United States
Consumer Product Safety Commission

November, 2022

CPSC Staff Statement on: Characterizing Organohalogen Flame Retardant (OFR) Chemistries, Sources, and Uses in United States and International Markets

The U.S. Consumer Product Safety Commission (CPSC, or Commission) contracted with Industrial Economics Inc. (Contract No. 47QRAA20D0044, Order No. 61320621F0021), to complete a market-use profile of organohalogen flame retardant chemicals (OFRs), organized by OFR chemical subclass. CPSC staff plans to use this report in our ongoing project to perform class-based hazard, exposure, and risk assessments for OFRs in specified consumer products.

This statement was prepared by the CPSC staff. Industrial Economics Inc., produced the following report for CPSC staff. The statement and report have not been reviewed or approved by, and do not necessarily represent the views of, the Commission.

The report consists of a main report that identifies and characterizes the relevant chemical properties of OFR chemicals, describes current and historical prevalence of OFRs in consumer products in the United States, and characterizes regulatory and market trends related to OFR use. The main report is accompanied by a document containing appendices that present information about the data collected for the report, and that synthesize data for each OFR subclass in greater detail. Additional details are found in several spreadsheet and workbook files.

The report will be posted on CPSC's website to keep the public informed of the technical research related to the agency's regulatory activities. The appendices, spreadsheets, and workbooks accompanying the final report also will be available to the public.

Table 1 presents the list of 27 files that resulted from performance of the contract (files are numbered only for convenience).

TABLE 1. CONTRACT FILES

	Descriptive Name	File name	Brief Description
1	Market Research Main Report	Vol 1 Main Report 03.24.2022_Final.pdf	Main report produced by the contractor.
2	Market Research Appendices	Vol 2 Appendices 03.09.2022_Final.pdf	Numerous appendices containing detailed information to accompany the main report.
3	Market Research Data SOP	Attachment A_Data SOP.pdf	Provides the standard operating procedure and code used to collect data from data sources.

	Descriptive Name	File name	Brief Description
4	Market Research Chemical Inventories	_OFR Market Data Workbook_mod1_01.25.2022.xlsx[1]	Contains the inventory of all identified OFR chemicals for this project, and tabs for national and international registries and inventories that contain data for any OFR.
5	Market Research Literature Search	OFR Source Review Workbook_mod1_02.28.2022.xlsx[2]	Contains detailed results of the targeted literature review for information related to production and use of OFRs in consumer products. Described in Section 3.2.6 of the main report.
6	Market Research Data Synthesis	Data Source Synthesis_03042022.xlsx	Contains OFR chemical data, manufacturing and use data sources, and patent and literature source information supporting the main report volumes.
7	Market Research Database Readme	00_ReadMe_03042022.xlsx	Summary of data sources used to create the databases and accompanying output files. Identical to Table 2.1 of the main report.
8	Market Research OFR Chemical List	01_Attachment 1_OFR_universe_cid_03042022	List of OFR compounds included in the databases.
9	Market Research Source List	02_SourcesList_03042022	Indicates whether a given OFR chemical is present in each data set.
10	Market Research Fields List	03_FieldsList_03042022	Provides a full list of fields included in each output file.
11	Market Research Field Counts	04_FieldCounts_03042022	Provides record counts for each field in each data source.
12	Market Research ECHA Plastics	OFR_universe_wECHA_add_03042022	List of functional additives used in plastics from European Chemicals Agency (ECHA) Plastic Additives Initiative.
13	Market Research ECHA Sources	OFR_universe_wECHA_links_03042022	Search for information on OFRs in ECHA sources.
14	Market Research NORMAN database	OFR_universe_wNorman_03042022	List of OFRs and accompanying information in the NORMAN-Network database.
15	Market Research PubChem chemical data	OFR_universe_wPCPy_03042022	From PubChem: chemical properties and patent information.
16	Market Research PubChem Chemical Identification	OFR_universe_wPCBrowser_ID_03042022	Search using PubChem Classification Browser for chemical identification information.
17	Market Research Pubchem Massbank spectra	OFR_universe_wPCBrowser_MoNA_03042022	Search using PubChem Classification Browser for OFRs with mass spectra information in the MassBank of North America repository.
18	Market Research PubChem Mass Spec	OFR_universe_wPCBrowser_MS_03042022	Search using PubChem Classification Browser for OFRs with mass spectra information.
19	Market Research PubChem Norman	OFR_universe_wPCBrowser_Norman_03042022	Search using PubChem Classification Browser for OFRs in the NORMAN Suspect List Exchange
20	Market Research CompTox Chemical Information	OFR_universe_wCompTox_batch_03042022	From U.S. EPA CompTox Dashboard: Integrated physicochemical properties, environmental fate and transport, exposure, external list presence.

	Descriptive Name	File name	Brief Description
21	Market Research CompTox Predicted Data	OFR_universe_wCompTox_pred_03042022	From U.S. EPA CompTox Dashboard: Predicted physicochemical properties, toxicity estimates.
22	Market Research CompTox Experimental Data	OFR_universe_wCompTox_exp_03042022	From U.S. EPA CompTox Dashboard: Experimental physicochemical properties.
23	Market Research CompTox Chemical Synonyms	OFR_universe_wCompTox_syns_03042022	From U.S. EPA CompTox Dashboard: Chemical synonyms with quality indicator.
24	Market Research CompTox Product Use	OFR_universe_wCompTox_prod_03042022	From U.S. EPA CompTox Dashboard: Product and use categories, chemical weight fractions.
25	Market Research QSUR	OFR_universe_wQSUR_03042022	List of chemicals with quantitative structure use relationship (QSUR) model predictions indicating potential flame retardant use.
26	Market Research TSCA Inventory	OFR_universe_wTSCA_03042022	List of OFRs in U.S. EPA Toxic Substances Control Act chemical substance inventory.
27	Market Research EPA TRI	OFR_universe_wTRI_03042022	List of OFRs in U.S. EPA Toxics Release Inventory.

[1] File has been modified from the original file delivered by the contractor to remove personally identifiable information and an unneeded quality control worksheet.
[2] File has been modified from the original file delivered by the contractor to remove unneeded formatting.

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Characterizing Organohalogen Flame Retardant (OFR) Chemistries, Sources, and Uses in United States and International Markets

Vol. 1 – Main Report

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LIST OF ACRONYMS

APCISS	Asia Pacific Chemical Inventory Search System
CAS	Chemical Abstracts Service
CBI	Confidential Business Information
CDR	Chemical Data Reporting
CEC	Commission on Environmental Cooperation
CECBP	California Environmental Contaminant Biomonitoring Program
CHAP	Chronic Hazard Advisory Panel
CIRS	Chemical Inspection and Regulation Service
CPSC	Consumer Product Safety Commission
CSCL	Chemical Substances Control Law
CSV	Comma Separated Values
Danish EPA	Danish Environmental Protection Agency
DSL	Domestic Substances List
ECHA	European Union Chemical Agency
EFSA	European Food Safety Agency
EU	The European Union
FDA	Food and Drug Administration
FHSA	Federal Hazardous Substances Act
HBM4EU	Human Biomonitoring for the European Union
IC2	Interstate Chemicals Clearing House
IDE	integrated development environment
IEc	Industrial Economics, Incorporated (IEc)
IECSC	Inventory of Existing Chemical Substances Produced or Imported in China
INSQ	Inventario Nacional de Sustancias Químicas
IPCS	International Program on Chemical Safety
ISHA	Industrial Safety and Health Act
MoNA	MassBank of North America

NAAEC	North American Agreement on Environmental Cooperation
NASEM	National Academy of Sciences, Engineering, and Medicine
NIH	National Institutes of Health
NORMAN	Network of reference laboratories, research centres and related organisations for monitoring of emerging environmental substances
OCSPP	U.S. EPA Office of Chemical Safety and Pollution Prevention
OECD	Organization of Economic Co-operation and Development
OFR	organohalogen flame retardant
OPERA	Open Structure-activity/property Relationship App
ORD	U.S. EPA Office of Research and Development
PBB	Polybrominated biphenyl
PBDE	Polybrominated diphenyl ether
QSUR	Quantitative Structure Use Relationship
REACH	EU Registration, Evaluation, Authorisation, and Restriction of Chemicals
SOW	Statement of Work
TEST	Toxicity Estimation Software Tool
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
U.S. EPA	United States Environmental Protection Agency
WHO	World Health Organization
WHO IPCS	World Health Association, International Programme on Chemical Safety

CHAPTER 1 | INTRODUCTION

The Consumer Product Safety Commission (CPSC or the Commission) is an independent Federal agency that protects the public against unreasonable risk of injury or death from consumer products. A legislative mandate gives CPSC regulatory authority and enforcement powers over a wide range of consumer products not regulated by other agencies.[1] In 2015, the CPSC received a petition requesting that it initiate a rulemaking pursuant to the Federal Hazardous Substances Act (FHSA) banning the use of non-polymeric, additive organohalogen flame retardants (OFRs) in certain consumer products.

The FHSA defines a "hazardous substance" as a substance or mixture that (1) is toxic, (2) is corrosive; (3) is an irritant, (4) is a strong sensitizer, (5) is flammable or combustible, or (6) generates pressure through decomposition, heat, or other means, if the substance "may cause substantial personal injury or substantial illness during or as a proximate result of any customary or reasonably foreseeable handling or use, including reasonably foreseeable use by children."[2] When considering whether to regulate a substance, CPSC staff assesses the human health risks associated with a product containing the chemicals of interest. This risk assessment includes (1) hazard identification (e.g., evidence that the chemical may cause adverse health effects in humans); (2) dose-response analysis; (3) exposure assessment; and (4) risk characterization, including qualitative and quantitative evaluation of the potential for adverse health effects associated with products (CPSC 2020).

The objective of this effort is to develop a class-based market use profile of OFR chemicals in consumer products. Specifically, this report identifies and characterizes the relevant chemical properties of OFR chemicals, describes their current and historical prevalence in consumer products in the United States, and characterizes regulatory and market trends related to OFR use. This information is intended for use by CPSC in its exposure and risk assessment.

1.1 BACKGROUND

In this section, we describe the petition requesting that CPSC ban the use of non-polymeric, additive OFRs in certain consumer products. We also describe recommendations by the National Academy of Sciences, Engineering, and Medicine (NASEM) for conducting the hazard assessment for these chemicals. The section concludes with a description of CPSC staff's project plan for conducting a class-based risk assessment of OFRs.

[1] Other agencies regulating products used in and around the home, schools, and recreational settings include the U.S. Food and Drug Administration (food, drugs, cosmetics), the U.S. Environmental Protection Agency (environmental media), and the U.S. Department of Transportation (automobiles, airplanes).

[2] 15 U.S.C. §§ 1261-1278.

1.1.1 CPSC PETITION (SCOPE, JUSTIFICATION, PRODUCTS)

The Consumer Product Safety Act of 1972 established the CPSC and authorized the Commission to take action to protect the public from risks posed by consumer products and products designed or intended for use by children. Regulations implementing the Act provide a process through which any individual may petition the Commission to begin proceedings to issue, amend or revoke regulations under any Act it administers. In 2015, a group of stakeholders[3] submitted a petition (HP 15-1) requesting the CPSC initiate rulemaking under the FHSA to ban the use of non-polymeric, additive OFRs in the following consumer products:

- Any durable infant or toddler product, children's toy, child care article, or other children's product (other than children's car seats);
- Any article of residential upholstered furniture;
- Any mattress or mattress pad; and
- The plastic casing of any electronic device.

The target OFRs are non-polymeric, halogenated substances incorporated into many products meant to diminish or slow the chance of combustion (Consumer Product Safety Commission 2020). These substances are described as "additive" flame retardants because they are not chemically bound to the substrates they are intended to protect from fire. Since the 1970s, these substances have been added to synthetic materials to meet flammability standards. The petition referenced above presented evidence that, based on their physicochemical properties, all OFRs will migrate from these products into the indoor environment "regardless of how they are used" (CPSC, 2017), exposing individuals to such substances at all stages of the product life cycle. The petitioners further present evidence that such exposures will result in adverse human health impacts.

1.1.2 NATIONAL ACADEMY OF SCIENCES, ENGINEERING AND MEDICINE (NASEM) REPORT

In 2017, the Commission granted the petition and commissioned NASEM to study the feasibility of evaluating the hazards of OFRs as a class. NASEM's report, published in 2019, inventoried a large number of OFRs but determined that it was not possible to evaluate all OFRs as a single class (NASEM, 2019). The study did, however, identify 14 subclasses of OFRs with similar chemical structure, physicochemical properties of the chemicals, and predicted biologic activity. It then recommended moving forward with an assessment using these 14 subclasses as a starting point. It is important to note that the NASEM report concluded that many of these organohalogen substances are not previously known to be used as flame retardants. Because they share properties with known OFRs, however, they "might have the potential of being used for the same purpose." (NASEM, 2019, p. 58). Exhibit 1-1 shows the number of chemicals in each subclass.

[3] The petitioners included the following groups and individuals: American Academy of Pediatrics, American Medical Women's Association, Consumer Federation of America, Consumers Union, Green Science Policy Institute, International Association of Fire Fighters, Kids in Danger, Philip J. Landrigan, M.D., M.P.H., League of United Latin American Citizens, Learning Disabilities Association of American, National Hispanic Medical Association, and Worksafe.

EXHIBIT 1-1. OFRS BY CHEMICAL SUBCLASS

SUBCLASS	NASEM ORIGINAL NUMBER OF CHEMICALS IN SUBCLASS*	CPSC EXPANDED NUMBER OF CHEMICALS IN SUBCLASS*
Polyhalogenated alicycles	17	22
Polyhalogenated aliphatic carboxylate	4	3
Polyhalogenated aliphatic chains	12	47
Polyhalogenated benzene alicycles	4	4
Polyhalogenated benzene aliphatics and functionalized	19	18
Polyhalogenated benzenes	19	50
Polyhalogenated bisphenol aliphatics and functionalized	11	14
Polyhalogenated carbocycles	15	21
Polyhalogenated diphenyl ethers	12	223
Polyhalogenated organophosphates (OPs)	22	42
Polyhalogenated phenol derivatives	7	8
Polyhalogenated phenol-aliphatic ether	9	11
Polyhalogenated phthalates/benzoates/imides	11	19
Polyhalogenated triazines	6	6
TOTAL	**161**	**488**

Source: NASEM, 2019, p. 59.
Notes:
*Two chemicals were categorized by using two chemotypes and included in two subclasses; "polyhalogenated carbocycles" and "polyhalogenated benzene aliphatics and functionalized," the latter of which is not shown in this table.

1.1.3 CPSC PROJECT PLAN

Following completion of the NASEM report and receipt of its recommendations, CPSC staff prepared a plan describing the steps needed to implement the recommendations and proceed with a class-based risk assessment for OFRs (CPSC, 2020). The primary steps include (CPSC, 2020):

- **Scope and Analysis Plan.** The purpose of the scope document is to identify how much relevant data are available, what types of data (e.g., hazard or exposure data) are available, and which of the product categories are relevant. This information is used to create a conceptual exposure model, which identifies likely sources, pathways, receptors, and effects. The scope document will help CPSC staff determine whether there is sufficient information available, as a class, to conduct a class-based risk assessment for these OFRs.
- **Draft risk assessment.** CPSC staff will next prepare a draft risk assessment, which will involve the following four steps: (a) hazard identification; (b) dose response analysis; (c) exposure assessment; and (d) risk characterization. This assessment will be more complicated under a class-based approach than for a single chemical. Because of expected data gaps, the risk assessment will likely rely on computer-based modeling methods (e.g., read-across, structure-activity relationships, toxicokinetic modeling, and exposure modeling) for both toxicology and exposure information to fill data gaps for data-poor chemicals within a subclass.

- **Final risk assessment.** The draft risk assessment will then be submitted for peer review. Any new or updated information or methods will be assessed and incorporated as appropriate. The peer-reviewed risk assessment will then be made available for public comment. Following review and consideration of all comments, CPSC staff will finalize the risk assessment and, in consultation with senior management, prepare its conclusions. This will include a determination of whether each subclass of OFRs presents a hazard to consumers. Depending on the strength of the evidence and level of certainty, this could lead to the convening of a Chronic Hazard Advisory Panel (CHAP), as a prelude to rulemaking; a recommendation that further data is needed; or in the event no hazard to consumers is suggested, no further action being required.

The CPSC staff report identifies several tasks it recommends the Commission complete during FY 2021. Some of these tasks, including the present market use study, it recommends completing with contractor support.

Included in the staff report is an appendix (Tab D), presenting existing market use profile data for OFR chemicals collected and reviewed by the CPSC staff. It identifies a number of potential sources for OFR market use data, including sources that may be helpful in identifying uses as a flame retardant. These sources were a starting point for the present study.

1.2 OFR SUBSTANCES OF INTEREST TO CPSC

Exhibit 1-1 above identifies the 14 subclasses of OFRs defined by NASEM, and the number of substances within each class. The total number of substances identified by NASEM across all classes is 161. The NASEM report acknowledged, however, that there could be many more substances having similar functional, structural, and predicted biological activity (NASEM, 2019). Subsequent work by CPSC staff, as presented in the OFR inventory provided by CPSC staff, identified additional substances beyond the 161 from the NASEM report. The current list of substances of interest to CPSC staff totals 488. Chapter Two of this report provides more detail on these chemicals.

1.3 REPORT OVERVIEW

The remainder of the report (**Volume 1**) is organized as follows:

- In **Chapter 2**, we present our approach for gathering and integrating chemical and physical properties and other key characteristics (e.g., uses, patent information) on the OFRs of interest to the CPSC. Information from each data source was paired to the list of OFR chemicals and saved as an individual Microsoft Excel-based workbook. Summary spreadsheets were also created to present data sources, fields, and record counts. This set of supporting data files accompanies the report, with a standard operating procedure in **Attachment A** of the **Supporting Materials**.
- In **Chapter 3**, we describe our methodology for conducting market research and a summary of class-based findings (e.g., our professional judgment of the commonalities or apparent differences among chemicals within each class; other observations based on information availability). Cross tabulations of our major data sources are provided in tables in **Appendix A**. Detailed information about each class, including production; imports; exports; demand; uses, functions, concentrations, lifecycles, and products; available exposure data; suppliers and importers; and legal, regulatory, and market trends, is provided separately in tables in **Appendices C through Q**.

- In **Chapter 4**, we summarize our findings regarding legal and regulatory developments and OFR market trends. Detailed information about existing regulations is provided in **Appendix R**.
- In **Chapter 5**, we provide a synthesis of the market use information provided in Chapters 2 through 4, along with our key conclusions.

The report **Appendices** are provided separately in **Volume 2** and the **Supporting Materials** are provided in a zip file.

CHAPTER 2 | ORGANOHALOGEN FLAME RETARDANT CHEMICALS AND CLASSES

This chapter presents the approach used to gather and integrate chemical and physical properties and other key characteristics on the OFRs of interest to the CPSC. Chemical properties, synonyms and tradenames, and other supporting characteristics for OFR chemicals were compiled into a database for the project, with individual working tables prepared for each data source. The complete list of chemicals considered for this analysis are provided as Attachment 1 in the supporting materials.

2.1 METHODOLOGY AND SOURCES

Chemical and physical properties and other key characteristics of chemical substances are found in a wide array of chemical and regulatory databases, as well as in lists and reports from academic, non-governmental, and governmental sources. These data sources are organized in a multitude of ways, with many databases having their own unique identifier systems even within the same agency. Our overarching goal under this task is to develop and implement a methodology to comprehensively and repeatably query data records associated with all chemicals of interest across multiple sources.

The process to compile data regarding OFR chemicals began by inventorying the list of potential information sources provided in Section 7 of the project Statement of Work (CPSC 2021). This inventory was supplemented with additional sources identified during conversations with project partners and subsequent internet searches. Each source was visited, reviewed, and prioritized in terms of relevance. Of these, seven individual data sources were included in the OFR data compilation process (Exhibit 2-1) (see Section 2.2 for discussion of the remaining sources that were not included). The OFR data compilation process was managed in the Spyder integrated development environment (IDE), which is an interface for scientific programming in the Python language. Each data source was loaded to Spyder and joined with the list of OFR chemicals of interest that were identified by the CPSC, provided in Attachment 1. Field names were then updated in place to append an abbreviated name for each data source to the front of the existing field name, allowing for clear and consistent information tracking. Each of the paired tables were exported to comma separated values (CSV) files that can be opened in Microsoft Excel or other spreadsheet software programs for straightforward cross-organizational sharing (see Attachment A for the Standard Operating Procedure used for producing these outputs). The set of paired tables accompanies this report in a package of database-related files.

EXHIBIT 2-1. SUMMARY OF DATA SOURCES USED TO CREATE THE DATABASE AND ACCOMPANYING OUTPUT FILES

NAME	DESCRIPTION	SOURCE	OUTPUT FILE[1]
EUROPEAN CHEMICALS AGENCY (ECHA)			
Plastic Additives Initiative	This joint project by ECHA and industry resulted in a list of functional additives used in plastics, including information on OFRs.	https://echa.europa.eu/mapping-exercise-plastic-additives-initiative	OFR_universe_wECHA_add_03042022
Advanced Search Function	Search criteria included molecular formulas that contain bromine or chlorine and either consumer product or article service life information. The output file provides the text in these sections as well as hyperlinks to the sections.	https://echa.europa.eu/	OFR_universe_wECHA_links_03042022
NETWORK OF REFERENCE LABORATORIES, RESEARCH CENTRES AND RELATED ORGANISATIONS FOR MONITORING OF EMERGING ENVIRONMENTAL SUBSTANCES (NORMAN)			
Substance Database	A merged list of NORMAN substances; Central Database to access various lists of substances for suspect screening and prioritization.	https://www.norman-network.com/nds/	OFR_universe_wNorman_03042022
PUBCHEM AND ASSOCIATED DATA			
PubChemPy	PubChem is the world's largest collection of freely accessible chemical information. PubChemPy provides a way to interact with PubChem in Python. It allows chemical searches by name, retrieval of chemical properties, and scraping of patent information.	https://pubchem.ncbi.nlm.nih.gov/	OFR_universe_wPCPy_03042022
PubChem Browser > Identification	The PubChem Classification Browser allows the user to browse the distribution of PubChem data among nodes in the hierarchy of interest, thereby providing an aggregate view of PubChem data. It also allows the user to search for PubChem records annotated with the desired hierarchy/term.	https://pubchem.ncbi.nlm.nih.gov/classification/#hid=72	OFR_universe_wPCBrowser_ID_03042022
PubChem Browser > Information Sources > MassBank of North America (MoNA)			OFR_universe_wPCBrowser_MoNA_03042022
PubChem Browser > Spectral Information > Mass Spectrometry			OFR_universe_wPCBrowser_MS_03042022
PubChem Browser > Classification > Ontologies > NORMAN Suspect List Exchange Classification			OFR_universe_wPCBrowser_Norman_03042022

NAME	DESCRIPTION	SOURCE	OUTPUT FILE[1]
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA) COMPTOX AND ASSOCIATED DATA			
CompTox Batch Export	Available chemical information, including physicochemical properties, environmental fate and transport, exposure, and external list presence, has been integrated.	https://comptox.epa.gov/dashboard	OFR_universe_wCompTox_batch_03042022
Open Structure-activity/property Relationship App (OPERA) and Toxicity Estimation Software Tool (TEST) Predictions	These backend exports from databases that support the CompTox dashboard provide information that both overlaps and may be in addition to that provided by the frontend CompTox batch export. For example, a list of synonyms is provided by the batch export, but the quality code is not.	Antony Williams, U.S. EPA[2]	OFR_universe_wCompTox_pred_03042022
Experimental Properties		Antony Williams, U.S. EPA[2]	OFR_universe_wCompTox_exp_03042022
Synonyms with Quality		Antony Williams, U.S. EPA[2]	OFR_universe_wCompTox_syns_03042022
Product & Use Categories and Chemical Weight Fractions		https://epa.figshare.com/articles/dataset/The_Chemical_and_Products_Database_CPDat_MySQL_Data_File/5352997	OFR_universe_wCompTox_prod_03042022
U.S. EPA QUANTITATIVE STRUCTURE USE RELATIONSHIP (QSUR) MODEL			
QSUR Model	Includes several iterations of predicted flame retardant use for chemicals relevant to this effort.	Charles Bevington, CPSC[2]	OFR_universe_wQSUR_03042022
U.S. EPA TOXIC SUBSTANCES CONTROL ACT (TSCA)			
Chemical Substance Inventory	Non-confidential portion of TSCA inventory.	https://www.epa.gov/tsca-inventory/how-access-tsca-inventory	OFR_universe_wTSCA_03042022
U.S. EPA TOXICS RELEASE INVENTORY (TRI) PROGRAM			
TRI	Synonyms, including trade names, for compounds reported on the TRI.	https://ofmpub.epa.gov/apex/guideme_ext/f?p=guideme:rfi-home	OFR_universe_wTRI_03042022

[1] A set of summary-level Excel workbooks accompany the output files: "01_Attachment 1_OFR_universe_cid_03042022" (Attachment 1) is the list of OFR compounds included in the database; "02_SourcesList_03042022" marks whether a given OFR chemical is present in each data set; "03_FieldsList_03042022" provides a full list of fields included in each output file; and "04_FieldCounts_03042022" provides record counts (total, unique, and unique compounds) for each field in each data source.

