	18.46
1.08	1.08	0.11	0.11
3.18	0	0.21	0
28.04	0	0.014	0
27.7	37.7	0.004	0.0054