[2] The original data source was subsequently revised to include DTXSID40888243 and DTXSID90871387, and to use 31780-26-4 instead of 7436-90-0 for "Benzene, dibromoethenyl-."

2.2 OTHER DATA SOURCES CONSIDERED BUT NOT INCLUDED

As described above, the sources provided in Section 7 (Government Furnished Materials) of the Statement of Work were inventoried and supplemented with additional sources identified during conversations with project partners and subsequent internet searches (CPSC 2021). A subset of these sources was included in the OFR data compilation process (Exhibit 2-1). The remaining sources were not included for a combination of reasons. For example, some sources:

1. Were provided for informational background purposes (e.g., an explanation of a particular regulation).
2. May have been provided for the market use and trends efforts (Tasks 2 and 3) and not the chemical characterization effort (Task 1) (IEc 2021).
3. Did not have searchable chemical information (e.g., white paper repositories).
4. May provide information that is duplicative of other sources (e.g., PubChem is widely used for common chemical and physical properties, like molecular weight).

Nearly forty individual data source suggestions across 17 groups were considered, including potential sources from the United States Environmental Protection Agency (U.S. EPA), National Institutes of Health (NIH), North American Agreement on Environmental Cooperation (NAAEC), Interstate Chemicals Clearing House (IC2), European Union Chemical Agency (ECHA), Danish EPA, European Food Safety Agency (EFSA), European Agency for Safety and Health at Work, World Health Organization (WHO) International Program on Chemical Safety (IPCS), and Organization of Economic Co-operation and Development (OECD). International sources were also considered, such as those from Asia (generally), China, Japan, Mexico, and Canada.[4] General resources considered included Alibaba, the U.S. Food and Drug Administration (FDA) drug approvals and databases, a patent database (SureChEMBL), and legislation tracking websites (e.g., the Safer States bill tracker).

[4] Specific international sources considered include the Asia Pacific Chemical Inventory Search System (APCISS) from Chemical Inspection and Regulation Service (CIRS), Inventory of Existing Chemical Substances Produced or Imported in China (IECSC), New Chemicals (searchable through Chemical Risk Information Platform or J-Check, Chemical Substances Control Law [CSCL]), Industrial Safety and Health Act (ISHA), National Inventory of Chemical Substances of Mexico (Inventario Nacional de Sustancias Químicas, INSQ), and Canada Domestic Substances List (DSL).

CHAPTER 3 | MARKET RESEARCH

This chapter describes the approach used to collect and analyze market research on the OFRs of interest to CPSC staff and summarizes our results. It begins by defining the type of data required by CPSC staff (Section 3.1) and then describes the methodology used to search for, obtain, organize, analyze, and present the available data (Section 3.2). It concludes with a summary of class-based findings (Section 3.3), with references to Appendices C through P, which present detailed findings for each class at the individual chemical level.

3.1 KEY MARKET DATA SOUGHT

As described in Chapter 1, CPSC staff is seeking information on certain OFRs used in products that fall under its authority. Products of interest include, but are not limited to upholstered furniture, mattresses, home furnishings, consumer electronics, appliances, children's products, building materials, and other household products.

The list of OFRs of interest to CPSC staff includes 488 substances which have been categorized into 14 chemical classes, based on the methodology described in the 2019 NASEM report (NASEM, 2019). Of these, 214 compounds are flagged as not covered in the petition (e.g., polymeric, UVCB[5], cations/anions, mixtures) or as uncommon polybrominated diphenyl ethers or biphenyls (PBDEs/PBBs). The substances and their categorization into classes are shown in Chapter 1.

The three main objectives of the market research are to (1) characterize each chemical class, (2) identify the use(s) of chemicals in consumer products for each chemical class, and (3) identify trends associated with each chemical class. This includes information on total production or consumption of chemicals in each class and the amount or percentage used. Within each class, CPSC staff is also interested in identifying the most significant substances, for example, based on those substance's share of total production within the class.

To meet these objectives, CPSC staff is seeking to answer questions including:

- Is there evidence the OFR chemical or class is in commerce? Is it produced in the United States or internationally? Do the OFR chemicals appear on U.S. and international registries of chemicals in commerce?
- Are there data on the amounts of OFR chemicals produced in the United States and internationally, and on the amounts imported into the United States?
- Is there evidence of increasing or decreasing trends in the manufacture or import of OFR chemicals?

[5] UVCB are chemical substances of unknown or variable composition, complex reaction products and/or biological materials.

- For which intermediate or end use products are OFRs used? What quantities of OFRs are used in such products?

3.2 METHODOLOGY

CPSC staff, in collaboration with EPA researchers and some market-use report co-authors, gathered data from fifty-nine government sources from U.S. Federal and State governments, Danish EPA, U.K. Environment Agency, World Health Organization, European Union Agencies, and the Canadian Government. Fifty-five data sources from the open literature were also identified through a forward search of Bergman et al., 2011 and using the PubMed MeSH terms and PubMed abstract sifter. We reviewed these sources and characterized them in terms of their relevance to the market research task and the OFR chemicals they covered. This search was then extended to additional sources such as flame retardant reference books and chapters in engineering handbooks focused on flame retardants. The next step involved searching U.S. and foreign chemical inventories and registries to determine whether each OFR is, or has previously been, in commerce. While their design and purpose vary by country and region, these registries are intended to document substances that have been produced domestically (or imported, usually) in order to determine which substances are "new" and may require review prior to entering commerce. Next, the search was extended to the general literature using standard search engine tools and searches of commercial online literature databases. Finally, a select number of industry experts were contacted for any additional information they could recommend or provide. The following sections describe each of these steps in turn.

3.2.1 EXISTING DATA SOURCES

In the United States, suppliers of consumer products are not legally obligated to inform consumers of the chemical content of their products. There is no complete database available to reference which consumer products sold in the United States (e.g., furniture, mattresses, home furnishings, consumer electronics, appliances, children's products, and other household products) contain OFRs, and which do not. Accordingly, we identified 13 existing data sources to help us better understand the market for OFR chemicals, and their uses in consumer products that are sold in the United States.

Exhibit 3-1 lists data sources identified and collected by CPSC staff in the initial stages of this project. In addition to reviewing the sources themselves, the reference lists from these sources were also examined and screened for relevance. We reviewed each of these sources to determine first whether they contained any market-related data (production, end uses) and next which OFR chemicals of interest to CPSC staff, if any, they covered. Then, we created a workbook in Microsoft Excel to track which sources had relevant data for each OFR chemical so these could be referenced and accessed when creating chemical-specific market profiles (see below).

EXHIBIT 3-1. DESCRIPTION OF KEY CPSC DATA SOURCES

SOURCE		DESCRIPTION
1	CPSC Staff	• Prior CPSC risk assessments of FRs used in specific products (upholstered furniture, mattresses) (2001-2006) • Contractor reports on exposure to selected FRs (2015) • NRC study prepared for CPSC covering toxicological, epidemiological, and exposure data on 16 FRs (2000)
2	EPA Office of Chemical Safety and Pollution Prevention (OCSPP)	• EPA reports on uses of, and alternatives to, individual FRs and groups of FRs (2009-2015) • EPA Action Plans for individual FRs and groups of FRs (2009)
3	EPA Office of Research and Development (ORD)	• Excel workbook cross-referencing over 400 chemicals against a number of ORD data sources (2021)
4	Danish Environmental Protection Agency (Danish EPA)	• Studies of FRs in electronics (2003) and textiles (2014). • Survey of short-chain and medium-chain chlorinated paraffins (uses, hazards, exposure) (2014) • Categorization study for selected BFRs (2016)
5	UK Environment Agency	• FR prioritization study for risk assessment purposes (2003)
6	World Health Association, International Programme on Chemical Safety (WHO IPCS)	• 13 environmental health criteria documents covering individual FR chemicals (1984-1995)
7	European Food Safety Authority (EFSA)	• 7 EFSA "Scientific Opinion" documents on the presence and risk of selected FR chemicals in food
8	European sources including the Human Biomonitoring for the EU (HBM4EU) project	• Scoping documents for FRs prepared in support of the EU human biomonitoring program • Additives found in plastics, their function, and concentrations, based on REACH data
9	California Environmental Contaminant Biomonitoring Program (CECBP)	• Study examining potential for biomonitoring of brominated and chlorinated FR chemicals (2008)
10	Health Canada and the Commission on Environmental Cooperation (CEC)	• Screening assessments and "state of the science" reports for individual FRs (2006-2019) • CEC study of FRs and use in manufactured items (2015)
11	Bergman et al. 2012	• Journal article: Abbreviation standard for organobromine, organochlorine and organophosphorus FRs (2012)
12	Forward search of Bergman et al.	• Fifty-two journal articles that cited Bergman et al. and contained a list of at least 10 OFRs.
13	Supplemental non-halogenated and inorganic data sources	• Bolinus et al., 2018 Journal article: Evaluating the consumption of chemical products and articles as proxies for diffuse emissions to the environment (2018) • Other non-halogenated flame retardant chemistries and future flame retardant solutions (Non-Halogenated Flame Retardant Handbook, 2014) • The history and future trends of non-halogenated flame retarded polymers (Non-Halogenated Flame Retardant Handbook, 2014)

3.2.2 ADDITIONAL "STANDARD" SOURCES

Flame retardant chemicals, their chemistry, and their applications have been the subject of numerous technical handbooks or chapters in such books. For example, the Kirk-Othmer Encyclopedia of Chemical Technology (Kirk-Othmer, 2000) includes three chapters focused on flame retardants. We conducted a search for reference sources of this type and obtained and reviewed 11 additional sources (Choi & Kim, 2020; Ekpe et al., 2020; Fiedler, 2010; Guerra et al., 2011; Hirschler, 2013; Morgan & Wilkie, 2014; Papaspyrides & Kiliaris, 2014; Poma et al., 2020; Toms et al., 2011; A. Wypych & Wypych, 2021; G. Wypych, 2021).

3.2.3 DETERMINING WHETHER CHEMICALS ARE IN OR HAVE BEEN IN COMMERCE

To determine whether individual OFRs are currently in commerce or have been in the past, we reviewed national and international chemical registries and inventories. Overall, 40.0 percent of the OFR chemicals of interest to CPSC staff appear on at least one registry or inventory, meaning that the substance is or has been in commerce in that country or region. Next, we conducted a detailed analysis of U.S. production, import, and use activity for the OFR chemicals, using data available from the EPA Chemical Data Reporting (CDR) program for the reporting periods 2016, 2012, 2006, and 1998.[6] We also reviewed any waste generation and waste management data available for OFRs from the Toxic Release Inventory (TRI). Each source we reviewed provided information on OFR chemicals that are in commerce currently or have been in commerce.

3.2.3.1 National and International Chemical Registries and Inventories

While their exact purpose, scope, and application may vary from region to region, registries and inventories generally help define "existing" or "active" chemicals, i.e., chemicals that are presently manufactured in or imported into a country or region. Chemicals that are not on these lists are considered "new" chemicals, and manufacturers or importers may be required to notify domestic or regional authorities before doing so.[7]

In the United States, the primary inventory is the TSCA Chemical Substance Inventory (U.S. EPA, 2021)[8], referred to as the "TSCA Inventory"). Initially created in 1979, the TSCA Inventory lists substances that have been commercially manufactured in or imported to the United States. When the TSCA was put into place, all existing chemicals were grandfathered in without prior review by the EPA. The TSCA Inventory has been continually updated since that time through the addition of "new" chemicals. In an effort to identify substances on the TSCA Inventory that are no longer manufactured or imported, in 2017 the U.S. EPA required manufacturers and importers to indicate whether chemicals on the TSCA Inventory had been manufactured or imported during the 10-year period ending June 21, 2016. This information allowed EPA to add "active" and "inactive" designations to the inventory. The current (February 2021) version of the TSCA Inventory contains 68,167 substances identified by CAS Number,

[6] Data are reported to the CDR (and its predecessor, the Inventory Update Rule, or IUR) every four years. Reporting under the IUR was required in 2002, but EPA was unable to provide us that data.

[7] Registries and inventories may establish minimum volume reporting thresholds and may provide exemptions for some classes of chemicals or certain uses (e.g., research and development).

[8] Information about the TSCA Inventory and how to access it may be found at https://www.epa.gov/tsca-inventory/how-access-tsca-inventory

of which 33,607 (49.3 percent) are active. There are another 18,390 substances whose identity is claimed as confidential, and of these 8,257 (44.9 percent) are active.

Other countries and regions have similar inventories or registries. In Canada, the Domestic Substances List (DSL) operates in a similar fashion to the TSCA Inventory. The European Union (EU) operates under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation. REACH entered into force in 2007 and requires manufacturers and importers to provide the EU authorities with information about the substances they manufacture and import.

To determine whether and where the OFR chemicals have been in commerce in the United States and for some of the major trading partners of the United States, we checked inventories and registries from the United States, Canada, Mexico, the EU, Japan, and China. It is important to note that inventories for the United States, Canada, the EU and Japan are maintained and updated regularly. Mexico's INSQ was published only once, in 2009, and reporting was not mandatory, and China's IECSC was published in 2013 with no subsequent updates.

Exhibit 3-2 shows the results from this exercise. Overall, 40.0 percent of the list of 488 OFR chemicals of interest to CPSC staff appear on at least one registry or inventory, meaning that the substance is or has been in commerce in that country or region. The inventory with the most OFR substances listed is Japan's (35.5 percent of the OFR substances are listed), while the inventory with the fewest is Mexico's (4.7 percent of the OFR substances are listed). Based on data from the non-confidential version of the TSCA Inventory, 18.8 percent of the OFR substances (92 of 488 substances) have been in commerce in the United States at some point since 2016.

Exhibits 3-3 and 3-4 provide further detail on the status of OFR substances in the United States. According to the TSCA Inventory, 92 OFR substances are designated as active. This means they have been in commerce at some point since June 2016 (Exhibit 3-3). An additional 42 substances are designated as inactive, meaning they had previously been in commerce in the United States, but as of June 2016 had been determined to no longer be in commerce (Exhibit 3-4). A further 354 substances, or 72.5 percent of total, do not appear on the non-CBI portion of the TSCA Inventory, meaning that these chemicals have never been in commerce in the United States or that their identity is CBI. An unknown number of OFR substances may be included on the CBI portion of the TSCA Inventory, which covers an additional 18,390 substances, as mentioned previously.[9]

[9] CBI claims by industry are not just a factor within the TSCA Inventory. Wang et al. (2020) reviewed inventories from ten countries/regions and determined that the identity of close to 20 percent of the chemicals on these inventories were not published due to CBI claims. The prevalence of CBI claims exacerbates the problem of supply chain transparency. In the present context, it means an unknown number of OFRs may be used in consumer and children's products, but the identify, volume, and concentration of those chemicals is never disclosed.

EXHIBIT 3-2. OFR APPEARANCE ON U.S. AND INTERNATIONAL SUBSTANCE REGISTRIES

OFR CLASS	TOTAL NO. OF OFRS IN CLASS	COUNTRY/REGION, REGISTRY, AND YEAR(S), NUMBER OF SUBSTANCES APPEARING						NO. OF OFRS IN CLASS ON ANY REGISTRY	PERCENT OF OFRS IN CLASS ON ANY REGISTRY
		US TSCA INVENTORY 2021[A]	EU REACH 2021[B,C]	CANADA DSL 2021[D]	MEXICO INSQ 2009[E]	JAPAN CSCL 2021[F]	CHINA IECSC 2013[G]		
Polyhalogenated alicycles	22	4	2	5	2	15	5	17	77.3%
Polyhalogenated aliphatic carboxylate	3	2				3	1	3	100.0%
Polyhalogenated aliphatic chains	47	21	8	15	7	20	15	27	78.7%
Polyhalogenated benzene alicycles	4	1						0	25.0%
Polyhalogenated benzene aliphatics and functionalized	18	5	2		1	5	5	6	33.3%
Polyhalogenated benzenes	50	7	1	4	3	23	3	25	52.0%
Polyhalogenated bisphenol aliphatics and functionalized	14	6	5	3	1	9		9	64.3%
Polyhalogenated carbocycles	19	7	3	4	2	8	5	10	52.6%
Polyhalogenated organophosphates	42	11	6	11	3	26	12	29	71.4%
Polyhalogenated phenol derivatives	8	4	1	3	1	5	3	5	75.0%
Polyhalogenated phthalates/benzoates/imides	19	8	5	5		8	6	10	52.6%
Polyhalogenated triazines	6	1	2	1		2	2	2	33.3%
Polyhalogenated diphenyl ethers	223	11	1	9	2	44	8	47	21.0%
Polyhalogenated phenol-aliphatic ether	11	4	1	1	1	5	4	5	45.5%
Polyhalogenated carbocycles/polyhalogenated benzene aliphatics and functionalized	2	0						0	0.0%
Grand Total	488	92	37	61	23	173	69	195	42.7%
Percent of all substances appearing on registry	--	18.9%	7.6%	12.5%	4.7%	35.5%	14.1%	40.0%	--

Sources and Notes:

[A] TSCA = Toxic Substances Control Act. These data are based on the public version of the TSCA Inventory, which includes only listings not claimed as Confidential Business Information (CBI). Thus, there may be additional, active OFR substances in commerce in the United States that cannot be identified because their listing in the TSCA Inventory is claimed as CBI. [As of February 2021, the non-CBI Inventory contained 68,167 substances, of which 33,607 (49.3 percent) were active. There were another 18,390 substances whose identity is claimed as confidential, of which 8,257 (44.9 percent) are active. In May, 2021, EPA announced that 390 substances on the CBI version of the Inventory would be moved to the non-CBI version following review of the CBI claims for these chemicals.]

[b] REACH = Registration, Evaluation, Authorisation, and Restriction of Chemicals. An inventory of substances manufactured in, or imported to, the EU on a commercial scale. Updated on a periodic basis to reflect new substances notifications.

[c] REACH applies to legal entities established in the following European Union countries: Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden. REACH also applies to non-EU Member States of the European Economic Area, including Norway, Iceland and Liechtenstein.

[d] DSL = Canada Domestic Substances List. An inventory of substances manufactured in, or imported to, Canada on a commercial scale. Updated approximately 12 times per year to reflect new substances notifications.

[e] INSQ = Inventario Nacional de Sustancias Químicas (National Inventory of Chemical Substances). An inventory of substances manufactured in, or imported to, Mexico. Reporting is not mandatory, and the preliminary list has not been updated since 2009.

[f] CSCL = Chemical Substances Control Law. An inventory of substances manufactured in, or imported to, Japan on a commercial scale. Updated regularly to reflect new substances notifications.

[g] IECSC = Inventory of Existing Chemical Substances Produced or Imported in China. Published in 2013 with no subsequent updates.

EXHIBIT 3-3. NUMBER OF ACTIVE AND INACTIVE OFR CHEMICALS ON THE TSCA INVENTORY, 2021

OFR CLASS	ACTIVE	INACTIVE	NOT ON INVENTORY	TOTAL NO. OF CHEMICALS
Polyhalogenated alicycles	4	3	15	22
Polyhalogenated aliphatic carboxylate	2		1	3
Polyhalogenated aliphatic chains	21	3	23	47
Polyhalogenated benzene alicycles	1		3	4
Polyhalogenated benzene aliphatics and functionalized	5	3	10	18
Polyhalogenated benzenes	7	5	38	50
Polyhalogenated bisphenol aliphatics and functionalized	6	3	5	14
Polyhalogenated carbocycles	7	5	7	19
Polyhalogenated organophosphates	11	12	18	42
Polyhalogenated phenol derivatives	4	2	2	8
Polyhalogenated phthalates/benzoates/imides	8	3	8	19
Polyhalogenated triazines	1		5	6
Polyhalogenated diphenyl ethers	11		212	223
Polyhalogenated phenol-aliphatic ether	4	3	4	11
Polyhalogenated carbocycles/polyhalogenated benzene aliphatics and functionalized			2	2
Grand Total	92	42	353	488

EXHIBIT 3-4. LIST OF 92 ACTIVE OFR CHEMICALS ON THE TSCA INVENTORY, 2021

92 ACTIVE OFR CHEMICALS ON THE TSCA INVENTORY, 2021	
POLYHALOGENATED ALICYCLES	
25637-99-4	Hexabromocyclododecane
3194-55-6	1,2,5,6,9,10-Hexabromocyclododecane
77-47-4	Hexachlorocyclopentadiene
87-84-3	Pentabromochlorocyclohexane
POLYHALOGENATED ALIPHATIC CARBOXYLATE	
19660-16-3	2,3-Dibromopropyl acrylate
5445-17-0	Propanoic acid, 2-bromo-, methyl ester
POLYHALOGENATED ALIPHATIC CHAINS	
106232-85-3	Alkanes, C18-20, chloro
1372804-76-6	Alkanes, C14-16, chloro
1401974-24-0	Alkanes, C22-30-branched and linear, chloro
1402738-52-6	Alkanes, C24-28, chloro
1417900-96-9	Alkanes, C21-34-branched and linear, chloro
2097144-43-7	Alkanes, C20-28, chloro
2097144-45-9	Alkanes, C20-24, chloro
2097144-46-0	Hexacosane, chloro derivs.

92 ACTIVE OFR CHEMICALS ON THE TSCA INVENTORY, 2021	
2097144-47-1	Octacosane, chloro derivs.
2097144-48-2	Octadecane, chloro derivs.
288260-42-4	Alkanes, C22-30, chloro
3296-90-0	Pentaerythritol dibromide
36483-57-5	Tribromoneopentyl alcohol
61788-76-9	Chloroalkanes
63449-39-8	Chlorinated paraffins
68527-01-5	Bromo chloro C12-30 a-alkenes
68527-02-6	Alkenes, C12-24, chloro
68920-70-7	Alkanes, C6-18, chloro
79-27-6	1,1,2,2-Tetrabromoethane
85535-85-9	Cercelor S 52 (MCCP)
96-13-9	2,3-Dibromopropanol
POLYHALOGENATED BENZENE ALICYCLES	
155613-93-7	1H-Indene, 2,3-dihydro-1,1,3-trimethyl-3-phenyl-, octabromo deriv.
POLYHALOGENATED BENZENE ALIPHATICS AND FUNCTIONALIZED	
147-82-0	2,4,6-Tribromoaniline
59447-55-1	(Pentabromophenyl)methyl acrylate
84852-53-9	1,1'-Ethane-1,2-diylbis(pentabromobenzene)
87-83-2	Pentabromotoluene
93-52-7	1,2-dibromo(phenyl)ethane
POLYHALOGENATED BENZENES	
2113-57-7	3-Bromobiphenyl
59447-57-3	Poly(pentabromobenzyl acrylate)
626-39-1	1,3,5-Tribromobenzene
636-28-2	1,2,4,5-Tetrabromobenzene
87-82-1	Hexabromobenzene
92-66-0	4-Bromobiphenyl
92-86-4	1,1'-Biphenyl, 4,4'-dibromo-
POLYHALOGENATED BISPHENOL ALIPHATICS AND FUNCTIONALIZED	
21850-44-2	Tetrabromobisphenol A-bis(2,3-dibromopropyl ether)
25327-89-3	Tetrabromobisphenol A diallyl ether
3072-84-2	2,2'-[(1-Methylethylidene)bis[(2,6-dibromo-4,1-phenylene)oxymethylene]]bis[oxirane]
37853-61-5	Tetrabromobisphenol A dimethyl ether
4162-45-2	Tetrabromobisphenol A bis(2-hydroxyethyl) ether
79-94-7	3,3',5,5'-Tetrabromobisphenol A
POLYHALOGENATED CARBOCYCLES	
115-27-5	Chlorendic anhydride
115-28-6	Chlorendic acid
13560-89-9	Dechlorane Plus
1770-80-5	Dibutyl chlorendate
2234-13-1	1,2,3,4,5,6,7,8-Octachloronaphthalene
34571-16-9	1,2,3,4,7,7-Hexachloro-5-(pentabromophenyl)bicyclo[2.2.1]hept-2-ene
52907-07-0	N,N'-(Ethylene)bis[4,5-dibromohexahydro-3,6-methanophthalimide]

92 ACTIVE OFR CHEMICALS ON THE TSCA INVENTORY, 2021	
POLYHALOGENATED ORGANOPHOSPHATES	
115-96-8	Tris(2-chloroethyl) phosphate
126-72-7	Tris(2,3-dibromopropyl) phosphate
13674-84-5	Tris(2-chloroisopropyl)phosphate
13674-87-8	Tris(1,3-dichloro-2-propyl) phosphate
140-08-9	Tris(2-chloroethyl) phosphite
19186-97-1	Tris(tribromoneopentyl)phosphate
38051-10-4	Phosphoric acid, 2,2-bis(chloromethyl)-1,3-propanediyl tetrakis(2-chloroethyl) ester
6145-73-9	Tris(2-chloropropyl) phosphate
6294-34-4	Bis(2-chloroethyl) 2-chloroethylphosphonate
76025-08-6	Bis(2-chloro-1-methylethyl) 2-chloropropyl phosphate
76649-15-5	(2-Chloro-1-methylethyl) bis(2-chloropropyl) phosphate
POLYHALOGENATED PHENOL DERIVATIVES	
118-79-6	2,4,6-Tribromophenol
42757-55-1	1,1'-Sulfonylbis[3,5-dibromo-4-(2,3-dibromopropoxy)benzene]
608-33-3	Phenol, 2,6-dibromo-
615-58-7	2,4-Dibromophenol
POLYHALOGENATED PHTHALATES/BENZOATES/IMIDES	
117-08-8	Tetrachlorophthalic anhydride
183658-27-7	2-Ethylhexyl 2,3,4,5-tetrabromobenzoate
20566-35-2	2-(2-Hydroxyethoxy)ethyl 2-hydroxypropyl 3,4,5,6-tetrabromophthalate
25357-79-3	1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, sodium salt (1:2)
26040-51-7	Bis(2-ethylhexyl) tetrabromophthalate
32588-76-4	1,2-Bis(tetrabromophthalimido)ethane
632-58-6	Tetrachlorophthalic acid
632-79-1	4,5,6,7-Tetrabromo-1,3-Isobenzofurandione
POLYHALOGENATED TRIAZINES	
25713-60-4	2,4,6-Tris-(2,4,6-tribromophenoxy)-1,3,5-triazine
POLYHALOGENATED DIPHENYL ETHERS	
101-55-3	p-Bromodiphenyl ether
1163-19-5	1,1'-Oxybis[2,3,4,5,6-pentabromobenzene]
2050-47-7	4,4'-Dibromodiphenyl ether
32534-81-9	Pentabromodiphenyl ether
32536-52-0	Octabromodiphenyl ether
36483-60-0	Hexabromodiphenyl ether
40088-47-9	Tetrabromodiphenyl ether
49690-94-0	Tribromodiphenyl ether
58965-66-5	Perbromo-1,4-diphenoxybenzene
63936-56-1	Nonabromodiphenyl ether
68928-80-3	Diphenyl ether, heptabromo derivative
POLYHALOGENATED PHENOL-ALIPHATIC ETHER	
20217-01-0	2,4-Dibromophenyl glycidyl ether
3278-89-5	1,3,5-Tribromo-2-(prop-2-en-1-yloxy)benzene
37853-59-1	1,2-Bis(2,4,6-tribromophenoxy)ethane
7347-19-5	Tribromophenoxyethyl acrylate

3.2.3.2 Chemical Data Reporting Under TSCA

In addition to determining whether OFR substances appear as active substances on the TSCA Chemical Inventory, we conducted a detailed analysis of U.S. production and import activity for the OFR chemicals, using data available from the EPA Chemical Data Reporting (CDR) program. The CDR rule requires manufacturers (including importers) to provide EPA with information on the production, import, and use of chemicals in commerce. Chemicals subject to the rule generally include substances on the TSCA Inventory at the start of the submission period.[10] Submissions must include exposure-related information including information on the types, quantities and uses of chemical substances produced domestically and imported into the United States. The information is collected every four years from manufacturers (including importers) of certain chemicals in commerce, generally when production volumes for the chemical are 25,000 pounds or greater for a specific reporting year.[11]

Appendix A contains a large number of tables derived from this analysis for the past several reporting periods. Exhibit 3-5 shows that in the 2015 CDR reporting year, the most recent year available, manufacturers submitted 26 notifications of manufacturing activity for OFR substances, two notices of both manufacturing and importing activity, and 56 notices of importing activity. An additional 25 notices claimed the activity (manufacturing or importing) as CBI and there were 11 reports for which a description of the activity was not available (NA).

Exhibit 3-7 shows these reports in greater detail. For each OFR class and substance reported, this table indicates the number of reports and the total volume, in pounds, reported to be manufactured, imported, used on site, and exported in 2015. It also shows the total production volume for the prior three years, 2014, 2013, and 2012. Eight chemicals listed (CAS Numbers 63449-39-8, 13674-84-5, 13674-87-8, 68527-02-6, 26040-51-7, 632-79-1, 77-47-4, and 20566-35-2) each account for more than one million pounds of combined manufacturing and importing activity. The highest volume chemical (CAS Number 63449-39-8, chlorinated paraffins) accounted for 12 reports, 68.0 million pounds manufactured, and 0.7 million pounds imported. In 2015 the two highest volume OFR subclasses were polyhalogenated aliphatic chains (76,953,679 pounds) and polyhalogenated organophosphates (64,266,362 pounds).

Exhibit 3-6 summarizes OFR production activity from 2012 to 2015. Over this period, over 150 million pounds of OFR chemicals are reported to be imported into the United States or manufactured domestically each year. Combined manufacturing and importing activity from 2012 to 2014 was fairly steady in a range from 166 to 170 million pounds, but dropped in 2015 to 155 million pounds, a decline of approximately 10 percent.

[10] Exemptions for substances that appear on the TSCA Inventory include polymers, microorganisms, naturally occurring chemical substances, water, and certain forms of natural gas. There are also CDR reporting exemptions available to small manufacturers and small government entities (EPA, 2020. Instructions for Reporting 2020 TSCA Chemical Data Reporting).

[11] A reduced reporting threshold of 2,500 lbs. applies to chemical substances subject to certain TSCA actions.

EXHIBIT 3-5. NUMBER OF REPORTS BY OFR CLASS, 2015

OFR CLASS	TYPE OF ACTIVITY					
	DOMESTICALLY MANUFACTURED	DOMESTICALLY MANUFACTURED AND IMPORTED	IMPORTED	CBI	NA	GRAND TOTAL
Polyhalogenated alicycles	2		6	2		10
Polyhalogenated aliphatic chains	6		12	5	2	25
Polyhalogenated benzene aliphatics and functionalized	2		6	5	1	14
Polyhalogenated bisphenol aliphatics and functionalized	1	1	5	3	1	11
Polyhalogenated carbocycles	1		2			3
Polyhalogenated organophosphates	3		18	4	3	28
Polyhalogenated phenol derivatives	2		1			3
Polyhalogenated phthalates/benzoates/imides	9	1	4	3	2	19
Polyhalogenated diphenyl ethers			1	2	2	5
Polyhalogenated triazines				1		1
Polyhalogenated phenol-aliphatic ether			1			1
Grand Total	26	2	56	25	11	120

Source: U.S. EPA CDR (2016).

EXHIBIT 3-6. OFR PRODUCTION ACTIVITY, 2012-2015

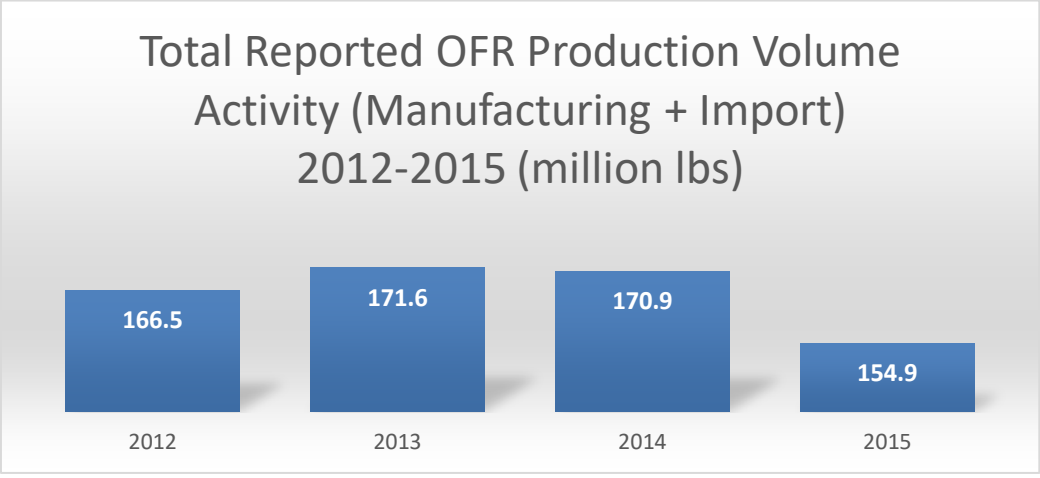


EXHIBIT 3-7. TOTAL POUNDS REPORTED BY CHEMICAL AND ACTIVITY TYPE, NONCONFIDENTIAL DATA ONLY, 2015

OFR CLASS AND CAS NO.	NO. OF REPORTS[a]	DOMESTIC MANUFACTURE (LBS)	IMPORT (LBS)	DOMESTIC MANUFACTURE PLUS IMPORT (LBS)[b]	VOLUME USED ON SITE (LBS)	VOLUME EXPORTED (LBS)	TOTAL PRODUCTION VOLUME, (LBS), 2014	TOTAL PRODUCTION VOLUME (LBS), 2013	TOTAL PRODUCTION VOLUME (LBS), 2012
POLYHALOGENATED ALICYCLES	10	-	1,971,159	1,971,159	202,647	1,591,032	2,456,460	3,200,515	1,475,332
25637-99-4	4	-	177,480	177,480	-	-	-	-	-
3194-55-6	5	-	536,164	536,164	202,647	333,517	427,769	504,265	22,046
77-47-4	1	-	1,257,515	1,257,515	-	1,257,515	2,028,691	2,696,250	1,453,286
POLYHALOGENATED ALIPHATIC CHAINS	25	75,610,000	1,343,679	76,953,679	45,655	2,377,745	92,109,137	98,236,684	96,724,493
1401974-24-0	1	-	-	-	-	-	-	-	-
1402738-52-6	1	-	-	-	-	-	-	-	-
1417900-96-9	1	-	-	-	-	-	-	-	-
3296-90-0	3	-	602,831	602,831	-	54,233	427,637	196,209	52,910
36483-57-5	2	-	-	-	-	-	-	-	-
61788-76-9	2	-	10,355	10,355	10,355	-	8,891	6,246	9,292
63449-39-8	12	68,000,000	730,493	68,730,493	35,300	2,167,512	82,312,609	90,424,229	89,932,291
68527-01-5	1	210,000	-	210,000	-	-	360,000	410,000	330,000
68527-02-6	2	7,400,000	-	7,400,000	-	156,000	9,000,000	7,200,000	6,400,000
POLYHALOGENATED BENZENE ALIPHATICS AND FUNCTIONALIZED	14	-	536,123	536,123	-	250,000	658,246	535,516	622,069
84852-53-9	14	-	536,123	536,123	-	250,000	658,246	535,516	622,069
POLYHALOGENATED BISPHENOL ALIPHATICS AND FUNCTIONALIZED	11	-	78,704	78,704	-	-	69,555	26,646	80,248
21850-44-2	1	-	-	-	-	-	-	-	-
25327-89-3	1	-	-	-	-	-	-	-	-
4162-45-2	1	-	12,566	12,566	-	-	25,463	4,630	58,202
79-94-7	8	-	66,138	66,138	-	-	44,092	22,016	22,046
POLYHALOGENATED CARBOCYCLES	3	-	802,482	802,482	-	802,482	1,238,759	1,265,139	1,389,706
115-27-5	1	-	802,482	802,482	-	802,482	1,040,581	1,073,650	1,389,706
13560-89-9	2	-	-	-	-	-	198,178	191,489	-
POLYHALOGENATED ORGANOPHOSPHATES	28	50,088,182	15,349,340	64,266,362	3,535,185	3,616,235	65,058,589	59,892,351	58,227,373
115-96-8	1	-	39,682	39,682	-	-	158,728	39,682	79,364

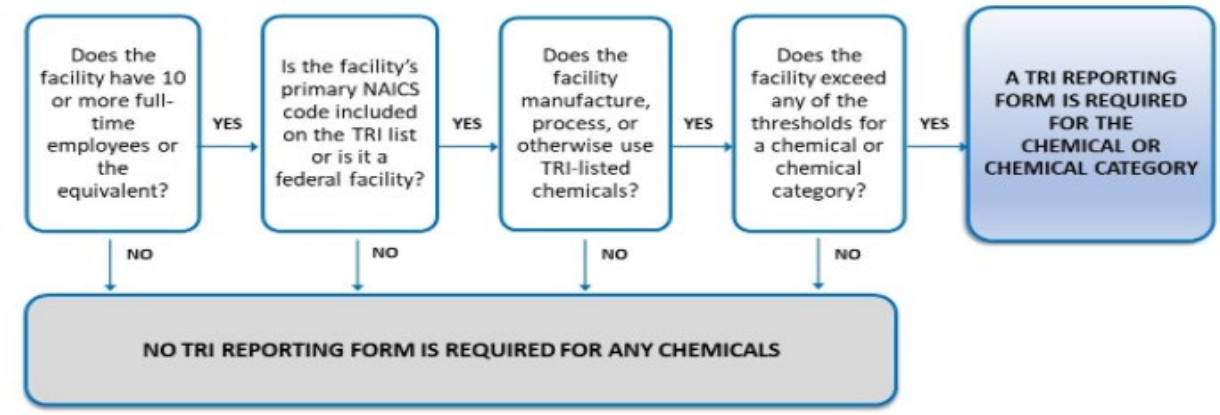
OFR CLASS AND CAS NO.	NO. OF REPORTS[a]	DOMESTIC MANUFACTURE (LBS)	IMPORT (LBS)	DOMESTIC MANUFACTURE PLUS IMPORT (LBS)[b]	VOLUME USED ON SITE (LBS)	VOLUME EXPORTED (LBS)	TOTAL PRODUCTION VOLUME, (LBS), 2014	TOTAL PRODUCTION VOLUME (LBS), 2013	TOTAL PRODUCTION VOLUME (LBS), 2012
13674-84-5	17	38,488,041	11,345,820	48,662,701	189,610	3,591,976	48,794,511	45,353,434	37,579,445
13674-87-8	5	11,600,141	3,087,177	14,687,318	3,345,575	22,080	15,306,692	13,508,589	19,809,021
19186-97-1	1	-	-	-	-	-	-	-	-
38051-10-4	1	-	-	-	-	-	-	-	-
6294-34-4	1	-	-	-	-	2,179	-	-	-
76025-08-6	2	-	876,661	876,661	-	-	798,658	990,646	759,543
POLYHALOGENATED PHENOL DERIVATIVES	3	-	27,557	27,557	-	-	-	276	-
118-79-6	2	-	-	-	-	-	-	-	-
42757-55-1	1	-	27,557	27,557	-	-	-	276	-
POLYHALOGENATED PHTHALATES/BENZOATES/IMIDES	19	8,270,502	1,376,832	9,647,334	-	1,050,247	8,982,680	8,121,647	7,943,212
117-08-8	1	-	110,000	110,000	-	-	-	10,000	-
183658-27-7	1	-	-	-	-	-	-	-	-
20566-35-2	4	1,174,900	-	1,174,900	-	-	223,797	176,156	196,356
26040-51-7	3	7,095,602	-	7,095,602	-	1,050,247	7,085,682	6,816,785	6,612,673
32588-76-4	1	-	-	-	-	-	-	-	-
632-79-1	9	-	1,266,832	1,266,832	-	-	1,673,201	1,118,706	1,134,183
POLYHALOGENATED DIPHENYL ETHERS	5	-	573,192	573,192	529,100	-	284,330	275,413	64,167
1163-19-5	5	-	573,192	573,192	529,100	-	284,330	275,413	64,167
POLYHALOGENATED TRIAZINES	1	-	-	-	-	-	-	-	-
25713-60-4	1	-	-	-	-	-	-	-	-
POLYHALOGENATED PHENOL-ALIPHATIC ETHER	1	-	-	-	-	-	-	-	-
3278-89-5	1	-	-	-	-	-	-	-	-
Grand Total	120	133,968,684	22,059,068	154,856,592	4,312,587	9,687,741	170,857,756	171,554,187	166,526,600

[a] The pounds reported in this table only include those amounts not claimed as CBI. Where the number of reports for a chemical is greater than zero and no pounds are reported (indicted by "-"), this means all amounts in those reports are CBI.

[b] This total does not equal the sum of domestic manufacture plus imports shown in the table. One submitter reported 0 pounds manufactured and 1.39 million pounds imported, but a combined production plus import total of 2.2 million pounds. This entry accounts for the discrepancy.

3.2.3.3 Toxic Release Inventory

Another U.S. data source for identifying chemicals in commerce is the Toxics Release Inventory (TRI). TRI is a resource for learning about toxic chemical releases and pollution prevention reported by industrial and federal facilities. Chemicals covered by the TRI Program are those that cause one or more of the following: cancer or other chronic human health effects, significant adverse acute human health effects, significant adverse environmental effects. They are referred to as TRI-listed or TRI-reportable chemicals.



Every year, U.S. facilities meeting TRI reporting requirements must submit a TRI Form R for each TRI-listed chemical it manufactures, processes, or otherwise uses in quantities above the reporting threshold at the facility and report various data to the TRI program by July 1 of the following year. For example, releases that occurred in 2019 are reported to TRI by July 1, 2020, and are called "Reporting Year 2019" data. Covered facilities include facilities in the manufacturing, hazardous waste management, and other sectors, as well as all federal facilities. These facilities are required to report if they have at least 10 full-time employee-equivalents and manufacture, process, or otherwise use a TRI-reportable chemical above the chemical's reporting threshold. For most chemicals, this threshold is 25,000 pounds for manufacturing or processing, and 10,000 pounds for chemicals that are "otherwise used."[12]

[12] "Otherwise use" is any use of TRI-listed chemical that does not fall under the definitions of "manufacture" or "process." Chemicals otherwise used are not incorporated into a product that is distributed into commerce and includes such uses as a processing or manufacturing aid and for such ancillary uses as treating wastes.

EXHIBIT 3-8. TRI-REPORTABLE OFR CHEMICALS AS OF REPORTING YEAR 2019 (RY19)

OFR SUBCLASS	CHEMICAL NAME	TRI ID	CAS NO.	REPORTING THRESHOLD (LB)	DE MINIMIS CONCENTRATION	FIRST YEAR REPORTABLE	FORMS RECEIVED (RY19)
Polyhalogenated alicycles	Hexachlorocyclopentadiene	000077474	77-47-4	25,000 / 10,000	1.0%	1987	6
	Hexabromocyclododecane	N270[1]	25637-99-4	100	N/A	2017	3
Polyhalogenated aliphatic chains	Pentaerythritol dibromide / 2,2-bis(bromomethyl)-1,3-propanediol	003296900	3296-90-0	25,000 / 10,000	0.1%	2011	3
	C10-13 chloro alkanes / Polychlorinated alkanes (C_{10} to C_{13})	N583[2]	85535-84-8	25,000 / 10,000	1.0%	1995	6
Polyhalogenated bisphenol aliphatics and functionalized	3,3',5,5'-Tetrabromobisphenol A / Tetrabromobisphenol A[3]	000079947	79-94-7	100	N/A	2000	54
Polyhalogenated carbocycles	Chlorendic acid	000115286	115-28-6	25,000 / 10,000	1.0%	1995	0
	1,2,3,4,5,6,7,8-Octachloronaphthalene / Octachloronaphthalene	002234131	2234-13-1	25,000 / 10,000	1.0%	1987	1
Polyhalogenated organophosphates	Tris(2,3-dibromopropyl) phosphate	000126727	126-72-7	25,000 / 10,000	0.1%	1987	1
Polybrominated diphenyl ethers (PBDEs)	1,1'-Oxybis[2,3,4,5,6-pentabromobenzene] / Decabromodiphenyl oxide[4]	001163195	1163-19-5	25,000 / 10,000	1.0%	1987	11
Polyhalogenated Benzenes	Polybrominated biphenyls (PBB)	N575[5]	59536-65-1	25,000 / 10,000	0.1%	1987	1

Notes:
[1] Hexabromocyclododecane in TRI is a group including 1,2,5,6,9,10-Hexabromocyclododecane (CAS # 3194-55-6) and Hexabromocyclododecane (CAS # 25637-99-4), also known as HBCD. This group was first reportable for RY2017.
[2] Defined in TRI as $C_xH_{2x-y+2}Cl_y$; Where x = 10 to 13; y = 3 to 12; and where the average chlorine content ranges from 40-70% with the limiting molecular formulas $C_{10}H_{19}Cl_3$ and $C_{13}H_{16}Cl_{12}$ more commonly referred to as "chlorinated paraffins."
[3] Commonly referred to as TBBPA.
[4] Commonly referred to as decaDBE.
[5] Defined in TRI as Biphenyl with Br_x and $H_{(10-x)}$ where x = 1 to 10.
Data source: U.S. EPA, TRI National Analysis Dataset. Published October 2020

Some exemptions allow facilities to ignore TRI chemicals meeting certain criteria. Two common exemptions are the articles exemption and the *de minimis* exemption. The articles exemption allows facilities to ignore TRI chemicals in articles (except articles manufactured on site) that retain their article status while at the facility. The *de minimis* exemption allows facilities to ignore TRI chemicals that are present in mixtures below the *de minimis* concentration. The *de minimis* concentration is 1.0 percent, unless the chemical is designated as a carcinogen in which case the *de minimis* concentration is 0.1 percent. The *de minimis* exemption may not be used for chemicals considered to be persistent, bioaccumulative, and toxic (PBT). Reporting thresholds and *de minimis* quantities for the 10 TRI-reportable OFR chemicals are listed in Exhibit 3-8, along with year in which each chemical first became reportable and the number of reporting forms (form Rs) received in Reporting Year 2019.

EPA considers at least three of the TRI-listed OFR chemicals to be PBT substances: Tetrabromobisphenol A (TBBPA); Alkanes, C10-13, chloro; and Hexabromocyclododecane (HBCD), and at least four to be possible carcinogens: TBBPA; decaBDE; tris(2,3-dibromopropyl) phosphate; and Alkanes, C10-13, chloro. In addition, the TRI-reportable OFR chemicals in Exhibit 3-8 may be mutagenic, toxic to reproduction, and/or endocrine disrupting.

In reporting year 2019, 83 Form Rs were filed for TRI-listed OFR chemicals, in seven OFR subclasses. Fifty-four forms were received from facilities reporting the release of TBBPA. Eleven forms for decaBDE were received, and six forms each for HCCPD and certain chlorinated paraffins.

Chemicals meeting certain criteria may be eligible for a Form A certification statement instead of the standard Form R. The Form A certification statement includes only facility identification information and chemical or chemical category information. The Form A omits many data elements required on the Form R. Facilities may only file a Form A certification statement if they manufacture, process, or otherwise use no more than 1 million pounds of a chemical, and if the on- and off-site waste management of the chemical does not exceed 500 pounds. The option to file a Form A certification statement instead of the Form R is not available for PBT chemicals. In 2019, two Form As were filed for OFRs, one each for CAS Nos. 3296-90-0 and 1163-19-5.

3.2.3.4 Activity Reporting

Facilities submitting a Form R must indicate all activities for which the chemical is used at the facility. This includes the categories of manufacture (including import), process, and otherwise use, and subcategories for each category. The TRI program defines manufacture as "to produce, prepare, compound, or import an EPCRA Section 313 chemical," process as "the preparation of a listed EPCRA Section 313 chemical, after its manufacture, for distribution in commerce," and otherwise use as "any use of an EPCRA Section 313 chemical, including an EPCRA Section 313 chemical contained in a mixture or other trade name product or waste, that is not covered by the terms manufacture or process."

Facilities report all activities that apply, and commonly report more than one activity. Facilities reporting manufacture of a chemical must report whether the chemical is produced at the facility or imported by the facility, as well as at least one code indicating the purpose of manufacture. Facilities reporting processing or otherwise use must select all applicable activities for the chemical at the facility, selecting at least one activity for each category reported. The activities reported for TRI-reportable OFR chemicals are shown in Exhibit 3-9. This table shows all activities reported on 83 Form R submissions for OFR chemicals in

2019; activity counts do not sum to category totals and category totals do not sum to the total number of forms because some facilities reported multiple activities.

Exhibit 3-10 shows activities reported for each TRI-reportable OFR chemical, limited to the most commonly reported activities. For OFR chemicals, the most commonly reported activities for 2019 were processing as a reactant, processing as a formulation component, processing as an article component, and otherwise use (ancillary or other uses).

EXHIBIT 3-9. ACTIVITIES REPORTED TO TRI FOR OFR CHEMICALS, REPORTING YEAR 2019 (RY19)

ACTIVITY CATEGORY	ACTIVITY	NUMBER OF FACILITIES REPORTING ACTIVITY, RY19
Manufacture	Manufacture: produced	3
	Manufacture: imported	1
	Manufacture: for on-site use/processing	1
	Manufacture: for sale/distribution	1
	Manufacture: as byproduct	2
	Manufacture: as impurity	1
	Manufacture - total forms	4
Process	Process: as reactant	11
	Process: as formulation component	34
	Process: as article component	19
	Process: repackaging	1
	Process: as impurity	3
	Process: recycling	2
	Process - total forms	62
Otherwise Use	Otherwise use: as chemical processing aid	2
	Otherwise use: as manufacturing aid	4
	Otherwise use: ancillary/ other	12
	Otherwise Use - total forms	18
Data source: TRI National Analysis dataset published October 2020		

EXHIBIT 3-10. MOST COMMONLY REPORTED ACTIVITIES REPORTED BY CHEMICAL, RY19

OFR CLASS	CHEMICAL NAME	PROCESS AS A REACTANT	PROCESS AS A FORMULATION COMPONENT	PROCESS AS AN ARTICLE COMPONENT	OTHERWISE USE: ANCILLARY/ OTHER
Polyhalogenated alicycles	Hexachlorocyclopentadiene	1	1	0	2
	Hexabromocyclododecane / HBCD	0	1	1	2
Polyhalogenated aliphatic chains	Pentaerythritol dibromide	1	1	0	0
	C10-13 chloro alkanes	0	0	2	2
Polyhalogenated bisphenol aliphatics and functionalized	3,3',5,5'-Tetrabromobisphenol A / TBBPA	10	26	10	5
Polyhalogenated carbocycles	Chlorendic acid	0	0	0	0
	1,2,3,4,5,6,7,8-Octachloronaphthalene	0	0	0	1
Polyhalogenated organophosphates	Tris(2,3-dibromopropyl) phosphate	0	0	0	1
Polyhalogenated diphenyl ethers	1,1'-Oxybis[2,3,4,5,6-pentabromobenzene] / decaDBE	0	5	6	0
Polyhalogenated Benzenes	Polybrominated biphenyls (PBB)	0	0	0	1
Data source: TRI National Analysis dataset published October 2020.					

3.2.3.5 Sub-Use Reporting

To provide more detail on activities and uses of TRI chemicals at reporting facilities, the TRI program introduced sub-use codes for the 2018 reporting year. Facilities reporting processing a chemical as a reactant or formulation component, or otherwise use of a chemical as a chemical processing or manufacturing aid or ancillary or other uses, must report at least once sub-use activity code. Facilities may report multiple sub-use codes for one activity if more than one applies. Exhibit 3-11 shows the sub-uses reported for TRI-reportable OFR chemicals. This table only includes those sub-uses that were reported at least once for these chemicals for 2019.

EXHIBIT 3-11. SUB-USES REPORTED FOR OFR CHEMICALS, RY19

ACTIVITY	FORMS WITH SUB-USES	SUB-USE	NUMBER OF TIMES REPORTED, RY19
Processing as a reactant	12	Raw materials	10
		Other	2
Processing as a formulation component	34	Additives	12
		Reaction diluents	1
		Initiators	1
		Flame retardants	18
		Other	3
Otherwise use as a chemical processing aid	2	Other	2
Otherwise use as a manufacturing aid	4	Process lubricants	1
		Metalworking fluids	2
		Other	1
Otherwise use: ancillary or other use	14	Cleaner	1
		Fuel	1
		Waste treatment	10
		Other	4
Data source: TRI National Analysis dataset published October 2020			

Two available sub-use codes correspond to flame retardants; one, under the processing as a formulation component activity, was reported 18 times for these chemicals for 2019. The other, corresponding to otherwise use (ancillary or other use) as a flame retardant, was reported once in 2018 for polychlorinated alkanes and was not reported for 2019. Not all activities have sub-use codes; for example, no sub-use codes exist for manufacturing or for processing a chemical in an article (i.e., incorporating a chemical into a final product), so this represents use of OFRs as flame retardants only in the context of processing as formulation components and ancillary or other uses. It is best to consider sub-use reporting in the context of each activity. For example, just over half of forms that reported processing an OFR as a formulation component (34 forms) reported that the chemical was used as a flame retardant (18 forms). It is worth considering that sub-use codes are relatively new and there may be overlap amongst the codes, especially for similar sub-uses, e.g., use of a chemical as an additive as opposed to a flame retardant. From this data, one can conclude that TRI facilities frequently process OFR chemicals as flame retardants, but this is not the only use of those chemicals at TRI facilities.

3.2.3.6 Releases and Waste Management

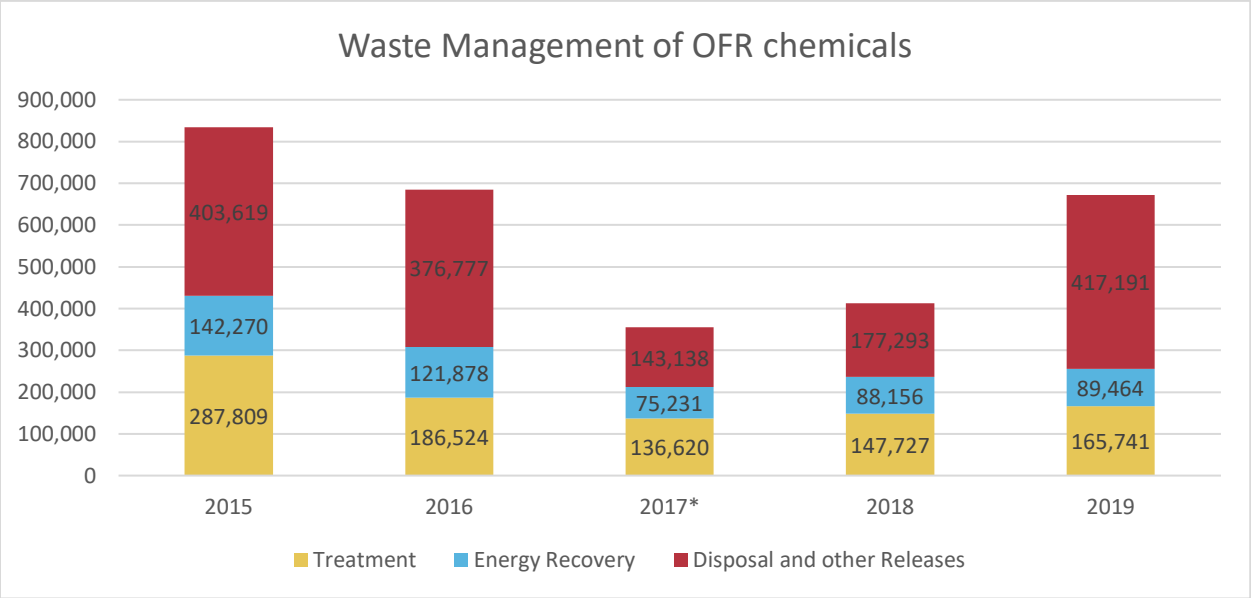
TRI-reporting facilities are required to track releases and disposal of chemicals throughout the year. They must also track other waste management, including treatment for destruction, combustion for energy recovery, and recycling. While details on waste quantities are reported, TRI reporting does not include the total quantity of the chemical used at the facility or the quantity of the chemical incorporated into products. Releases, treatment, and energy recovery represent final disposition of waste, while recycling prepares the chemical to be used again. The same chemical may be recycled many times, and may later be managed through treatment, combustion for energy recovery, or release or disposal. For this reason, recycling quantities may not correspond to the quantities of a chemical being used at a facility. Quantities

of waste managed by the other methods (release or disposal, treatment, and energy recovery) represent a minimum quantity of the chemical handled by the facility. For example, for 2019, TRI facilities reported treating, combusting for energy recovery, and releasing or disposing of a total 672 thousand pounds of OFR chemicals. Therefore, these facilities must have collectively handled at least 672 thousand pounds of these chemicals. Exhibit 3-12 shows the five-year trend in treatment, energy recovery, and disposal or other release of TRI-reportable OFR chemicals.

Quantities of OFR chemicals managed as waste, excluding recycling, decreased from a high of 834 thousand pounds in 2015 to a low of 355 thousand pounds in 2017, then increased through 2018 and 2019 (see Exhibit 3-13). These trends could indicate changing usage of these chemicals, or it could indicate implementation of pollution prevention activities to reduce the waste generated.

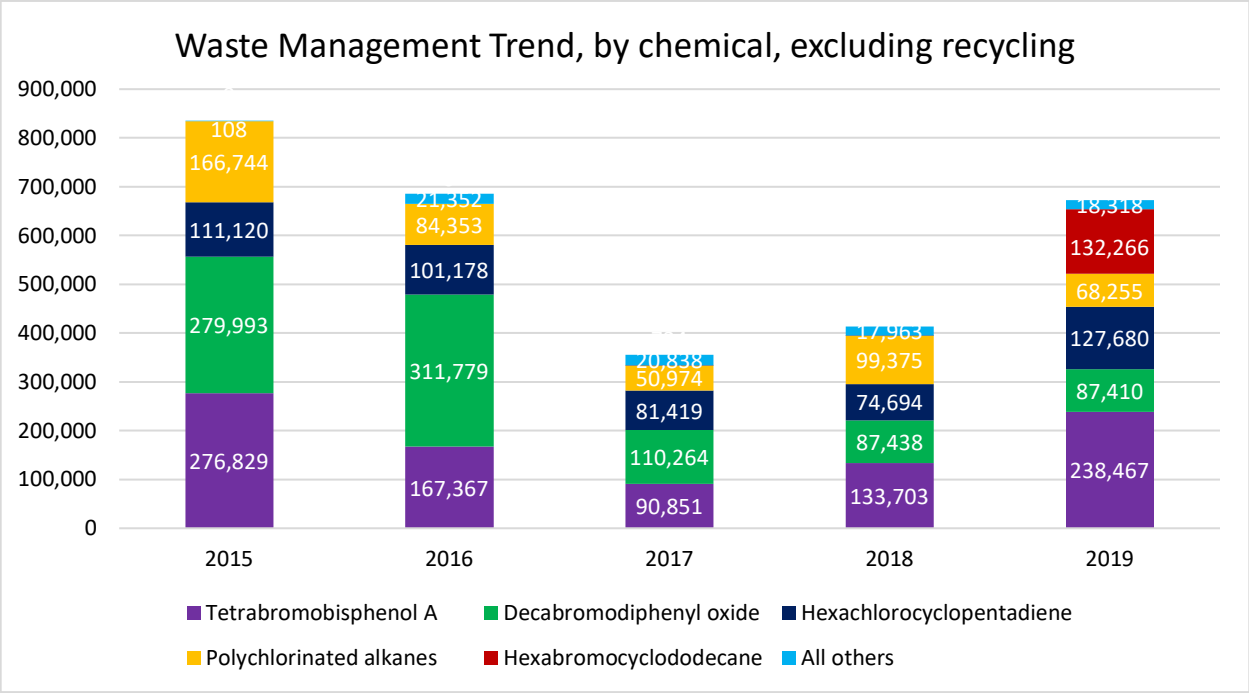
Quantities of OFR chemicals recycled (not shown in Exhibit 3-12) ranged from about 150 thousand pounds to about 320 thousand pounds from 2015 through 2018, but increased to over 2.27 million pounds in 2019, due to one facility reporting 2.2 million pounds of tetrabromobisphenol A (TBBPA) recycled in 2019.

EXHIBIT 3-12. DISPOSAL/RELEASE, ENERGY RECOVERY, AND TREATMENT OF TRI OFRS, 2015-2019



*Hexabromocyclododecane reporting began in RY2017.
Data source: TRI National Analysis dataset published October 2020

EXHIBIT 3-13. WASTE MANAGEMENT OF TRI-REPORTABLE OFR CHEMICALS, EXCLUDING RECYCLING, BY CHEMICAL



*Reporting for hexabromocyclododecane began in RY2017.
Data source: TRI National Analysis dataset published October 2020

Key trends for these chemicals include:

- For Tetrabromobishphenol A, the amount of TRI-reported waste managed fell from 277,000 pounds in 2015 to 91,000 pounds in 2018, but has since increased to 238,000 pounds in 2019.
- The quantity of waste managed for decabromodiphenyl oxide has fallen, going from around 300,000 pounds in 2015 and 2016 to under 100,000 pounds in 2018 and 2019.
- Polychlorinated alkanes waste has also declined, going from 167,000 pounds in 2015 to below 100,000 pounds in each of the following four years.
- Reporting for hexabromocyclododecane, which began in 2017, was under 1,000 pounds in 2017 and 2018 but increased to 132,000 pounds in 2019.

Other Information

Exhibit 3-14 shows the number of forms filed for each TRI-reportable OFR each year from 2015-2019. For many chemicals, the number of forms filed has remained about the same each year. Overall, the number of forms filed for OFRs has decreased from 2015 to 2019, driven by decreases in the number of forms filed for decaBDE (1,1'-oxybis[2,3,4,5,6-pentabromobenzene]).

EXHIBIT 3-14. TREND IN TRI FORMS SUBMITTED BY CHEMICAL, 2015-2019

CATEGORY	CHEMICAL NAME	2015	2016	2017	2018	2019	GRAND TOTAL
Polyhalogenated alicycles	Hexachlorocyclopentadiene	8	8	6	5	6	33
	Hexabromocyclododecane			4	1	3	8
Polyhalogenated aliphatic chains	Pentaerythritol dibromide	2	2	2	3	3	12
	C10-13 chloro alkanes	7	4	2	9	6	28
Polyhalogenated bisphenol aliphatics and functionalized	3,3',5,5'-Tetrabromobisphenol A / TBBPA	56	58	54	50	54	272
Polyhalogenated carbocycles	Chlorendic acid						0
	1,2,3,4,5,6,7,8-Octachloronaphthalene					1	1
Polyhalogenated organophosphates	Tris(2,3-dibromopropyl) phosphate	1	1	1	1	1	5
Polyhalogenated diphenyl ethers	1,1'-Oxybis[2,3,4,5,6-pentabromobenzene] / decaDBE	30	24	17	16	11	98
Polyhalogenated Benzenes	Polybrominated biphenyls (PBB)					1	1
Total	Total	104	97	86	85	86	458

* Reporting for HBCD began in 2017
Data source: TRI National Analysis dataset published October 2020.

The number of forms filed for a chemical can be used to calculate a minimum value for the amount of that chemical used by TRI facilities. For facilities submitting Form Rs, the facility must indicate whether they manufacture, process, or otherwise use the chemical. For most chemicals, the reporting threshold for otherwise use is 10,000 pounds, while the reporting thresholds for manufacture and for processing are each 25,000 pounds. Assuming facilities only report to TRI if required (i.e., all reporting facilities reached an activity threshold), minimum national usage quantities can be calculated for each chemical (see Exhibit 3-15). This assumes that all forms reporting a chemical of special concern used exactly 100 pounds of that chemical; forms reporting otherwise use of a chemical and Form A's (which do not include activity codes) used exactly 10,000 pounds of that chemical; and forms reporting only manufacturing and/or processing used exactly 25,000 pounds of that chemical. This may substantially underestimate actual usage of these chemicals but represents the minimum usage of these chemicals by TRI-reporting facilities.

EXHIBIT 3-15. MINIMUM USAGE QUANTITY OF OFRS BASED ON TRI REPORTING, REPORTING YEAR 2019

CATEGORY	CHEMICAL NAME	CALCULATED MINIMUM USAGE QUANTITIES, LBS, RY19
Polyhalogenated alicycles	Hexachlorocyclopentadiene	120,000
	Hexabromocyclododecane	300
Polyhalogenated aliphatic chains	Pentaerythritol dibromide	60,000
	C10-13 chloro alkanes	90,000
Polyhalogenated bisphenol aliphatics and functionalized	3,3',5,5'-Tetrabromobisphenol A	5,400
Polyhalogenated organophosphates	Tris(2,3-dibromopropyl) phosphate	10,000
Polybrominated diphenyl ethers (PBDEs)	1,1'-Oxybis[2,3,4,5,6-pentabromobenzene]	230,000
Polyhalogenated carbocycles	Chlorendic acid	0
	1,2,3,4,5,6,7,8-Octachloronaphthalene	10,000
Polyhalogenated Benzenes	Polybrominated biphenyls (PBB)	10,000
Data source: TRI National Analysis dataset published October 2020.		

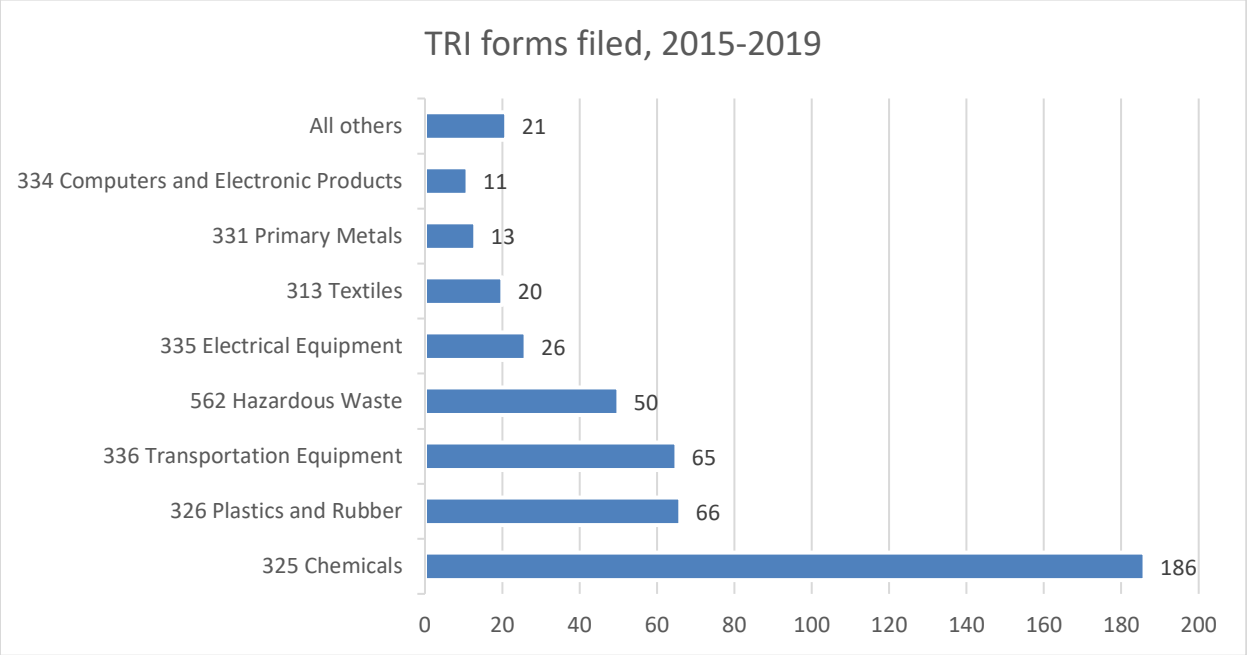
3.2.3.7 TRI Reporting by NAICS Industry Sector

TRI collects information on facilities' industry as six-digit NAICS codes, in section 4 of Form R. TRI does not require facilities to report the products manufactured at the facility. Facilities in the chemical manufacturing sector (NAICS 325) reported for OFR chemicals more than any other sector, representing 41 percent of all forms filed for these chemicals from 2015 to 2019. Of forms filed by chemical manufacturing facilities, over half were from facilities in the plastics material and resin manufacturing sector (NAICS 325111) and custom compounding of purchased resins sector (NAICS 325991), representing 24% of all TRI forms filed for these chemicals from 2015-2019.

Another 14% of all forms were submitted by facilities in the plastics and rubber sector (NAICS 326). Other uses of OFRs relevant to products under CPSC jurisdiction could include textiles and furniture. From 2015 through 2019, 20 forms were submitted for OFRs from facilities in the textile mill sector (NAICS 313), but no forms were submitted from facilities in the textile product mill sector (NAICS 314) or the furniture and related product manufacturing sector (NAICS 337). The sectors reporting OFRs to TRI have been fairly consistent from 2015 through 2019.

Recall, facilities manufacturing these products may be using OFRs but may not be required to report to TRI if they: employ fewer than 10 full-time equivalent employees, use OFRs in less than threshold quantities, or use OFRs in articles or at concentrations below *de minimis.* Furthermore, for products imported into the United States, importing facilities may not be required to report if they are not in TRI-covered sectors or if they are importing articles.

EXHIBIT 3-16. TRI FORMS FILED FOR OFR CHEMICALS, BY NAICS INDUSTRY SECTOR



Data source: TRI National Analysis dataset published October 2020.

3.2.4 OFR PROCESSING AND END USES

3.2.4.1 Chemical Data Reporting Under TSCA

In addition to disclosing their manufacturing or importing activity, CDR submitters are required to identify how and where the substances they manufacture or import are used, to the extent they have knowledge of such uses. For each substance manufactured or imported, they may report on up to ten downstream uses. In 2015, 172 of these use reports were submitted on 37 OFR substances. Exhibit 3-17 shows the "Type of Processing or Use" (TPU) status reported for these substances. It indicates that the majority of uses (110 of 172) involved incorporating the substance into a formulation, mixture, or reactant product. An additional 23 reports involved incorporation of the substance into an article, and 19 involved processing as a reactant.

Exhibit 3-18 shows the "Industrial Sector Use" (IS) status reported for each substance. It indicates that the most common reported uses for OFRs were in plastic product manufacturing, plastic material and resin manufacturing, chemical manufacturing, and construction, although a large number of uses were classified as "other." Textiles and furniture accounted for some OFR uses as well.

The "Industrial Function" for CDR substances refers to the function the substance serves in a particular TPU and IS combination the submitter is reporting on. Exhibit 3-19 shows the distribution of reports by industrial function. Not surprisingly, "Flame Retardant" is the most common industrial function reported, accounting for 115 of 172 reports, or 67 percent of the total. The table does show, however, that OFRs are used for functions other than flame retardancy.

EXHIBIT 3-17. TYPE OF PROCESSING OR USE REPORTED, 2015

OFR CLASS	PROCESSING AS A REACTANT	PROCESSING—INCORPORATION INTO ARTICLE	PROCESSING—INCORPORATION INTO FORMULATION, MIXTURE, OR REACTION PRODUCT	PROCESSING—REPACKAGING	USE—NON-INCORPORATIVE ACTIVITIES	CBI	NKRA	GRAND TOTAL
Polyhalogenated alicycles	2	7	6					15
Polyhalogenated aliphatic chains	1	1	42	1		8	1	54
Polyhalogenated benzene aliphatics and functionalized		4	7		2	3		16
Polyhalogenated bisphenol aliphatics and functionalized	3	5	10					18
Polyhalogenated carbocycles			6	1			1	8
Polyhalogenated organophosphates	4		22			1	1	28
Polyhalogenated phenol derivatives	2	1						3
Polyhalogenated phthalates/benzoates/imides	6	4	14	1				25
Polyhalogenated diphenyl ethers		1	2					3
Polyhalogenated phenol-aliphatic ether	1							1
Polyhalogenated triazines			1					1
Grand Total	19	23	110	3	2	12	3	172

CBI = Confidential Business Information
NKRA = Not known or reasonably ascertainable

EXHIBIT 3-18. INDUSTRIAL SECTOR USE REPORTED, 2015

OFR Class	Chemical Manufacturing	Construction	Furniture and Related Product Manufacturing	Paint and Coating Manufacturing	Plastic Material and Resin Manufacturing	Plastics Product Manufacturing	Textiles, Apparel, and Leather Manufacturing	Other	NKRA	CBI	Grand Total
Polyhalogenated alicycles	1	9			3	1		1			15
Polyhalogenated aliphatic chains	5		1	8	3	7	4	17	1	8	54
Polyhalogenated benzene aliphatics and functionalized					4	6	1	1		4	16
Polyhalogenated bisphenol aliphatics and functionalized	2				4	4	1	7			18
Polyhalogenated carbocycles				1	1			1	1	4	8
Polyhalogenated organophosphates	2	9	3		4	3	2	2	1	2	28
Polyhalogenated phenol derivatives	2							1			3
Polyhalogenated phthalates/benzoates/imides	7	1	4	1	3	7		2			25
Polyhalogenated diphenyl ethers						1	2				3
Polyhalogenated phenol-aliphatic ether	1										1
Polyhalogenated triazines						1					1
Grand Total	20	19	8	10	22	30	10	32	3	18	172

CBI = Confidential Business Information
NKRA = Not known or reasonably ascertainable

Exhibits 3-20 and 3-21 take a closer look at substances reported to be serving the "industrial function" of flame retardant, using data from the 2006, 2012, and 2016 CDR. Exhibit 3-20 shows that such substances were about equally divided between OFRs and non-OFRs in 2005, but the non-OFR share of these increased in 2011, to 78 percent, and then again in 2015, to 83 percent. A similar increase in the non-OFR share of use reports can be seen between 2005 and 2011 (growing from 41 to 78 percent), although both the share and the number of non-OFR reports decrease slightly in 2015 (Exhibit 3-21).

EXHIBIT 3-19. INDUSTRIAL FUNCTION REPORTED, 2015

Row Labels	Adhesives and Sealant Chemicals	Cartridge Materials	Finishing Agents	Flame Retardants	Industrial Manufacturing	Intermediates	Lubricants and Lubricant Additives	Other	Paint Additives and Coating Additives Not Described by Other	Plasticizers	Processing Aids, Not Otherwise Listed	Processing Aids, Specific to Petroleum Production	CBI	NKRA	Grand Total
Polyhalogenated alicycles				12		2		1							15
Polyhalogenated aliphatic chains				33		1	7		2	1		1	8	1	54
Polyhalogenated benzene aliphatics and functionalized		1		11									4		16
Polyhalogenated bisphenol aliphatics and functionalized				13	1	3					1				18
Polyhalogenated carbocycles				6		1								1	8
Polyhalogenated organophosphates	2		1	19		1			2				2	1	28
Polyhalogenated phenol derivatives				1		2									3
Polyhalogenated phthalates/benzoates/imides	1			16		4				3	1				25
Polyhalogenated diphenyl ethers				3											3
Polyhalogenated phenol-aliphatic ether						1									1
Polyhalogenated triazines				1											1
Grand Total	3	1	1	115	1	15	7	1	4	4	2	1	14	3	172

CBI = Confidential Business Information
NKRA = Not known or reasonably ascertainable

EXHIBIT 3-20. NUMBER OF OFRS AND NON-OFRS REPORTED TO BE USED AS FLAME RETARDANT, 2005, 2011, 2015

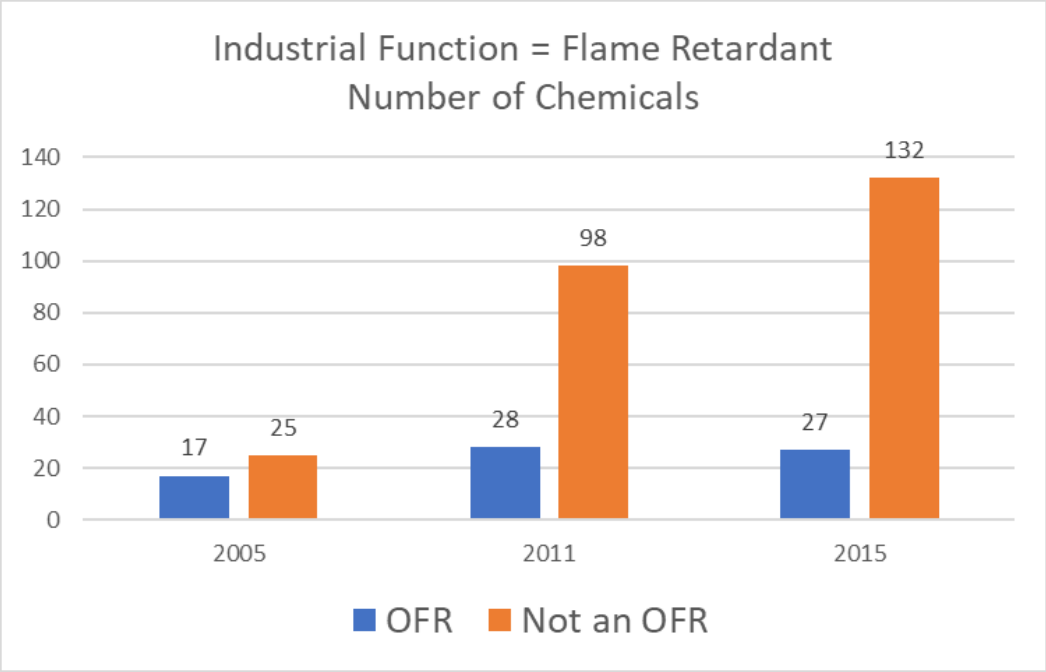
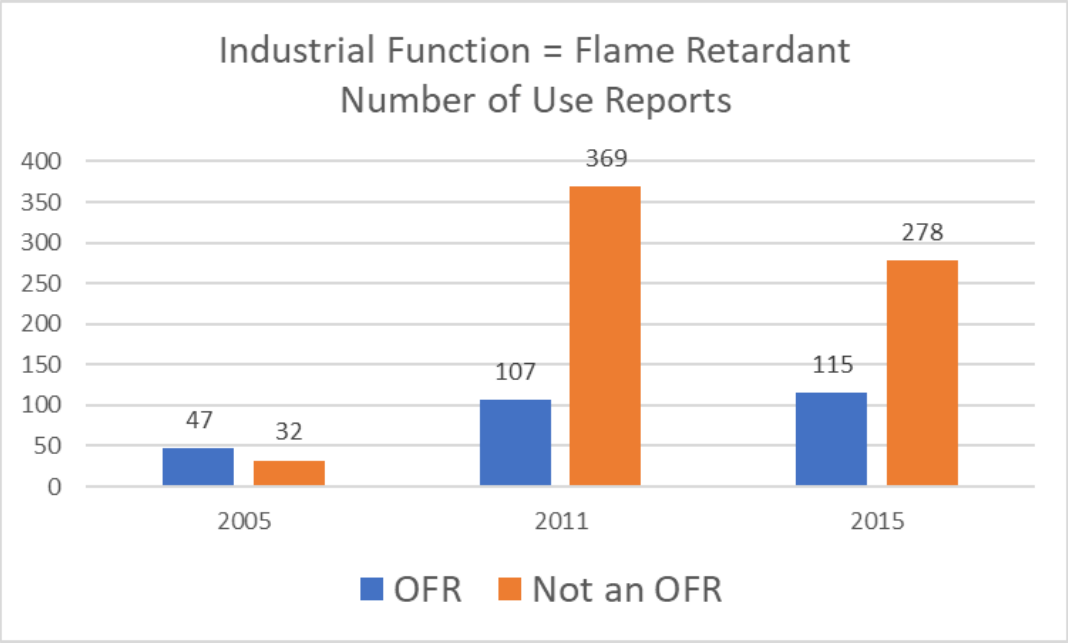


EXHIBIT 3-21. NUMBER OF FLAME RETARDANT USE REPORTS, OFRS AND NON-OFRS, 2005, 2011, 2015



3.2.5 IDENTIFYING USES IN CONSUMER OR CHILDREN'S PRODUCTS

To determine whether individual OFR chemicals are used in consumer and/or children's products, we reviewed two sources, information available from the EPA's CDR and the High Priority Chemicals Data System (HPCDS). The 2016 CDR data contain consumer use information, including chemical-specific product categories, and also indicate whether the chemical was used in products intended for children. The HPCDS is an online platform that supports reporting information on the presence of chemicals of concern in children's products, required by the Oregon Toxic-Free Kids Act (TFKA) and the Washington Children's Safe Products Act (CSPA). Another resource available for identifying the use of hazardous OFR chemicals in consumer and children's products would be the SCIP database. SCIP is the database for information on Substances of Concern In articles or in complex objects (Products), established under the Waste Framework Directive of the European Chemicals Agency (ECHA). SCIP data was first released in September 2021 and could not be reviewed in time for publication of this report.

3.2.5.1 Chemical Data Reporting Under TSCA

Chemical manufacturers and importers are encouraged to report, as part of their CDR submissions, whether the substances they are reporting are known to be used in products intended for use by consumers or children. In 2015, there were 120 consumer/child product use disclosures for OFR substances. This included 34 reports of OFR use in a consumer (or consumer/commercial) product and six reports of OFR use in a children's product. The six reports of OFR use in children's products likely undercounts the actual number of child product uses for a variety of reasons. For example, manufacturers and importers can report product use information as CBI, or report that such product use cannot be reasonably known or ascertained, when in fact the chemical is used in children's products. The specific OFRs for which reports of consumer or child use were submitted are shown in Exhibit 3-22. Exhibit 3-23 shows the distribution of these reports by product category.

Electrical and electronic products account for 12 of 34 consumer use reports and four of six child use reports. Foam seating and bedding products account for five consumer use reports as well as the two remaining child use reports. Additional consumer uses are reported in the remaining product categories: building/construction materials (6 reports), plastic and rubber products (4 reports), fabric, textile, and leather products (2 reports), insulating foam (1 report) and adhesives and sealants (1 report). An additional three consumer use reports claimed the product category as CBI.

Exhibit 3-24 shows report details for the 34 consumer reports and six child product reports submitted. In four instances, manufacturers and importers of children's products report that use of the chemical in children's products is not known or cannot be reasonably ascertained (NKRA). This is likely due to a lack of complete communication across the supply chain when the end-use of the chemical is for use in a consumer or children's product. To this end, stakeholders have indicated a need to increase information sharing throughout the supply chain and improve chemical tracking information for the use of retailers and consumers when chemical substances, especially hazardous ones, are used in consumer or children's products.

EXHIBIT 3-22. CONSUMER AND CHILD USE REPORTS, 2015

OFR CLASS AND CAS NO.	NUMBER OF CONSUMER USE PRODUCT REPORTS	NUMBER OF CHILD PRODUCT USE REPORTS
Polyhalogenated alicycles	2	
25637-99-4	1	
3194-55-6	1	
Polyhalogenated aliphatic chains	2	
36483-57-5	1	
63449-39-8	1	
Polyhalogenated benzene aliphatics and functionalized	9	
84852-53-9	9	1
Polyhalogenated bisphenol aliphatics and functionalized	4	
79-94-7	4	2
Polyhalogenated carbocycles	3	
13560-89-9	3	
Polyhalogenated organophosphates	8	
13674-84-5	6	
13674-87-8	2	
Polyhalogenated phthalates/benzoates/imides	6	
183658-27-7	1	1
26040-51-7	5	1
Grand Total	**34**	**6**

EXHIBIT 3-23. CONSUMER AND CHILD USE REPORTS, BY PRODUCT CATEGORY, 2015

PRODUCT CATEGORY	NUMBER OF CONSUMER USE PRODUCT REPORTS	NUMBER OF CHILD PRODUCT USE REPORTS
Electrical and electronic products	12	4
Building/construction materials not covered elsewhere	6	
Foam seating and bedding products	5	2
Plastic and rubber products not covered elsewhere	4	
Fabric, textile, and leather products not covered elsewhere	2	
Insulating foam	1	
Adhesives and sealants	1	
CBI	3	
Grand Total	**34**	**6**

EXHIBIT 3-24. CONSUMER AND CHILD USE DETAILED REPORTS, 2015

OFR CLASS	CAS NO.	PRODUCT CATEGORY	USE IN CONSUMER PRODUCT	USE IN CHILD PRODUCT	PERCENT OF USE	MAX CONCENTRATION
Polyhalogenated alicycles	25637-99-4	Building/construction materials not covered elsewhere	Consumer and commercial	No	CBI	At least 90% by weight
Polyhalogenated alicycles	3194-55-6	Building/construction materials not covered elsewhere	Consumer	No	1	At least 1 but less than 30% by weight
Polyhalogenated aliphatic chains	36483-57-5	Foam seating and bedding products	Consumer and commercial	NKRA	100	At least 60 but less than 90% by weight
Polyhalogenated aliphatic chains	63449-39-8	Plastic and rubber products not covered elsewhere	Consumer and commercial	No	100	At least 90% by weight
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	CBI	Consumer and commercial	No	CBI	CBI
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	CBI	Consumer and commercial	No	CBI	CBI
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	Electrical and electronic products	Consumer and commercial	No	100	At least 1 but less than 30% by weight
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	Electrical and electronic products	Consumer and commercial	No	22	At least 30 but less than 60% by weight
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	Building/construction materials not covered elsewhere	Consumer and commercial	No	6	At least 30 but less than 60% by weight
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	Electrical and electronic products	Consumer and commercial	Yes	100	At least 1 but less than 30% by weight
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	Fabric, textile, and leather products not covered elsewhere	Consumer and commercial	No	1	NKRA
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	Electrical and electronic products	Consumer and commercial	No	80	NKRA
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	Plastic and rubber products not covered elsewhere	Consumer and commercial	No	19	NKRA
Polyhalogenated bisphenol aliphatics and functionalized	79-94-7	Electrical and electronic products	Consumer and commercial	Yes	40	At least 1 but less than 30% by weight
Polyhalogenated bisphenol aliphatics and functionalized	79-94-7	Electrical and electronic products	Consumer and commercial	No	100	At least 1 but less than 30% by weight
Polyhalogenated bisphenol aliphatics and functionalized	79-94-7	Electrical and electronic products	Consumer and commercial	No	51	At least 30 but less than 60% by weight
Polyhalogenated bisphenol aliphatics and functionalized	79-94-7	Electrical and electronic products	Consumer and commercial	Yes	40	At least 1 but less than 30% by weight

OFR CLASS	CAS NO.	PRODUCT CATEGORY	USE IN CONSUMER PRODUCT	USE IN CHILD PRODUCT	PERCENT OF USE	MAX CONCENTRATION
Polyhalogenated carbocycles	13560-89-9	Building/construction materials not covered elsewhere	Consumer and commercial	No	CBI	At least 1 but less than 30% by weight
Polyhalogenated carbocycles	13560-89-9	Electrical and electronic products	Consumer and commercial	No	CBI	At least 1 but less than 30% by weight
Polyhalogenated carbocycles	13560-89-9	Plastic and rubber products not covered elsewhere	Consumer and commercial	No	CBI	At least 1 but less than 30% by weight
Polyhalogenated organophosphates	13674-84-5	Building/construction materials not covered elsewhere	Consumer	No	5	At least 1 but less than 30% by weight
Polyhalogenated organophosphates	13674-84-5	Foam seating and bedding products	Consumer and commercial	NKRA	50	At least 1 but less than 30% by weight
Polyhalogenated organophosphates	13674-84-5	Electrical and electronic products	Consumer and commercial	NKRA	50	At least 1 but less than 30% by weight
Polyhalogenated organophosphates	13674-84-5	Insulating foam	Consumer and commercial	No	100	At least 1 but less than 30% by weight
Polyhalogenated organophosphates	13674-84-5	Building/construction materials not covered elsewhere	Consumer and commercial	No	100	At least 1 but less than 30% by weight
Polyhalogenated organophosphates	13674-84-5	Adhesives and sealants	Consumer and commercial	No	CBI	CBI
Polyhalogenated organophosphates	13674-87-8	Foam seating and bedding products	Consumer and commercial	NKRA	100	At least 30 but less than 60% by weight
Polyhalogenated organophosphates	13674-87-8	CBI	Consumer and commercial	No	100	At least 1 but less than 30% by weight
Polyhalogenated phthalates/ benzoates/imides	183658-27-7	Foam seating and bedding products	Consumer and commercial	Yes	100	At least 1 but less than 30% by weight
Polyhalogenated phthalates/ benzoates/imides	26040-51-7	Fabric, textile, and leather products not covered elsewhere	Consumer and commercial	No	NKRA	NKRA
Polyhalogenated phthalates/ benzoates/imides	26040-51-7	Electrical and electronic products	Consumer and commercial	No	NKRA	NKRA
Polyhalogenated phthalates/ benzoates/imides	26040-51-7	Plastic and rubber products not covered elsewhere	Consumer and commercial	No	NKRA	NKRA
Polyhalogenated phthalates/ benzoates/imides	26040-51-7	Foam seating and bedding products	Consumer and commercial	Yes	25	At least 1 but less than 30% by weight
Polyhalogenated phthalates/ benzoates/imides	26040-51-7	Electrical and electronic products	Consumer and commercial	Yes	75	At least 1 but less than 30% by weight
NKRA = Not known or reasonably ascertainable						

3.2.5.2 High Priority Chemicals Data System

The HPCDS is an online platform that is operated by the Interstate Chemicals Clearinghouse (IC2), a project of the Northeast Waste Management Officials (NEWMOA). HPCDS provides public access to information reported by companies. The HPCDS has operated since 2012 and currently, reporting requirements under the TFKA and CSPA cover 80 OFRs. Manufacturers or importers must report the presence and use of these OFRs and other chemicals of concern in children's products offered for sale in Washington or Oregon.[13]

By using a centralized platform, the HPCDS helps to reduce the manufacturer's reporting burden. Broadly, the HPCDS provides four main functions and features, (1) company registration, (2) company profile, (3) reporting tools, and (4) product search functions. To report the use of a chemicals of concern in a children's products offered for sale, manufacturers and importers are provided drop down fields for reporting the product brick[14], component, chemical of concern, chemical function, and concentration category.

While informative, the HPCDS data on children's product containing chemicals of concern is not suitable for use by parents interested in making informed purchasing decisions. Parents would not be able to accurately or definitively identify which baby products, clothing and accessories, or toys for children contain chemicals of concern, and which do not, by reviewing the database.

HPCDS identifies substantially more uses of OFR chemicals in children's products than are reported in the CDR. Exhibit 3-25 shows the number of OFRs reported on by year, followed by the number of reports submitted for those OFRs. Since 2016, manufacturers and importers of children's products have made over 100 reports each year of potentially hazardous OFR chemicals being used in children's products. 2017 was the largest reporting year, when manufacturers and importers submitted a total of 350 reports. In the most recent full reporting year, 2019, manufacturers and importers reported on 13 OFRs across 7 OFR classes, and submitted 226 reports. Substances accounting for the highest number of reports in 2019 included:

- Alkanes, C10-13, chloro (CAS No. 85535-84-8), 83 reports
- Tetrabromobisphenol A (CAS No. 79-94-7), 40 reports
- Chlorinated paraffins (CAS No. 108171-26-2), 22 reports
- Tris(1-chloro-2-propyl) phosphate (CAS No. 13674-84-5), 19 reports

Similar to CDR, reporters to the HPCDS must indicate the function each reportable chemical serves in the product where it is present. Exhibit 3-26 shows the distribution of reports, in this case across all reporting years, by function. Not surprisingly, "Flame retardant" is the most frequently listed function, representing

[13] Recently, the IC2 has added State Chemical Lists from California, Maine, Minnesota, Oregon, Vermont, and Washington. These lists identify candidate chemicals, chemicals of concern to children, and high priority chemicals. These chemical lists will be discussed in a separate section of this report.

[14] HPCDS refers to each end product category as a product "brick." "Brick" refers to the "brick" level of the GS1Global Product Classification (GPC) standard, which identifies products that serve a common purpose, are of a similar form and material, and share the same set of attributes. For more information, see https://www.gs1.org/standards/gpc/how-gpc-works andhttps://www.gs1.org/services/gpc-browser.

39 percent of all reports, or 64 percent of reports, if reports indicating the subject chemical is only present as a contaminant are excluded.

EXHIBIT 3-25. OFR REPORTING UNDER THE HPCDS, 2012-2020

OFR CLASS	2012	2013	2014	2015	2016	2017	2018	2019	2020[1]
NUMBER OF OFRS									
Polyhalogenated alicycles		1	1	1	1	1	1	1	1
Polyhalogenated aliphatic chains						2	2	2	2
Polyhalogenated benzene aliphatics and functionalized							1	1	1
Polyhalogenated bisphenol aliphatics and functionalized		1	1	1	1	1	1	1	1
Polyhalogenated diphenyl ethers	1	1	1	1	1	1	1	1	1
Polyhalogenated organophosphates		1	2	2	2	2	3	5	3
Polyhalogenated phthalates/ benzoates/imides							2	2	1
Total	1	4	5	5	5	7	11	13	10
NUMBER OF REPORTS									
Polyhalogenated alicycles		2	16	1	29	63	4	8	3
Polyhalogenated aliphatic chains						5	50	105	46
Polyhalogenated benzene aliphatics and functionalized							7	10	5
Polyhalogenated bisphenol aliphatics and functionalized		25	28	13	40	71	20	40	9
Polyhalogenated diphenyl ethers	1	7	27	10	30	82	8	17	4
Polyhalogenated organophosphates		1	21	6	55	129	20	38	12
Polyhalogenated phthalates/benzoates/imides							16	8	1
Total	1	35	92	30	154	350	125	226	80

[1] Partial year reporting.
Source: High Priority Chemical Data System, Interstate Chemicals Clearinghouse.

Exhibit 3-26 shows the distribution of the 424 reports that indicated "flame retardant" as the function of the chemical, by chemical concentration in the children's use product, between 2012 and 2020. Over the period, decaBDE (CAS No. 1163-19-5) was one of the most reported OFR chemicals of concern in children's products, reported 91 times for use as a flame retardant.[15]

[15] DecaBDE is classified within the OFR subclass of polyhalogenated diphenyl ethers.

EXHIBIT 3-26. OFR REPORTS BY FUNCTION, 2012-2020

OFR Class	Adhesive	Catalyst	Coloration/Pigments/ Dyes/Inks	Component of Plastic Resin or Polymer Process	Dispersant	Flame Retardant	Lubricant	Manufacturing Additive (to Facilitate Manufacturing Process)	No Function - Contaminant	Physical Characteristics (Abrasive Quality, Reflecting Agent, Electronic Connectivity, etc.)	Plasticizer/Softener	Protective Coating	Solvent	Source Contaminant	Stabilizers	Total
Polyhalogenated alicycles			18	3		63	1	4	37							126
Polyhalogenated aliphatic chains	11		8			10		2	156		19					206
Polyhalogenated benzene aliphatics and functionalized						10			11		1					22
Polyhalogenated bisphenol aliphatics and functionalized	4	1	40	15		84		4	94						4	246
Polyhalogenated diphenyl ethers			19	1		91		5	60	2		3	1	1	3	186
Polyhalogenated organophosphates			36	7	2	163		15	56		1			2		282
Polyhalogenated phthalates/benzoates/ imides						3			17		5					25
Totals	15	1	121	26	2	424	1	30	431	2	26	3	1	3	7	1,093

Source: High Priority Chemical Data System, Interstate Chemicals Clearinghouse.

Exhibit 3-27 shows the number of reports by industry of OFR use in children's products, when the intended use of the chemical is for flame retardancy, and for a variety of chemical concentrations. In total, there have been 46 reports of concentrations in excess of 1,000 ppm (0.1 percent), a threshold CPSC staff considers to be above the level of contaminant. A total of nine different OFRs are represented in these 46 reports:

- CAS No. 79-94-7: 12 reports
- CAS No. 13674-84-5: 12 reports
- CAS No. 1163-19-5: 8 reports
- CAS No. 84852-53-9: 3 reports
- CAS No. 25637-99-4: 3 reports
- CAS No. 13674-87-8: 3 reports
- CAS No. 108171-26-2: 2 reports
- CAS No. 85535-84-8: 2 reports
- CAS No. 115-96-8: 1 report

EXHIBIT 3-27. CONCENTRATION OF OFRS IN PRODUCT WHEN USED AS FLAME RETARDANT, NUMBER OF REPORTS, 2012-2020

OFR CLASS	EQUAL TO OR GREATER THAN 10,000 PPM	EQUAL TO OR GREATER THAN 5,000 BUT LESS THAN 10,000 PPM	EQUAL TO OR GREATER THAN 1,000 BUT LESS THAN 5,000 PPM	EQUAL TO OR GREATER THAN 500 BUT LESS THAN 1,000 PPM	EQUAL TO OR GREATER THAN 100 BUT LESS THAN 500 PPM	PQL TO LESS THAN 100 PPM	TOTAL
Polyhalogenated alicycles			3		2	58	63
Polyhalogenated aliphatic chains			4	2	4		10
Polyhalogenated benzene aliphatics and functionalized			3	5		2	10
Polyhalogenated bisphenol aliphatics and functionalized	12			6	7	59	84
Polyhalogenated diphenyl ethers	5		3		13	70	91
Polyhalogenated organophosphates	6	4	6	3	19	125	163
Polyhalogenated phthalates/benzoates/imides					1	2	3
Total	23	4	19	16	46	316	424

Source: High Priority Chemical Data System, Interstate Chemicals Clearinghouse.

Exhibit 3-28 shows these 46 reports distributed by end-product category, referred to previously as "the product brick". The table shows that reports are distributed across a variety of children's product categories: arts and crafts, baby products, clothing and accessories, and toys. The most common end product categories for children's products that contain OFR chemicals are arts/crafts variety packs and toy vehicles – non-ride (powered), followed by dolls/soft toys (non-powered).

- Finally, HPCDS also requires reporters to indicate the "component" of each product where the reportable chemical is found. This information is important to consider when assessing the exposure pathway of the potentially harmful OFR chemical to the child. Among these 46 reports, the OFRs are most commonly present in:
- Synthetic polymers (synthetic rubber, plastics, foams, etc.) 30 reports
- Textiles (synthetic fibers and blends) 15 reports
- Surface coatings (paints, plating, waterproofing) 1 report

EXHIBIT 3-28. OFRS USED AS FLAME RETARDANT AT CONCENTRATIONS ABOVE 1,000 PPM, REPORTS BY PRODUCT CATEGORY, 2012-2020

OFR Class	Artists Accessories	Artists Painting/Drawing Supplies Other	Arts/Crafts Variety Packs	Baby Car/Booster Seats	Baby Carrier	Baby Feeding Accessories	Baby Play Pens/Dens	Baby Safety Protection (Non Powered)	Baby Swings	Camping Tents	Dolls/Soft Toys (Non Powered)	Fancy Dress Accessories (Non Powered)	Outdoor Play Structures	Role Play - Housekeeping/Gardening/DIY Toys	Shoes - General Purpose	Toy Vehicles - Non-Ride (Non Powered)	Toy Vehicles - Non-Ride (Powered)	Toys - Ride-On (Powered)	Toys/Games - Other	Grand Total
Polyhalogenated alicycles				1								1				1				3
Polyhalogenated aliphatic chains											4									4
Polyhalogenated benzene aliphatics and functionalized								1			1							1		3
Polyhalogenated bisphenol aliphatics and functionalized				1	1	2	1		1								6			12
Polyhalogenated diphenyl ethers	2												2	1	3					8
Polyhalogenated organophosphates		3	6							3			2	1					1	16
Grand Total	**2**	**3**	**6**	**2**	**1**	**2**	**1**	**1**	**1**	**3**	**5**	**1**	**4**	**2**	**3**	**1**	**6**	**1**	**1**	**46**

Source: High Priority Chemical Data System, Interstate Chemicals Clearinghouse.

Exhibit 3-29 shows that chemicals of concern in children's products are most commonly reported to be found in synthetic polymers (such as synthetic rubber, plastics, foams, etc.) and in textiles (such as synthetic fibers and blends), when used as a flame retardant in concentrations greater than 1,000 ppm. TBBPA (CAS No. 79-94-7), TCPP (CAS No. 13674-84-5), decaBDE (CAS No. 1163-19-5), Chlorinated paraffins (CAS Nos. 85535-84-8 and 108171-26-2), and TDCPP (CAS No. 13674-87-8) are reported to be in both the synthetic polymers and the textiles of children's products, and used as flame retardants at these concentrations. HBCD (CAS No. 25637-99-4) is also reported by industry to be in the surface coatings (such as paints, plating, waterproofing, etc.) of children's products.

EXHIBIT 3-29. COMPONENT PARTS THAT CONTAIN A CHEMICAL OF CONCERN, IN CONCENTRATIONS EQUAL TO OR GREATER THAN 1,000 PPM, WHEN USED AS A FLAME RETARDANT IN A CHILDREN'S PRODUCT (2012-2020)

CHEMICAL (CAS NO.)	CHEMICAL ABBREVIATION	SYNTHETIC POLYMERS (SYNTHETIC RUBBER, PLASTICS, FOAMS, ETC.)	TEXTILES (SYNTHETIC FIBERS AND BLENDS)	SURFACE COATINGS PAINTS (PAINTS, PLATING, WATERPROOFING, ETC.)
79-94-7	TBBPA	X	X	
13674-84-5	TCPP	X	X	
1163-19-5	decaBDE	X	X	
25637-99-4	HBCD	X		X
85535-84-8	Alkanes, C10-13, chloro	X	X	
108171-26-2	Alkanes, C10-12, chloro	X	X	
84852-53-9	DBDPE	X		
13674-87-8	TDCPP	X	X	
115-96-8	TCEP		X	

3.2.5.3 The European Chemicals Agency SCIP database

The European Chemicals Agency (ECHA) maintains a database of information through the REACH regulation, which was enacted in 2007 to improve the protection of human health from risks posed by chemicals. REACH, which stands for Registration, Authorization and Restriction of Chemicals, applies to consumer products, such as chemical cleaners and disinfectants, paints, articles of clothing, furniture, and electrical appliances, as well as to the chemicals industry. REACH has established procedures for collecting and assessing information on chemicals and hazardous substances, with the goals of improved safety and a more complete understanding of the chemicals industry in Europe. Companies are required to register any toxic or hazardous substances, including a number of OFR chemicals, with the agency. ECHA receives and compiles the data made available from these registrations.

In addition, the REACH Regulation requires suppliers of articles (products) containing potentially hazardous chemicals, including OFRs, to communicate down the supply chain and to consumers sufficient information to allow for the safe use of those products that contain them. Any supplier of an article containing a substance of very high concern (SVHC) in a concentration above 0.1% weight by weight (w/w) on the EU market is required to submit information on that article to ECHA. This is

commonly referred to as a "SCIP notification". Suppliers of articles which contain an identified SVHC must also inform professional users and distributors of the article, within the supply chain, and consumers can request the product hazard information from the supplier. Upon this request, the supplier of the article containing the SVHC is obligated to provide information to the consumer, free of charge, on the product that contains the hazardous substance.

SCIP notifications have supported the development of the SCIP database. The SCIP database is an important tool of the REACH framework and helps ensure that information regarding the use of hazardous substances in products is more readily and efficiently shared within the supply chain, and that certain information regarding the use of hazardous substances in products is also available to the public. It makes available the product name and other product identifiers of articles containing SVHC that have been placed on the EU market. The SCIP database is available online and free to consumers and any concerned parties to search.

The SCIP database contains additional information on the use of OFR chemicals in consumer and children's products. However, as mentioned, SCIP data was first released in September 2021 and could not be reviewed in entirety, in time for the publication of this report. We are aware of the following potentially hazardous OFR chemicals included in the SCIP database, shown in Exhibit 3-30.

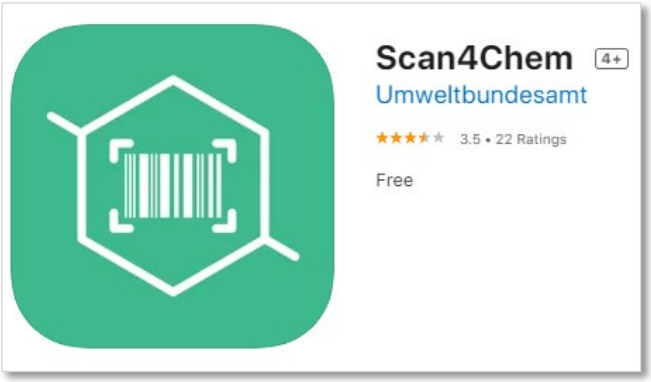
EXHIBIT 3-30. OFR CHEMICALS INCLUDED IN THE SCIP DATABASE

OFR SUBCLASS	CAS NO.
polyhalogenated alicycles	134237-52-8
	134237-51-7
	25637-99-4
	3194-55-6
	134237-50-6
polyhalogenated aliphatic chains	85535-85-9
	198840-65-2
	1372804-76-6
	1522-92-5
	96-13-9
	36483-57-5
	3296-90-0
	85535-84-8
polyhalogenated carbocycles	135821-03-3
	135821-74-8
	13560-89-9
polyhalogenated diphenyl ethers	1163-19-5
polyhalogenated organophosphates	115-96-8

3.2.5.4 SCAN4CHEM

On February 27, 2020, the Scan4Chem app launched in the EU. The Scan4Chem app makes it easier for consumers to get information from article suppliers about SVHC in articles. This right to information is made possible in Europe by the EU chemicals regulation, REACH Article 33. (The underlying consumers' "right to know" established in the EU chemicals regulation REACH Article 33(2) is discussed in a separate section of this report.)

The Scan4Chem app is used by consumers in Europe to automatically send SVHC requests to the appropriate article supplier, by scanning the product barcode on their mobile device. The information available from the supplier is then made available to the consumer directly, via the app. Since November 2019, the app has been downloaded more than 35,000 times. The app is not available for download in the United States.



App users in 12 countries have scanned 66,000 barcodes, and more than 5,000 requests have been sent by app users to article suppliers in Europe. Information about more than 17,000 products from roughly 170 different suppliers is currently available to users of the Scan4Chem app.

Real-time information available through the Scan4Chem app supports informed decision making by consumers and empowers them to make better informed purchasing decisions. Information available from the Scan4Chem app also increases consumer awareness of a potential exposure to harmful substances and can help the consumer to consciously evaluate consumer product choices.

Though we are not currently able to confirm, information for OFR chemicals used in articles is likely available from the Scan4Chem app, because certain OFR chemicals are considered SVHC by REACH and have been confirmed to be in consumer products listed in the SCIP database.

3.2.6 TARGETED LITERATURE SEARCH

The next step in developing the market use profile involved targeted searches for literature related to flame retardant markets generally, and to OFR subclasses and individual OFRs more specifically. These searches can be divided into two types. First, we identified and searched specific sources known or believed to include relevant material. These sources included specific databases, websites, or other online information repositories. Second, we conducted broader searches of internet-based sources using standard search tools (e.g., Google) and selected searches of commercial online literature databases.

3.2.6.1 Data Sources

As noted earlier, we began with a set of references and articles identified by CPSC staff, a combination of government sources and citations from the open literature. CPSC staff also provided results of a "forward search" of Bergman et. al. (2012), an important reference outlining a nomenclature system for OFRs. The forward search focused on subsequent articles that cited the Bergman article and discussed ten or more specific flame retardants. These were identified using the "Cited By" feature in Google Scholar. A final set of references included several reports presenting results of analysis of chemicals, including OFRs, found in products (e.g., children's products, products found in the home).

We conducted additional searches of individual websites identified during previous chemical market data efforts. Some of the principal sites searched are shown in Exhibit 3-31 below.

Finally, we conducted searches using the Dialog/Proquest commercial online search platform. Dialog Proquest is an online tool that provides access to literature citations and articles. It provides subscribers the ability to execute searches across multiple databases simultaneously. We executed searches using the broadest set of literature databases available through the Dialog Proquest platform. Exhibit 3-32 lists all 140 databases; a full description of each can be found at https://dialog.com/commercial-databases.

EXHIBIT 3-31. PARTIAL LIST OF DATA SOURCES SEARCHED

SITE	DESCRIPTION/CONTENTS
Sciencedirect.com	Scientific journals/articles, health focus
Researchgate.net	Scientific journals/articles
World Health Organization IARC Monographs monographs.iarc.who.int	Identification of carcinogenic hazards to humans; contain some production and use data
National Library of Medicine Hazardous Substances Data Bank https://pubchem.ncbi.nlm.nih.gov/source/11933	Toxicology-focused database; contains data on production volumes, chemical concentration info, manufacturing/import activity, products.
EPA Chemical and Products Database www.epa.gov/chemical-research/chemical-and-products-database-cpdat	Database mapping 49,000 chemicals to products they are used in, and their functions in those products. Part of EPA's CompTox Dashboard (see below).
Organization for Economic Cooperation and Development Chemical Safety Program OECD.org/chemicalsafety	The Chemical Safety and Biosafety program tracks developments in member countries related to chemical risk management.
Marketwatch.com	Provides access to market research reports for a wide variety of commodities, products, and services.
Independent Commodity Information Services ICIS.com	Tracks and reports chemical industry and market news/data.
Businesswire.com	General industry news, focused on press release distribution and regulatory disclosures.
EPA CompTox Dashboard comptox.epa.gov/dashboard	EPA site compiling information from many sources related to chemicals in commerce in the United States Includes data on exposure, production, and presence on U.S. and international regulatory lists.
Bromine Science and Environmental Forum BSEF.com	Trade association for organizations in the bromine industry.
European Brominated Flame Retardant Industry Panel EBFRIP.org	Organization of manufacturers of brominated flame retardants. Sector group of CEFIC, the European Chemical Industry Council.
Google Scholar https://scholar.google.com/	A Google search tool that indexes scholarly literature across multiple publishing formats and disciplines. It includes most peer-reviewed online academic journals and books, conference papers, theses and dissertations, preprints, abstracts, and technical reports.
Chemicalbook.com	Online chemical sourcing marketplaces (e-commerce).
Buyersguidechem.com	
Chemnet.com	
Alibaba.com	

EXHIBIT 3-32. DATA SOURCES SEARCHED USING DIALOG/PROQUEST

• ABI Inform • Adis Insight • Aerospace • Agricola • Agris • Aluminum Industry Abstracts • AMED • Analytical Abstracts • Animal Behavior • Ante • Aqualine • Asfa Aquaculture • Asfa Aquatic Pollution • Asfa Biological • Asfa Marine • Asfa Ocean • Australian Education Index • Biochemistry Abstracts • Biosis • Biosis Toxicology • Biotech Research • British Library Inside • British Nursing Index • Business and Industry • CAB Abstracts • Calcium Abstracts • Ceramic Abstracts • Chemical Business News	• Chemical Engineering Biotech • Chemical Safety • Chemoreception Abstracts • Civil Engineering • Clinical Trials • Clinical Trials Insight • Computer Info • Copper • Corrosion Abstracts • Covid19 • Current Contents • Daily Essentials • Derwent Drug File • Derwent Drug Registry • DH Data • Diogenes FDA Regulatory • Drug Information • Drugs of the Future • Earthquake • Ecology • EconLit • Ei Compendex • Ei Encompass Lit • EIS Digests • Electronics & Communications Abstracts • EMBASE • EM Care • Endocrinology Abstracts	• Engineering Materials Abstracts • Entomology Abstracts • Environmental Abstracts • Environmental Engineering Abstracts • ERIC • ESPICOM News • FDA News • Fluidex • Foodline Market • Foodline Product • Foodline Sciences • Food Science Tech • Gale Computer • Gale Health Periodicals • Gale New Product • Gale Newsletter • Gale Trade and Industry • Genetic Abstracts • Geobase • Geo Refi • Global Health • Health Research • Health Safety Abstracts • HSE Line • Human Genome Abstracts • International Construction Database • Immunology Abstracts • IMS Company	• IMS New Product • IMS Pharma • IMS R and D Focus • IMS R and D Focus Drug • Inspec • Investext Premium • Investext Standard • IPAB • Janes Defense • Kings Fund • Kosmet • Lancet • Material Safety • Materials Business File • Medline • Metadex • MGA Module • Microbiology • Morressier Life Science • MTE Abstracts • New England Journal of Medicine • Neurosci Abstracts • Northern Light • NTIS • Nucleic Acids Abstracts • Oceanic • Oncogenes • PAIS	• Paperbase • Paperchem • Petroleum Abstracts • Pharmabiomed Business • Pharmacoeconomics • Plant Science • Pollution • Professional Newsstand • Prompte • Prous Drug Data • Psycinfo • Publicly Available Content • Risk Abstracts • RTECS • Scisearch • Social Sci Search • Solid State Abstracts • SSA Module • Tablebase • Toxfile • Toxicology Abstracts • Toxline • Tris • UBM Computer • Virology Aids • Water Resources • Weldasearch • Zoological Record
Note: A full description of each database can be found at https://dialog.com/commercial-databases.				

3.2.6.2 Search Methodology

General Searches Focused on Flame Retardants

We searched each site shown in Exhibit 3-30 (with the exception of the e-commerce sites; see below) using manual search techniques focused on identifying general literature related to OFRs. We refined our search term strategy to properly focus the search on relevant results, while ensuring the searches do not overlook useful information. For example, we determined it is generally preferable to use the broad term "flame retardant" as opposed to specifying "organohalogen flame retardant" (or "brominated flame retardant," "chlorinated flame retardant"). While this may produce results unrelated to OFRs, such as studies of organophosphorus or mineral compounds, these can be readily identified, flagged, and eliminated from further consideration during review. We used the term "flame retardant" in combination with additional terms to help limit the focus to topics of interest for this study, for example "consumer," "children's," "products," "items," "materials," and "sources." Some sites allow the use of Boolean operators (e.g., AND, NOT), while others do not. During search planning, we determined the optimum

search structure for each source. Where possible, searches were limited to sources published since 2010, to limit the searches to more recent literature.

We applied the same search strategy to the Dialog/Proquest databases shown in Exhibit 3-30.

We reviewed results of these searches to identify sources that appeared relevant to this study, based on the source title, description, or abstract (where available). We captured or created a citation for each source using EndNote software from Clarivate Analytics.[16] When abstracts were available, we added the abstract text to the EndNote citation. When full-text sources were available as a search link, we downloaded these for later review.

Chemical-Specific Searches

After completing the general searches above, the next step involved chemical-specific searches focused on each OFR of interest to CPSC staff. Recognizing that not all citations relevant for the study will necessarily use CAS Number when identifying a chemical, we constructed search strings that combined the CAS Number for each chemical with the more common synonyms and trade names. These were identified by reviewing the list of synonyms included in the OFR inventory (see Task 1 above). We applied professional judgment when identifying the most common synonyms and trade names.[17] We developed search strings for submission to both Google Scholar and Dialog Proquest. As an example, the search string for Google Scholar for CAS No. 92-86-4 was:

> (CAS* AROUND(2) 92-86-4 OR "1,1'-Biphenyl, 4,4'-dibromo-" OR "4, 4'-dibromobiphenyl" OR "PBB 15" OR "PBB-15") AND "flame retardant*"

This includes the chemical name (1,1'-Biphenyl, 4,4'-dibromo-), three synonyms (4, 4'-dibromobiphenyl, PBB 15, and PBB-15), and the term "flame retardant*"). We used the (undocumented) AROUND(x) Google operator to connect the term "CAS" with the numeric part of the CAS Number. This operator allows us to find sources that include a word between CAS and the CAS number (e.g., CAS No. 92-86-4, CAS Number 92-86-4) as well as those that do not (e.g., CAS 92-86-4). We added the '*' wildcard to the CAS term to ensure we found citations that used both CAS and CASRN (CAS Registry Number). Note that the CAS No., chemical name, and synonyms are enclosed in parentheses and separated by the "OR" operator, with the term "flame retardant*" then added in to ensure its inclusion in any results. We constructed similar search strings for use in Dialog/Proquest using that system's own search syntax rules.

We submitted these searches individually to Google Scholar and Dialog/Proquest, saved the results from each search to a PDF file, and reviewed the results offline. We flagged results that appeared relevant for further review and obtained or created citations in EndNote for each. As above, we added abstract text, where available, to each EndNote citation.

E-Commerce Sites

We identified the e-commerce or business to business (B2B) sites focused on the chemicals industry and listed in Exhibit 3-33 from two sources (e.g., Bonde & Ewald, 2020; Raviraj, 2017).

[16] In many cases, EndNote citations can be generated by locating the source using Google Scholar and using the "Import into RefMan" option. This generates an .RIS file that can be imported into EndNote to create an EndNote citation.

[17] Due to limitations on the number of search terms it was not possible to include all known synonyms and trade names. OFRs in the inventory had an average of 20 synonyms each, with some having more than 100.

According to the B2B market research site digitalcommerce360.com, the chemical industry has been gradually adapting to B2B material sourcing, but estimates 2020 global sales at only $27.8 billion, based on data from DuPont and Deloitte (Demery, 2020). While growing, this represents only a small segment of the estimated $3 to $4 trillion global chemicals market (Research and Markets, 2021).

E-commerce sites generally allow searching based on CAS number and/or chemical name, synonym or trade name, and identify suppliers registered with the site that can supply the chemical of interest. Some sites include quantity and pricing information for their chemicals, while other sites only identify suppliers and provide their contact information.

For these sites, we experimented with and had some success using automated "web scraping" tools. Web scraping can automate the copying and pasting of information from web pages into a data repository, including data from search results. The data repository can then be reviewed offline by the user. Web scraping can be effective when web data are highly structured and when that structure is consistent across all pages returned as search results, as is generally the case with these e-commerce sites. Some e-commerce sites can detect web scraping by a user and block the attempt. When search results involve pages of varying structure, web scraping is less effective.

3.2.6.3 Search Results Processing

As noted above, search results from both our general and chemical-specific OFR searches, and the initial sources identified by CPSC staff, were captured as citations in an EndNote citation database (including abstracts, where available). We first used an EndNote tool to find and eliminate any duplicate citations. Next, we exported the EndNote database into an Excel workbook and added several fields to assist with source review and processing. These included fields assigning sources to individual reviewers and fields for recording the date of the review, the relevance score assigned by the reviewer to the source (see below), the source type (see below), and a flag indicating that a PDF version of the sources had been obtained.

Literature Data Source Prioritization and Classification

Data sources from literature were reviewed using an operating procedure for conducting the source reviews. The overarching objective of the review is to identify sources with information relevant to the production and use of OFRs in products intended for use by U.S. consumers, including children. Sources with broader information about the market for OFRs are also of interest. Source rating was conducted using a scale of 1 to 5 and was based on review of the source title and abstract. We began with a score of 5 as the default and then deducted points as follows:

-1 point	Source is from study done outside the United States
-1 point	Source describes the presence of OFRs in only the ambient environment (or from an unknown source)
-1 point	Source is over 10 years old (with some exceptions, such as textbooks, handbooks, or sources of very high relevance)
-1 or -2 points	Source is expected to have minimal or no market information (deduction depends on how relevant or irrelevant the source appears)

We further classified all sources based on the primary study type or source topic, as described in Exhibit 3-31.

EXHIBIT 3-33. SOURCE TYPE CLASSIFICATION

SOURCE TYPE	DESCRIPTION OR EXAMPLE
Product Testing	Products used by consumers have been tested in a laboratory to determine the presence and concentrations of OFRs
Biomonitoring/Health Study	Biological samples (blood, urine, hair) have been taken from humans and analyzed for the presence of OFRs
Market Study	Source contains market data on OFR chemicals or products which may contain OFR chemicals
Ambient Environmental/ Exposure Study	Samples collected from indoor environments (typically house dust or wipe samples) or from non-specific outdoor sources (such as a lake or air in a neighborhood) have been tested to determine the presence and concentrations of OFRs
Risk Assessment	Source examines or calculates the risk of exposure to OFRs
Toxicology study	Source examines the relationship between exposure to chemicals, including OFRs, and adverse effects in human or animal subjects
Life Cycle Assessment	Source details what happens to OFRs as products are used and eventually disposed or recycled
Policy Information/Study	Source examines policy or regulatory issues related to OFRs
Meta Analysis / Review	Source summarizes literature on OFRs or attempts to combine/synthesize results from multiple studies
News article or item	General news or industry source discussing issues related to OFRs.
Other	Not otherwise classifiable

Data Source Retrieval

We obtained (or created) PDF copies of as many of the sources identified as possible, with priority given to those sources rated higher for relevance.

Source Characterization from Literature Data Sources

The next step was to review each literature data source using the PDF versions obtained above in order to characterize the types of information contained in the PDF. We used this step to identify literature sources that contained information on topics of interest for the study, such as manufacturing or importing activity, use of chemicals in products, lifecycle considerations, and regulatory or other trends. Most of the data elements were simply coded as yes/no at this stage. Exhibit 3-34 shows the coding system used for this source characterization.

While reviewing each PDF, we highlighted information such as that shown in Exhibit 3-34 so it could be readily located during subsequent review steps.

EXHIBIT 3-34. SOURCE CHARACTERIZATION DATA ELEMENTS

SOURCE DATA ELEMENT AND DESCRIPTION	
CHEMICAL INFORMATION	
Flame Retardant Chemical (name and/or structure)	Reference identifies one or more flame retardants by name
Synonyms	Reference includes synonyms or trade names for flame retardants
Chemical Categories	Reference provides or uses a classification scheme for flame retardants
CHEMICAL MANUFACTURING INFORMATION	
Company Name and location of flame retardant manufacturer	Reference identifies one or more flame retardant manufacturers
Manufacturing location	Reference provides name and location of manufacturing facilities
Manufacturing Volumes	Reference provides manufacturing volume information
Trade names	Reference identifies trade names for flame retardants
USE IN MANUFACTURED ITEMS	
Company Name/Location	Reference identifies one or more companies manufacturing products into which flame retardants are incorporated
Final Manufactured Articles (which component resides)	Reference identifies specific product/s into which flame retardants are incorporated
Compositional info and/or use volume of manufactured item	Reference provides data on flame retardant quantities used, concentrations in products, or volume of products manufactured
CHEMICAL IMPORTING	
Import company/name location	Reference identifies one or more flame retardant importers
Manufacturer or distributor name/location	Reference identifies one or more flame retardant distributors
Type of Import (raw material, product formulation, manufactured article)	Reference specifies the form of imported items (raw material, formulated product, or manufactured items)
Imported amt or volume	Reference provides import volume information
Compositional info of imported chemical/component product or manufactured article	Reference provides data on flame retardant quantities used, concentrations in products, or volume of products imported
Chemical or product trade names	Reference identifies trade names for imported items
LIFECYCLE FOR END USE PRODUCTS	
Type of article or consumer product use category (end use, consumer product, or formulation)	Reference describes lifecycle information for specific type of product
Typical users (industrial sector)	Reference describes typical uses for product, including industrial sector where it is used
Where/how used (number of facilities in each life cycle stage)	Reference describes where and how product is used
Age of item at time of disposal/recycling (typical article use or shelf life)	Reference describes typical product lifespan or product age at time of disposal
Compositional info (weight fraction, concentration) of flame retardant in article	Reference provides data on flame retardant quantities used or concentrations in products

SOURCE DATA ELEMENT AND DESCRIPTION	
End of Life management (recycling, treatment, disposal)	Reference provides data on what happens to products at end of life
OTHER INFORMATION	
Is chemical on regulatory lists (banned, restricted use, required to report)	Reference describes regulatory status of chemical (e.g., appearance on regulatory lists)
Applicable regulatory and industry FR standards	Reference cites legal or other requirement that applies to the chemical
Other trend information (whether it be economic or legal/regulatory)	Reference provides other trend data (related to use of the chemical or regulatory developments)

Chemical Identification

During literature data source review, we performed the further step of identifying all chemicals (or classes of chemicals) discussed in the source. We captured these in a separate workbook which contains the source name and all of the chemicals discussed in that source. Where available, we captured the CAS Number for each chemical and any synonyms, abbreviations, and trade names. We highlighted chemicals identified in the source using a separate color from that used in the source characterization step above.

Where the literature data source used CAS Numbers, we used a drop-down list of all chemicals in the OFR inventory to determine whether or not the chemical is an OFR and to validate the data entry step. If the CAS Number did not appear on the OFR inventory, the CAS Number was recorded nonetheless. We later shared this list with CPSC staff as part of an effort to identify additional OFRs.

If the literature data source did not use the CAS Number and instead used a synonym, abbreviation, or trade name, we inserted the chemical name in a separate field ("Other chemical"). If that synonym, abbreviation, or trade name appears on the OFR synonym list, a lookup function populated the CAS Number for that chemical.

The output from this exercise is illustrated below:

DATA SOURCE	CAS NUMBER	OTHER CHEMICAL	OFR?
Source 1, 2010.	CAS Number 1		Yes
Source 1, 2010.	CAS Number 2		No
Source 1, 2010.	CAS Number 3	Chemical 3	Yes
Source 2, 2018.	CAS Number 4		Yes
Source 2, 2018		Chemical 5	No

In the example above, Chemical 2 was listed in the source by CAS Number but was determined not to be an OFR. Chemical 3 was listed in the source using a synonym, abbreviation, or trade name, but it was mapped to an OFR and the CAS Number was populated. Chemical 5 was also listed as a synonym, abbreviation, or trade name but was determined not to be an OFR.

Finally, if the source did not identify an individual chemical but instead referenced a class of chemicals (e.g., brominated flame retardants, polybrominated diphenyl ethers), we captured the class description in the "Other chemical" field.

3.2.6.4 Search Results

Literature Citations

The literature review began with 109 sources identified by CPSC staff. Of these, 61 were government reports and the remainder were individual sources from the open literature. The search steps described above located an additional 308 sources, for a total of 417 sources. Of these, we were able to obtain 255 sources in PDF format for review and evaluation. Exhibit 3-35 shows the distribution of sources by rating, and the percent of sources within each rating category for which we were able to obtain PDFs for further review. Overall, we obtained PDFs for 61 percent of the sources, including 88 percent of sources rated three or higher.

EXHIBIT 3-35. NUMBER OF SOURCES BY RATING AND PDF AVAILABILITY

RATING	NUMBER OF SOURCES	NUMBER OF PDF OBTAINED (PERCENT OF TOTAL)
1 (low relevance)	144	30 (21%)
2	91	65 (71%)
3	86	69 (80%)
4	59	56 (95%)
5 (high relevance)	37	35 (95%)
Total	417	255 (61%)

Based on the ratings we assigned to each source, we prioritized our source review and extraction effort on 187 of the 255 sources we obtained. In addition to capturing the information shown in Exhibit 3-33 above, we scanned each source to determine how many (and which) OFRs are discussed or referenced in each source. From these sources we made over 2,200 OFR identifications (for 488 unique OFRs). The resulting workbook allowed us to identify all of the sources we reviewed that reference a particular OFR or class of OFRs.

E-Commerce Sites

As noted earlier, we made efforts to identify chemicals in commerce by determining their availability on several chemical B2B or e-commerce sites, using automated techniques to "scrape" data on OFRs from these sites. Of the four sites we attempted to scrape for chemical supply and pricing data, we were successful with three (Buyersguidechem.com, Chemnet.com, and Alibaba.com). The fourth site, Chemicalbook.com, detected and blocked our scraping attempt. From Buyersguide.com and Chemnet.com we obtained the identity, country, and website of OFR suppliers. From Alibaba.com, we obtained the name and website of OFR suppliers (but not the country),[18] as well as some data on quantities available and pricing. For purposes of aggregation, we assumed all OFR suppliers listed on Alibaba are Chinese. Overall, we found 255 unique suppliers across these sites, who collectively have 1,772 listings for 261 OFRs. Of the three sites, Buyersguide.com account for the most OFRs and listings, while Chemnet.com has the highest number of suppliers listed (see Exhibit 3-36).

[18] Alibaba is open to both Chinese companies and non-Chinese companies, although Chinese suppliers make up the vast majority of suppliers.

EXHIBIT 3-36. E-COMMERCE SUPPLIERS AND OFR LISTINGS

SITE	NUMBER OF OFR SUPPLIERS	NUMBER OF OFRS LISTED	NUMBER OF OFR LISTINGS
Buyersguide.com	85	258	1,338
Chemnet.com	118	71	253
Alibaba.com	55	31	181
TOTAL	255	261	1,772

Exhibit 3-37 shows the distribution of suppliers, OFRs listed, and listings by country. China accounts for the majority of the supply listings on these sites (recall that Alibaba listings do not indicate the supplier's country, but this analysis assumes all suppliers listed there are Chinese firms). The United States, Canada, and Europe are represented here, but to a much lesser degree. Noticeably, Japan is missing from this list, though it is generally known to be consumer of flame retardants of various types and a global chemicals supplier.[19]

EXHIBIT 3-37. E-COMMERCE SUPPLIERS AND OFR LISTING, BY COUNTRY

COUNTRY	NUMBER OF OFR SUPPLIERS	NUMBER OF OFRS LISTED	NUMBER OF OFR LISTINGS
China	181	257	1,281
United States	22	95	157
Germany	11	125	218
United Kingdom	7	23	24
India	6	6	6
The Netherlands	6	20	25
Belgium	5	4	6
Switzerland	4	31	37
Canada	3	3	3
Israel	3	5	5
France	2	2	2
South Korea	2	5	5
Poland	1	1	1
Sweden	1	1	1
Ukraine	1	1	1
Totals	255	261	1,772

[19] According to buyersguide homepage (https://www.buyersguidechem.com) there are 89 Japanese suppliers with listings on the site. When we searched each OFR CAS No. on the site, however, none of these suppliers showed up.

Listings from Buyersguide.com and Chemnet.com included 22 U.S. companies. These are shown in Exhibit 3-38 along with the number of OFRs each is listed for.

EXHIBIT 3-38. U.S. SUPPLIERS OF OFRS LISTED ON E-COMMERCE SITES

COMPANY NAME	NUMBER OF OFRS
Santa Cruz Biotechnology, Inc.	79
AK Scientific, Inc.	33
Ambeed, Inc.	15
Aozeal Certified Standards (AOCS), Inc.	7
Alfa Aesar	3
CBC (America) Corp.	2
Morre-Tec Industries, Inc.	2
Richman Chemical Inc.,	2
Cerilliant Corporation	1
Digital Specialty Chemicals	1
Esprit Chemical company	1
FAR Chemical	1
Fisher Scientific	1
Greenwood Products, Inc.	1
Magical Scientific	1
Magical Scientific LLP	1
PCI	1
Rit-Chem Co. Inc.	1
The Chemical Company	1
Unistar International, Inc.	1
Unitex Chemical Corp.	1
Velsicol Chemical Corp.	1
Note: Listings obtained from Buyersguide.com and Chemnet.com	

As noted, listings on Alibaba.com include pricing data for most chemicals. Pricing is generally presented in a range along with a minimum purchase quantity. The most common minimum purchase quantity quoted is 1 kg (approximately 46 percent of listings). Pricing at quantities of 25 kg or more are not uncommon, accounting for 47 percent of listings, and there are 55 listings that quote prices for purchases of one ton or greater.

As we would expect, pricing from an individual supplier may also be tiered depending on the quantity purchased. A business that purchases a smaller amount of chemical might expect to pay more per unit, compared with a business that purchases in bulk. Prices paid to the supplier would be negotiated to also include terms for international delivery, product packaging (in plastic bag or metal drum), and other negotiated terms of sale such as delivery date. Differences in pricing among supplier listings could also reflect differences in grade or purity levels available from different suppliers, or other factors.

Our review of the Alibaba.com price data, however, raises some questions about the reliability of the data and whether the prices quoted reflect actual purchasing conditions. First, while the price ranges quoted may be reasonably narrow for a particular chemical when purchased at the same quantity, these ranges

may also be quite large. As one example, listings for the chemical Tris(2-chloroethyl) phosphate (CAS 115-96-8) include:

- $1.50 - $1.60 per kg (Chemfine International Co)
- $1.00 - $70.00 per kg (Jinan Future Chemical Co.)
- $100.00 - $300.00 per kg (Shanghai Epoch Material Co., Ltd.)

Second, as illustrated in the example above, pricing from different suppliers can vary widely for the same chemical. Finally, pricing does not indicate whether the pricing is "FOB origin," with the seller paying shipping and freight, or reflects some version of a "delivered" price.

With these concerns noted, Exhibit 3-39 summarizes the listings found for 31 OFRs. As noted above, most sellers provide tiered pricing depending on the purchase quantity. This table shows pricing in $/kg, the most common minimum purchase quantity used in listings.

EXHIBIT 3-39. OFR PRICING ON ALIBABA.COM

OFR CLASS AND CAS NO.	NO. OF SUPPLIERS	"BEST" PRICE FOR QUANTITY PURCHASE ($/KG)		MINIMUM QUANTITY FOR "BEST" PRICE (KG)	
		LOW	HIGH	HIGH	LOW
POLYHALOGENATED ALICYCLES					
3194-55-6	6	$1.30	$50.00	5,000	1
POLYHALOGENATED ALIPHATIC CHAINS					
3234-02-4	1	$12.00	$15.00	1,000	1
3296-90-0	10	$1.00	$50,000.00	1,000	0.001
36483-57-5	2	$5.00	$99.00	1,000	1,000
63449-39-8	2	$0.76	$1.25	100	100
79-27-6	1	$380.00	$380.00	1	1
85535-85-9	1	$1.50	$3.00	100	100
96-13-9	1	$1,000.00	$1,000.00	100	100
POLYHALOGENATED BENZENE ALIPHATICS AND FUNCTIONALIZED					
84852-53-9	6	$1.00	$100.00	200,000	1
93-52-7	4	$10.00	$75.00	18,000	1
POLYHALOGENATED BENZENES					
626-39-1	3	$1.00	$762.39	1	1
92-66-0	4	$0.02	$70,000.00	100	1
92-86-4	1	$0.60	$5.00	1,000	1,000
POLYHALOGENATED BISPHENOL ALIPHATICS AND FUNCTIONALIZED					
21850-44-2	1	$6.00	$6.10	14,512	1
79-94-7	2	$1.00	$120.00	100	100
97416-84-7	3	$5.00	$6,800.00	18,000	0.1
POLYHALOGENATED CARBOCYCLES					
115-27-5	4	$1.00	$15.00	1	1

OFR CLASS AND CAS NO.	NO. OF SUPPLIERS	"BEST" PRICE FOR QUANTITY PURCHASE ($/KG)		MINIMUM QUANTITY FOR "BEST" PRICE (KG)	
		LOW	HIGH	HIGH	LOW
POLYHALOGENATED ORGANOPHOSPHATES					
115-96-8	9	$0.08	$300.00	50,000	0.01
13674-84-5	11	$1.00	$900.00	1,000	1
13674-87-8	6	$1.50	$75.00	20,000	1
140-08-9	1	$15.40	$15.40	1,000	1,000
19186-97-1	1	$256.00	$256.00	1,000	1,000
6145-73-9	2	$2.00	$2,000.00	1,000	1
POLYHALOGENATED PHENOL DERIVATIVES					
118-79-6	5	$3.80	$35.00	1,000	1
42757-55-1	1	$8.00	$15.00	1,000	1,000
608-33-3	2	$1.00	$100.00	1,000	1,000
POLYHALOGENATED PHTHALATES/BENZOATES/IMIDES					
117-08-8	2	$0.90	$2.50	1	1
32588-76-4	1	$96.00	$96.00	1	1
632-79-1	8	$1.00	$100.00	907	1
POLYHALOGENATED TRIAZINES					
52434-90-9	1	$5.00	$35.00	1,000	1,000
POLYHALOGENATED TRIAZINES; POLYHALOGENATED PHENOL DERIVATIVES					
25713-60-4	2	$4.85	$10.00	100	1

The table shows the low and high "best" prices listed, which are based on each supplier's highest purchase tier. For example, six suppliers are listed for CAS No. 3194-55-6. Among them, the lowest "best" price quoted is $1.30/kg, which requires a minimum purchase of 5,000 kg. The highest "best" price (from a different supplier) is $50.00/kg, requiring a minimum purchase of 1 kg. Pricing for these 31 OFRs is based on listings from 55 unique suppliers, some of whom provide multiple listings per chemical.

Another interpretation of data available from Alibaba.com is that the chemicals listed for sale on the site (in English) are available in global commerce, and that B2B solutions for supplying OFR chemicals are likely available to U.S. businesses importing from China. Currently, OFR chemicals are available at a variety of prices and quantities, including those that are hazardous.

Overall, the price data available from Alibaba.com provide some indication of what manufacturers may pay for OFR substances, subject to the caveats discussed above. Prices for 20 of the 31 OFRs found are in the range of $1 to $10 per kg ($1,000 to $10,000 per tonne). While independent pricing data for many chemicals is difficult to obtain, one industry source reporting on price trends in 2021 for TCPP and TCDP described prices in the range of €3,000 to €4,000 ($3,400 to $4,500) per tonne (Ellis, 2021). Prices on Alibaba that are considerably higher than this could indicate low demand, specialty-type chemicals.

Many supplier listings on Alibaba.com also indicate a supply capacity for the OFR chemical. Supply capacity data is available for 11 of the 14 OFR chemical subclasses. For a single OFR chemical, suppliers sometimes have multiple listings, which may reflect differences in grade or purity levels, or different packaging specifications, or could represent capacities of different sites under their control. Where a

supplier has multiple listings for an OFR chemical, the supply capacities are shown for each, in Exhibit 3-39. All supply capacities have been converted to a common unit, metric tons per month. "NA" indicates no information on supply capacity was available for that listing.

For example, the OFR supply capacity for Jinan Realong Chemical Co., Ltd. as shown in Exhibit 3-40 should be interpreted as having at least three listings for OFR chemical HBCD (CAS No. 3194-55-6): two listings with (effective) supply capacity of 50 metric tons per month and one with (effective) supply capacity of 1,000 metric tons per month. Some suppliers provide incomplete capacity information. While the OFR supply capacity for Shandong Kejian Chemical Co., Ltd., for OFR chemical (CAS No. 3296-90-0) is 1,000 metric tons per month according to one listing, they do not explicitly provide information on their supply capacity in a second listing. In the data provided, it is incorrect to interpret or assume that suppliers of OFR chemicals that do not list their monthly supply capacity do not or cannot supply the OFR chemical.

EXHIBIT 3-40. OFR SUPPLY CAPACITIES ON ALIBABA.COM

OFR CLASS, CAS NO, AND SUPPLIER	SUPPLY CAPACITY (METRIC TONS/MONTH)
POLYHALOGENATED ALICYCLES	
3194-55-6	
Flag Chemical Industry Co., Ltd.	2,000
Henan Shuohong Trade Co., Ltd.	NA
Jinan Future Chemical Co., Ltd.	50
Jinan Realong Chemical Co., Ltd.	50 | 50 | 1,000
Qingdao Echemi Technology Co., Ltd.	NA
Yangzhou Juhechang Technology Co., Ltd.	2,000
POLYHALOGENATED ALIPHATIC CHAINS	
3234-02-4	
Boluo Changning Yuandongxing Chemical Co., Ltd.	1| 1
3296-90-0	
Anstar New Material Technology Co., Ltd.	110
HAIHANG INDUSTRY CO., LTD.	1| 50| 1| 300
Jiangsu Medler Medical Technology Co., Ltd.	10| 300| 4,167
Shandong Bilifu Chemical Co., Ltd.	1 | 300
Shandong Green New Materials Co., Ltd	1 | 1 | 10 | 10| 10| 200,000
Shandong Kejian Chemical Co., Ltd.	1,000|NA
Shandong Richnow Chemical Co., Ltd	1| 167 | 500
Shanghai Sinorefine Industrial Corporation	5
Wuhan Lullaby Biotechnology Co., Ltd.	1
Zhishang New Materials (Shandong) Co., Ltd.	20
36483-57-5	
Hebei Zhiyu Trading Co., Ltd.	20,000
Shanghai Talent Chemical Co., Ltd.	100
63449-39-8	
Samuda Chemical Complex Limited	50
Shandong Chenxu New Material Co., Ltd.	50
79-27-6	

OFR CLASS, CAS NO, AND SUPPLIER	SUPPLY CAPACITY (METRIC TONS/MONTH)
Shanghai 3H Biochem Co., Ltd.	800
85535-85-9	
Beyond Industries (China) Limited	50| 50|NA
96-13-9	
Shanghai Sinorefine Industrial Corporation	83
POLYHALOGENATED BENZENE ALIPHATICS AND FUNCTIONALIZED	
84852-53-9	
Anstar New Material Technology Co., Ltd.	50
Hebei Zhiyu Trading Co., Ltd.	10
Hefei Zhaohui New Material Technology Co., Ltd.	50| 50
Jinan Future Chemical Co., Ltd.	50
Shanxi Naipu Import and Export Co., Ltd	500| 1,500
Yurui (Shanghai) Chemical Co., Ltd.	42
93-52-7	
Boluo Changning Yuandongxing Chemical Co., Ltd.	50
Flag Chemical Industry Co., Ltd.	10| 100
Shanghai Zoran New Material Co., Ltd.	100|NA
Shenzhen VTOLO Industrial Co., Ltd.	50| 1,000
POLYHALOGENATED BENZENES	
626-39-1	
Shandong Bilifu Chemical Co., Ltd.	1
Wuhan Dujiang Industrial Co., Ltd.	500| 500
Zhengzhou Alfa Chemical Co., Ltd.	1
92-66-0	
Flag Chemical Industry Co., Ltd.	NA
Jiangsu Medler Medical Technology Co., Ltd.	1,000| 50| 167
Shanghai Sunchem Inc.	50
Suzhou Leba Chemical Company Ltd	50
92-86-4	
Kunshan Yalong Trading Co., Ltd.	3,000| 3,000
POLYHALOGENATED BISPHENOL ALIPHATICS AND FUNCTIONALIZED	
21850-44-2	
Shandong Unitools Machinery Co., Ltd.	1| 30| 50| 50| 50| 300|NA|NA
79-94-7	
Shandong Bilifu Chemical Co., Ltd.	NA
Xiamen Aiboke Chemical Industrial Co., Ltd.	50
97416-84-7	
Hebei Zhiyu Trading Co., Ltd.	1,000
Shandong Unitools Machinery Co., Ltd.	1 | 2 | 5 | 10 | 100| 100| 100 | 200 | 1,000 | NA
Weifang Yukai Chemical Co., Ltd.	50| 50| 100
POLYHALOGENATED CARBOCYCLES	
115-27-5	
Boluo Changning Yuandongxing Chemical Co., Ltd.	1
Flag Chemical Industry Co., Ltd.	1
Haihang Industry Co., Ltd.	NA
Shenzhen VTOLO Industrial Co., Ltd.	NA

OFR CLASS, CAS NO, AND SUPPLIER	SUPPLY CAPACITY (METRIC TONS/MONTH)
POLYHALOGENATED ORGANOPHOSPHATES	
115-96-8	
ChemFine International Co., Ltd.	100
Flag Chemical Industry Co., Ltd.	100
Henan GP Chemicals Co., Ltd.	1| 2
Jiangsu Medler Medical Technology Co., Ltd.	200
Jinan Future Chemical Co., Ltd.	20 | 100 | 1,000 | 20,000
Shandong Richnow Chemical Co., Ltd	200
Shandong Zhishang New Materials Co., Ltd.	200
Shanghai Epoch Material Co., Ltd.	200
Simagchem Corp.	2,000| 5,000
13674-84-5	
Haihang Industry Co., Ltd.	1| 500
Hangzhou Bayee Chemical Co., Ltd.	2
Hebei Zhiyu Trading Co., Ltd.	NA
Henan Aolang Trading Co., Ltd.	30,000
Henan GP Chemicals Co., Ltd.	50| 50
Jiangsu Changyu Chemical Co., Ltd	NA
Jinan Future Chemical Co., Ltd.	100,000| 100,000
Qingdao Cemo Technology Develop Co., Ltd.	NA
Shandong Green New Materials Co., Ltd	20 | 50 | 500 | 1,500| NA|NA|NA
Shanxi Naipu Import and Export Co., Ltd	1
Zhengzhou Alfa Chemical Co., Ltd.	100
13674-87-8	
HBC Chem Llc	20,000
Hebei Zhiyu Trading Co., Ltd.	20
Hefei TNJ Chemical Co., Ltd.	NA
Henan Aolang Trading Co., Ltd.	NA
Henan GP Chemicals Co., Ltd.	50
Shandong Zhishang New Materials Co., Ltd.	20,000
140-08-9	
Flag Chemical Industry Co., Ltd.	1,000
19186-97-1	
Simagchem Corp.	1,500
6145-73-9	
Shandong Zhishang New Materials Co., Ltd.	167
Shanghai Richem International Co., Ltd.	NA
POLYHALOGENATED PHENOL DERIVATIVES	
118-79-6	
Flag Chemical Industry Co., Ltd.	1
Haihang Industry Co., Ltd.	3,000
Jinan Future Chemical Co., Ltd.	NA
Shandong Xingrui Chemical Co., Ltd.	83
Simagchem Corp.	500
42757-55-1	
Shenzhen Feiming Science and Technology Co., Ltd.	20,000

OFR CLASS, CAS NO, AND SUPPLIER	SUPPLY CAPACITY (METRIC TONS/MONTH)
608-33-3	
Haihang Industry Co., Ltd.	6,000,000
Shanghai Jiangqing International Co., Ltd.	6,000,000|NA
POLYHALOGENATED PHTHALATES/BENZOATES/IMIDES	
117-08-8	
Jinan Realong Chemical Co., Ltd.	1| 100
Shanghai Sunwise Chemical Co., Ltd.	10,000
32588-76-4	
Shanghai Jiangqing International Co., Ltd.	2,000
632-79-1	
Changsha Yibainian International Co., Ltd.	42
Flag Chemical Industry Co., Ltd.	50
Haihang Industry Co., Ltd.	42| 500
Jinan Future Chemical Co., Ltd.	50| 50|NA
Shandong Kejian Chemical Co., Ltd.	1
Shandong Richnow Chemical Co., Ltd	10
Shandong Unitools Machinery Co., Ltd.	1 | 10 | 20 | 167 | 200| 500| NA|NA|NA
Shandong Xinyiyuan Chemical Co., Ltd.	1| 1,000
POLYHALOGENATED TRIAZINES	
52434-90-9	
Jinan Future Chemical Co., Ltd.	100
POLYHALOGENATED TRIAZINES; POLYHALOGENATED PHENOL DERIVATIVES	
25713-60-4	
Haihang Industry Co., Ltd.	50
Shandong Tianxin Pharma-Tech Co., Ltd.	50

Capacity data from Alibaba.com suggests there may be limited capacity for some OFRs; however, the aggregate capacity from these suppliers appear reasonably large (see Exhibit 3-41). For example, the combined capacity of all suppliers is below 1,000 tonnes per month for 11 of the 31 OFRs, but for 10 OFRs it ranges from 1,000 to 5,000 tonnes per month, and for another 10 OFRs it greater than 5,000 tonnes per month. In three instances, capacity exceeds 100,000 tonnes per month (CAS Nos. 3296-90-0, 13674-84-5, and 608-33-3).

By characterizing supply capacity as low, when aggregate supply capacity is less than 1,000 tonnes per month, medium when aggregate supply capacity is between 1,000 and 5,000 tonnes per month, and high when aggregate supply capacity is greater than 5,000 tonnes per month, it is easier to understand the supply capacities of the 11 OFR subclasses for which data are available. Six of the OFR subclasses include OFR chemicals with a high aggregate supply capacity.

EXHIBIT 3-41. AGGREGATE SUPPLY CAPACITY FOR OFRS ON ALIBABA.COM

OCR CLASS AND CAS NO.	AGGREGATE SUPPLY CAPACITY (TONNES PER MONTH)	CAPACITY CHARACTERIZATION
POLYHALOGENATED ALICYCLES		
3194-55-6	5,150	High
POLYHALOGENATED ALIPHATIC CHAINS		
3234-02-4	2	Low
96-13-9	83	Low
63449-39-8	100	Low
85535-85-9	100	Low
79-27-6	800	Low
36483-57-5	20,100	High
3296-90-0	206,964	High
POLYHALOGENATED BENZENE ALIPHATICS AND FUNCTIONALIZED		
93-52-7	1,310	Medium
84852-53-9	2,252	Medium
POLYHALOGENATED BENZENES		
626-39-1	1,002	Medium
92-66-0	1,317	Medium
92-86-4	6,000	High
POLYHALOGENATED BISPHENOL ALIPHATICS AND FUNCTIONALIZED		
79-94-7	50	Low
21850-44-2	481	Low
97416-84-7	2,718	Medium
POLYHALOGENATED CARBOCYCLES		
115-27-5	2	Low
POLYHALOGENATED ORGANOPHOSPHATES		
6145-73-9	167	Low
140-08-9	1,000	Medium
19186-97-1	1,500	Medium
115-96-8	29,123	High
13674-87-8	40,070	High
13674-84-5	232,774	High
POLYHALOGENATED PHENOL DERIVATIVES		
118-79-6	3,584	Medium
42757-55-1	20,000	High
608-33-3	12,000,000	High
POLYHALOGENATED PHTHALATES/BENZOATES/IMIDES		
32588-76-4	2,000	Medium
632-79-1	2,642	Medium
117-08-8	10,101	High
POLYHALOGENATED TRIAZINES		
52434-90-9	100	Low
POLYHALOGENATED TRIAZINES; POLYHALOGENATED PHENOL DERIVATIVES		
25713-60-4	100	Low

3.3 SUMMARY OF CLASS-BASED FINDINGS

This section provides a summary of OFR class-based findings. Most classes are a clear combination of data-rich and data-poor chemicals. We provided information on the OFRs in commerce, OFR production and importation, trends, and the use of OFRs in consumer products. Detailed information is provided for data-rich OFR chemicals.

Comparison both within classes, to compare data-poor and data-rich chemicals, and between classes, to compare the relative prevalence and use of different classes, is essential for understanding the landscape of OFR chemistry. Industry production and use, use in consumer and children's products, and presence in general literature vary greatly throughout the OFR classes. Appendices C through P present detailed findings for each class at the individual chemical level. Each appendix includes a summary table synthesizing the data sources described in this chapter with other key parameters and patent data from the database described in Chapter 2.

3.3.1 OFRS IN COMMERCE

For purposes of classifying OFRs that are "in commerce" in the United States, we focus on chemicals for which there has been domestic manufacturing or importing activity reported during the most recent CDR reporting period (2012-2015). By this definition, all OFR classes except one (polyhalogenated triazines) include at least one chemical that was manufactured in or imported to the United States during this period. Of the 37 individual OFRs that were reportable during this period, 23 reported some manufacturing or importing activity, but 14 (across seven OFR classes) reported no manufacturing or importing activity. Exhibit 3-42 lists the chemicals by OFR class and indicates whether manufacturing or importing activity was reported in each of the 2012-2015 reporting years. Of the 23 chemicals for which manufacturing or importing was reported in one of these years, 19 were reported in all four years, three were reported in two of the four years, and one was reported in only a single year.

EXHIBIT 3-42. OFR MANUFACTURING OR IMPORTING ACTIVITY, 2012-2015

OFR CLASS	CAS NO.	2012	2013	2014	2015
Polyhalogenated alicycles	25637-99-4				X
	3194-55-6	X	X	X	X
	77-47-4	X	X	X	X
Polyhalogenated aliphatic chains	1401974-24-0				
	1402738-52-6				
	1417900-96-9				
	3296-90-0	X	X	X	X
	36483-57-5				
	61788-76-9	X	X	X	X
	63449-39-8	X	X	X	X
	68527-01-5	X	X	X	X
	68527-02-6	X	X	X	X

OFR CLASS	CAS NO.	2012	2013	2014	2015
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	X	X	X	X
Polyhalogenated bisphenol aliphatics and functionalized	21850-44-2				
	25327-89-3				
	4162-45-2	X	X	X	X
	79-94-7	X	X	X	X
Polyhalogenated carbocycles	115-27-5	X	X	X	X
	13560-89-9		X	X	
Polyhalogenated diphenyl ethers	1163-19-5	X	X	X	X
Polyhalogenated organophosphates	115-96-8	X	X	X	X
	13674-84-5	X	X	X	X
	13674-87-8	X	X	X	X
	19186-97-1				
	38051-10-4				
	6294-34-4				
	76025-08-6	X	X	X	X
Polyhalogenated phenol derivatives	118-79-6				
	42757-55-1		X		X
Polyhalogenated phenol-aliphatic ether	3278-89-5				
Polyhalogenated phthalates/benzoates/imides	117-08-8		X		X
	183658-27-7				
	20566-35-2	X	X	X	X
	26040-51-7	X	X	X	X
	32588-76-4				
	632-79-1	X	X	X	X
Polyhalogenated triazines	25713-60-4				

For the 2012-2015 CDR reporting period, submitters were required to specify whether they manufactured or imported individual chemicals only during the most recent reporting year, 2015. During 2015, domestic manufacturing activity was reported for 18 of the 37 OFRs and importing activity was reported for 22 of the 37 chemicals. Exhibit 3-43 identifies the chemicals for which manufacturing and/or importing activity was reported in 2015. As shown, 8 of these chemicals were manufactured only (CAS Nos. 68527-02-6, 36483-57-5, 68527-01-5, 6294-34-4, 118-79-6, 26040-51-7, 183658-27-7, and 32588-76-4), 12 chemicals were imported only (CAS Nos. 77-47-4, 3296-90-0, 61788-76-9, 25327-89-3, 4162-45-2, 115-27-5, 1163-19-5, 115-96-8, 76025-08-6, 42757-55-1, 3278-89-5, and 117-08-8, and 10 chemicals were both manufactured and imported (CAS Nos. 25637-99-4, 3194-55-6, 63449-39-8, 84852-53-9, 79-94-7, 13560-89-9, 13674-87-8, 13674-84-5, 632-79-1, and 20566-35-2).

EXHIBIT 3-43. OFRS REPORTING DOMESTIC MANUFACTURING AND IMPORTING ACTIVITY, 2015

OFR CLASS	CAS NO.	DOMESTICALLY MANUFACTURED	IMPORTED
Polyhalogenated alicycles	77-47-4		X
	25637-99-4	X	X
	3194-55-6	X	X
Polyhalogenated aliphatic chains	3296-90-0		X
	61788-76-9		X
	63449-39-8	X	X
	68527-02-6	X	
	36483-57-5	X	
	68527-01-5	X	
	1401974-24-0		
	1402738-52-6		
	1417900-96-9		
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	X	X
	79-94-7	X	X
	25327-89-3		X
	4162-45-2		X
	21850-44-2		
Polyhalogenated carbocycles	13560-89-9	X	X
	115-27-5		X
Polyhalogenated diphenyl ethers	1163-19-5		X
Polyhalogenated organophosphates	115-96-8		X
	13674-87-8	X	X
	76025-08-6		X
	13674-84-5	X	X
	6294-34-4	X	
	19186-97-1		
	38051-10-4		
Polyhalogenated phenol derivatives	42757-55-1		X
	118-79-6	X	
Polyhalogenated phenol-aliphatic ether	3278-89-5		X
Polyhalogenated phthalates/benzoates/imides	632-79-1	X	X
	20566-35-2	X	X
	117-08-8		X
	26040-51-7	X	
	183658-27-7	X	
	32588-76-4	X	
Polyhalogenated triazines	25713-60-4		

A number of countries and regions, including the United States, maintain registries (also known as inventories) of chemicals that are currently, or have previously been, manufactured and used in commerce. Individual registries may differ in terms of the types of substances that must appear on the registry, threshold quantities that trigger listings on the registry, and the frequency with which the registry is updated. As described in Section 3.2.3, we compiled information on the appearance of OFRs on a number of such registries. Exhibit 3-2 summarizes the findings from this exercise.

The percentage of substances within each OFR class that appear on these registries varies, from a low of 21.0 percent (polyhalogenated diphenyl ethers; 47 of 223 total substances) to a high of 100.0 percent (polyhalogenated aliphatic carboxylate; 2 total substances). Overall, 195 of the 488 substances (40.0 percent) appear on at least one registry, including 92 substances (18.9 percent of the total) that appear on the U.S. TSCA Inventory.

3.3.2 OFR PRODUCTION AND IMPORTATION

The U.S. EPA's CDR program requires manufacturers and importers to report the quantity of chemicals they manufacture or import, subject to certain provisions under which they may claim such quantities as confidential. Here, manufacturing and importing volumes are combined and denoted as "production volume," or PV.

OFR classes with the highest average annual reported PV over this period include polyhalogenated aliphatic chains (91.0 million pounds) and polyhalogenated organophosphates (61.8 million pounds). Combined, these two classes account for 92 percent of the total PV across all OFR classes. Individual chemicals that represent the highest volume average PV over 2012-2015 are show in Exhibit 3-44:

EXHIBIT 3-44. HIGHEST PRODUCTION VOLUME OFRS REPORTED UNDER THE 2016 CDR

OFR CLASS	CAS NO.	CHEMICAL NAME	AVERAGE PV 2012-2015 (MILLION LBS.)
Polyhalogenated aliphatic chains	63449-39-8	Chlorinated paraffins	82.8
Polyhalogenated organophosphates	13674-84-5	Tris(2-chloroisopropyl)phosphate	45.1
Polyhalogenated organophosphates	13674-87-8	Tris(1,3-dichloro-2-propyl) phosphate	15.8
Polyhalogenated aliphatic chains	68527-02-6	Alkenes, C12-24, chloro	7.5
Polyhalogenated phthalates/benzoates/imides	26040-51-7	Bis(2-ethylhexyl) tetrabromophthalate	6.9
Polyhalogenated alicycles	77-47-4	Hexachlorocyclopentadiene	1.9

The breakdown between quantities manufactured and quantities imported is reported only for the last year of the reporting period, 2015. Exhibit 3-45 shows the reported volumes for 2015. Overall, U.S. industry reported manufacturing 133.9 million pounds of OFRs and importing another 22.0 million pounds. Thus, domestic manufacturing represents 86.5 percent of the total PV, and importing represents the remaining 14.2 percent. This breakdown between manufacturing and importing, however, differs greatly across OFR classes. Manufacturing accounts for most of the PV for three OFR classes: polyhalogenated aliphatic chains (98 percent of total PV), polyhalogenated organophosphates (78 percent of total PV), and polyhalogenated phthalates/benzoates/imides (86 percent of total PV). For all other OFR classes for which PV was reported,[20] import volumes dominate, accounting for 100 percent of reported PV.

Similar reporting of detailed chemical manufacturing and importing activity is not available for countries outside the United States, and certainly there are no data available showing global production volumes for individual OFRs. Thus, information on OFR manufacturing outside the United States is limited to what is shown in Exhibit 3-45, which simply identifies which OFRs may be in commerce in various countries or regions.

[20] These OFR classes are: polyhalogenated alicycles, polyhalogenated benzene aliphatics and functionalized, polyhalogenated bisphenol aliphatics and functionalized, polyhalogenated carbocycles, polyhalogenated diphenyl ethers, and polyhalogenated phenol derivatives.

EXHIBIT 3-45. OFR MANUFACTURING AND IMPORTING VOLUMES, 2015

ROW LABELS	QUANTITY MANUFACTURED (LBS)	QUANTITY IMPORTED (LBS).	TOTAL (LBS).
POLYHALOGENATED ALICYCLES	-	1,971,159	1,971,159
25637-99-4	-	177,480	177,480
3194-55-6	-	536,164	536,164
77-47-4	-	1,257,515	1,257,515
POLYHALOGENATED ALIPHATIC CHAINS	75,610,000	1,343,679	76,953,679
1401974-24-0	-	-	-
1402738-52-6	-	-	-
1417900-96-9	-	-	-
3296-90-0	-	602,831	602,831
36483-57-5	-	-	-
61788-76-9	-	10,355	10,355
63449-39-8	68,000,000	730,493	68,730,493
68527-01-5	210,000	-	210,000
68527-02-6	7,400,000	-	7,400,000
POLYHALOGENATED BENZENE ALIPHATICS AND FUNCTIONALIZED	-	536,123	536,123
84852-53-9	-	536,123	536,123
POLYHALOGENATED BISPHENOL ALIPHATICS AND FUNCTIONALIZED	-	78,704	78,704
21850-44-2	-	-	-
25327-89-3	-	-	-
4162-45-2	-	12,566	12,566
79-94-7	-	66,138	66,138
POLYHALOGENATED CARBOCYCLES	-	802,482	802,482
115-27-5	-	802,482	802,482
13560-89-9	-	-	-
POLYHALOGENATED DIPHENYL ETHERS	-	573,192	573,192
1163-19-5	-	573,192	573,192
POLYHALOGENATED ORGANOPHOSPHATES	50,088,182	15,349,340	64,266,362
115-96-8	-	39,682	39,682
13674-84-5	38,488,041	11,345,820	48,662,701
13674-87-8	11,600,141	3,087,177	14,687,318
19186-97-1	-	-	-
38051-10-4	-	-	-
6294-34-4	-	-	-
76025-08-6	-	876,661	876,661

ROW LABELS	QUANTITY MANUFACTURED (LBS)	QUANTITY IMPORTED (LBS).	TOTAL (LBS).
POLYHALOGENATED PHENOL DERIVATIVES	-	27,557	27,557
118-79-6	-	-	-
42757-55-1	-	27,557	27,557
POLYHALOGENATED PHENOL-ALIPHATIC ETHER	-	-	-
3278-89-5	-	-	-
POLYHALOGENATED PHTHALATES/BENZOATES/IMIDES	8,270,502	1,376,832	9,647,334
117-08-8	-	110,000	110,000
183658-27-7	-	-	-
20566-35-2	1,174,900	-	1,174,900
26040-51-7	7,095,602	-	7,095,602
32588-76-4	-	-	-
632-79-1	-	1,266,832	1,266,832
POLYHALOGENATED TRIAZINES	-	-	-
25713-60-4	-	-	-
Grand Total	133,968,684	22,059,068	154,856,592

3.3.3 TRENDS IN OFR MANUFACTURE AND IMPORT

Section 4.2.1 presents available data on trends in the production (manufacturing and importing) of OFRs in the United States. Combining data from the 2016 and 2012 CDR reporting cycles (i.e., for reporting years 2010 through 2015) indicates that:

- PV was reported for five OFR classes in each of the six years captured: (1) polyhalogenated alicycles, (2) polyhalogenated aliphatic chains, (3) polyhalogenated bisphenol aliphatics and functionalized, (4) polyhalogenated organophosphates, and (5) polyhalogenated diphenyl ethers.
- PV was reported in only some years for the following OFR classes: (1) polyhalogenated carbocycles (five years), (2) polyhalogenated benzene aliphatics and functionalized (five years), (3) polyhalogenated phthalates/benzoates/imides (four years), (4) polyhalogenated phenol derivatives (two years), and (5) polyhalogenated triazines (one year).
- Lack of reporting for the remaining four OFR classes indicates that either no manufacturing or importing occurred, or that no manufacturers or importers met the reporting thresholds described above.

The major conclusions from this trend data are:

- In each year, the largest PV reported was for the polyhalogenated aliphatic chains OFR class. The annual average PV for this class is over 81 million pounds, representing more than half the reported PV of all OFRs. Chlorinated paraffins (CAS No. 63449-39-8) account for 79 percent of the reported PV within this class.

- The next highest-volume OFR classes are: polyhalogenated organophosphates (54 million pounds); polyhalogenated alicycles (7.1 million pounds), and polyhalogenated phthalates/benzoates/imides (5.8 million pounds). Notably, PV has been reported for this last OFR class in only the last four years, and the PV reported in the most recent year (2015) was 9.6 million pounds.

While not directly comparable, data from the 2006 and 1998 IUR (the predecessor to the CDR) suggest that the PV for OFRs as a whole have decreased over the 1998-2005 timeframe. While the total PV for all OFRs averaged 152 million pounds from 2010-2015, the combined PV for all OFRs was considerably higher in prior reporting periods: 752 million pounds in 2005 and 1.4 billion pounds in 1997 (see Appendix Q). In 2005, the three OFR classes with the highest estimated PV were polyhalogenated bisphenol aliphatics and functionalized (305 million pounds), polyhalogenated organophosphates (121 million pounds), and polyhalogenated diphenyl ethers (75 million pounds). In 1997, the three highest volume OFR classes were polyhalogenated diphenyl ethers (767 million pounds), polyhalogenated bisphenol aliphatics and functionalized (261 million pounds), and polyhalogenated organophosphates (119 million pounds). Thus, there is evidence of both a general decrease in the manufacturing and importing volume of OFRs over this more extended time period, as well as some shifting among the various OFR classes.

3.3.4 KNOWN AND UNKNOWN OFR USE IN PRODUCTS

Information about OFR use in products has been collected from a variety of sources including chemical reporting programs and literature sources. Below we attempt to answer several questions to shed light on where and how OFRs are used, which OFRs are most often used, and the types of products they can be expected to be found in.

3.3.4.1 Summary of OFR Uses

A general picture of OFR uses can be compiled by reviewing the various U.S. chemical reporting programs (CDR, TRI, HPCDS) and use information found in the OFR literature. In Exhibit 3-46 below, we identify the chemicals within each OFR class for which use information can be ascertained, and classify them by the end use(s) identified, including use in children's products. Generally, use information is available for only a small subset of OFRs within each class; the table identifies 26 OFRs (from a total of 488) for which use information is readily ascertainable. The reported uses do not necessarily apply to every chemical within the OFR class, but in many cases, common uses can be found for multiple chemicals within a class. One conclusion from these data is that OFR classes exhibit different patterns of end use, but certain end uses cut across multiple OFR classes.

It is important to note that end use information for individual OFRs is not widely available either from chemical reporting programs or in the literature. As noted below in Section 3.4.1.2, end use data from programs such as the CDR must be interpreted with care because manufacturers and importers may have only limited knowledge of such end uses. The literature on OFRs, summarized in Appendices C through P by OFR class, also contains limited information on end uses. Much of it is anecdotal and results from testing of materials, products, or articles. Generally, industry is not obligated to disclose the use of OFRs in specific products they manufacture, and have limited incentives to do so. Furthermore, it is not clear to what extent U.S. manufacturers or importers have knowledge of the use of OFRs in products they sell. OFRs may be introduced into intermediate products they purchase from upstream suppliers. The U.S.

manufacturer or importer may be unaware of such use, or may be informed that the product contains flame retardants while the specific chemicals being used are not disclosed to them. In the current integrated global economy, many intermediate and final products are imported to the United States from countries that do not require disclosure of OFR use.

EXHIBIT 3-46. SUMMARY OF REPORTED OFR USES

OFR CLASS	NO. OF CHEMICALS IN CLASS	MOST FREQUENTLY REPORTED/ CITED CAS NOS.	REPORTED USES								
			Construction	Plastic Material/Resin	Plastic Products	Pu Foam	Textiles	Paints, Coatings	Rubber Products	Electrical/Electronic Products	Children's Products
Polyhalogenated Alicycles	22	25495-98-1 25637-99-4 3194-55-6 77-47-4	X	X	X	X	X				X
Polyhalogenated aliphatic carboxylates	3	None	No citations or reporting to indicate uses								
Polyhalogenated aliphatic chains	47	85535-85-9 63449-39-8 68527-02-6 3296-90-0		X	X	X	X	X	X		X
Polyhalogenated benzene alicycles	4	None	No citations or reporting to indicate uses								
Polyhalogenated benzene aliphatics and functionalized	18	84852-53-9	X		X		X			X	X
Polyhalogenated benzenes	50	87-82-1		X	X		X			X	X
Polyhalogenated bisphenol aliphatics and functionalized	14	79-94-7 21850-44-2		X	X		X			X	X
Polyhalogenated carbocycles	19	115-27-5 13560-89-9 1770-80-5		X				X			
Polyhalogenated diphenyl ethers	223	1163-19-5	X		X		X			X	X
polyhalogenated organophosphates	42	115-96-8 13674-84-5 13674-87-8 76025-08-6 38051-10-4	X	X	X	X	X				X
Polyhalogenated phenol derivatives	8	42757-55-1		X						X	
Polyhalogenated phenol-aliphatic ethers	11	3278-89-5 37853-59-1 35109-60-5		X	X					X	X

OFR CLASS	NO. OF CHEMICALS IN CLASS	MOST FREQUENTLY REPORTED/ CITED CAS NOS.	REPORTED USES								
			Construction	Plastic Material/Resin	Plastic Products	Pu Foam	Textiles	Paints, Coatings	Rubber Products	Electrical/Electronic Products	Children's Products
Polyhalogenated phthalates/benzoates/imides	19	26040-51-7 632-79-1 20566-35-2 183658-27-7		X	X	X	X				X
Polyhalogenated triazines	6	25713-60-4		X	X					X	
Source: Multiple sources described throughout this report.											

3.3.4.2 OFR Use in Intermediate and End Products

There is limited data available to help distinguish OFR uses in intermediate versus end uses. The most relevant and useful source is probably the EPA's CDR program, under which submitters are requested to identify the "type of processing or use operation" for the chemicals they manufacture or import. Chemical manufacturers and importers identify these uses by selecting from the following:

- **Processing as a reactant**. Chemical substance is used in chemical reactions for the manufacturing of another chemical substance or product.
- **Processing—incorporation into formulation, mixture, or reaction product**. Chemical substance is added to a product (or product mixture) prior to further distribution of the product.
- **Use—non-incorporative activities**. Chemical substance is otherwise used (e.g., as a chemical processing or manufacturing aid).
- **Processing—incorporation into article**. Chemical substance becomes an integral component of an article distributed for industrial, trade, or consumer use.
- **Processing—repackaging**. Preparation of a chemical substance for distribution in commerce in a different form, state, or quantity.

Under this scheme, the first three of these can reasonably be considered an intermediate use, while reports classified as "incorporation into article" and (perhaps) "repackaging" can be considered end uses.

In the most recent CDR reporting period, industry submitted 100 reports of OFR manufacturing or importing activity in 2015, covering 37 OFRs. For each activity, submitters are requested to complete up to 10 reports that indicate processing or use information to the extent such information "is known or reasonably ascertainable." From the 100 manufacturing/importing reports, a total of 172 processing/use reports were submitted indicating the type of processing or use. Exhibit 3-47 shows the distribution of these by type of processing or use, and chemical/OFR class. Note that there is no reporting of the volumes of OFRs associated with these processing or use reports.

"Processing-incorporation into formulation, mixture, or reaction product," an indication of intermediate use, accounts for 110 of the 172 total reports (63.9 percent). Only 23 reports are classified as "Processing-incorporation into article," a clear indication of end product use. These nine reports are associated with only 11 different OFRs (CAS Nos. 1163-19-5, 183658-27-7, 25327-89-3, 25637-99-4, 26040-51-7, 3194-55-6, 4162-45-2, 42757-55-1, 61788-76-9, 79-94-7, and 84852-53-9).

EXHIBIT 3-47. OFR INTERMEDIATE AND END USES IDENTIFIED, 2015

OFR CLASS AND CAS NO.	"INTERMEDIATE USES"			"END USES"		NKRA	CBI	TOTAL
	Processing As A Reactant	Processing-Incorporation Into Formulation, Mixture, Or Reaction Product	Use-Non-Incorporative Activities	Processing-Incorporation Into Article	Processing-Repackaging			
POLYHALOGENATED ALICYCLES	**2**	**6**		**7**				**15**
25637-99-4		4		3				7
3194-55-6	1	1		4				6
77-47-4	1	1						2
POLYHALOGENATED ALIPHATIC CHAINS	**1**	**42**		**1**	**1**	**1**	**8**	**54**
1401974-24-0							2	2
1402738-52-6							2	2
1417900-96-9							4	4
3296-90-0		3						3
36483-57-5		2						2
61788-76-9	1			1				2
63449-39-8		22			1	1		24
68527-01-5		1						1
68527-02-6		14						14
POLYHALOGENATED BENZENE ALIPHATICS AND FUNCTIONALIZED		**7**	**2**	**4**			**3**	**16**
84852-53-9		7	2	4			3	16
POLYHALOGENATED BISPHENOL ALIPHATICS AND FUNCTIONALIZED	**3**	**10**		**5**				**18**
21850-44-2		1						1
25327-89-3		1		1				2
4162-45-2				1				1
79-94-7	3	8		3				14

OFR CLASS AND CAS NO.	"INTERMEDIATE USES"			"END USES"		NKRA	CBI	TOTAL
	Processing As A Reactant	Processing-Incorporation Into Formulation, Mixture, Or Reaction Product	Use-Non-Incorporative Activities	Processing-Incorporation Into Article	Processing-Repackaging			
Polyhalogenated carbocycles		**6**			**1**	**1**		**8**
115-27-5		2						2
13560-89-9		4			1	1		6
Polyhalogenated diphenyl ethers		**2**		**1**				**3**
1163-19-5		2		1				3
Polyhalogenated organophosphates	**4**	**22**				**1**	**1**	**28**
115-96-8						1		1
13674-84-5	2	14					1	17
13674-87-8	1	2						3
19186-97-1		1						1
38051-10-4		2						2
6294-34-4	1							1
76025-08-6		3						3
Polyhalogenated phenol derivatives	**2**			**1**				**3**
118-79-6	2							2
42757-55-1				1				1
Polyhalogenated phenol-aliphatic ether	**1**							**1**
3278-89-5	1							1
Polyhalogenated phthalates/benzoates/imides	**6**	**14**		**4**	**1**			**25**
117-08-8	1							1
183658-27-7		1		1				2
20566-35-2	1	3						4
26040-51-7		4		3	1			8
32588-76-4		3						3
632-79-1	4	3						7
Polyhalogenated triazines		**1**						**1**
25713-60-4		1						1
Grand Total	**19**	**110**	**2**	**23**	**3**	**3**	**12**	**172**

NKRA = not known or reasonably ascertainable. CBI = use not disclosed, confidential business information.
Source: U.S. EPA, CDR (2016).

These data from CDR should be interpreted with caution. As noted, manufacturers and importers are only requested to identify the type of processing or use if such information is known to or can be reasonably ascertainable by them. In practice, many manufacturers and importers are likely to have limited knowledge or the ability to ascertain how chemicals they manufacture or import are used. Furthermore, to the extent they have such information it is more likely to be information about intermediate uses than end product uses. End-product manufacturers are further downstream from them in the product supply chain compared to intermediate product manufacturers. Thus, the data may be biased towards intermediate uses. Additionally, as noted above the number of reports does not reflect the relative volumes of OFRs associated with these processing or use activities.

3.3.4.3 Quantities of OFRs Used in Intermediate and End Products

Currently, there are no known data sources in the United States or internationally that identify the quantities of OFRs used in specific intermediate or end products. Available data for the United States, which is generally more comprehensive than that of other countries, is summarized above.

In addition to reviewing these sources, we also reviewed and considered obtaining data from market research reports focused on flame retardants. A number of these are cited in Section 4.2.4. While many of these reports present flame retardant consumption by end use market (e.g., tonnes or percent of total consumption going to electronics, construction, etc.), some reports only provide these breakdowns for "all" flame retardants. Others may provide breakdowns for categories of flame retardants, but these do not closely align with the CPSC OFR category definitions. Furthermore, it is often not clear how such end use estimates are developed. Where the methodology is described, it is common to reference "industry sources" without further description or detail. This suggests the report authors are relying on industry sources, who may have a limited perspective on the overall market, to make such estimates. For these reasons, further data from market research reports was not pursued.

CHAPTER 4 | ORGANOHALOGEN FLAME RETARDANT TRENDS

In this chapter, we begin with a discussion of the trends in the regulation of OFRs over the past several decades. Then, we discuss market trends for these chemicals. In Chapter 5, we provide our overall summary and conclusions.

4.1 LEGAL AND REGULATORY DEVELOPMENTS

OFRs have received considerable regulatory attention from governmental jurisdictions in the United States and around the world; however, the scope and applicability of these regulatory actions varies significantly. In this section, we provide a detailed discussion of legislative action taken in the United States, followed by a similar discussion of action taken by other nations. Volume 2, Appendix R of this report provides detailed fact sheets describing specific pieces of legislation enacted or under consideration since 1986 in 21 U.S. states and the District of Columba, at the U.S. federal level, and by Canada, the EU, and Japan.[21]

4.1.1 METHODOLOGY

To identify relevant legal requirements related to OFRs, we undertook the following steps.

- **Sources provided by CPSC.** We began by reviewing the sources identified in the Request for Proposal (RFP) for this effort (e.g., Oregon Toxic-Free Kids Act, Washington Children's Safe Products Act, webpages published by the European Chemicals Agency). Additionally, CPSC provided approximately 20 papers and book chapters for our review.
- **SaferState.org website.** One of the sources listed in the RFP was a website maintained by Safer States, a network of environmental health coalitions and organizations in the United States. The website includes a "Bill Tracker" tool that allows the user to identify current and pending legislation for specific types of chemicals by state. Using this tool, we reviewed relevant legislation for each state.
- **Literature review.** Finally, relying on the literature review described in Chapter 3, we identified approximately 75 publications that were coded as including some information related to the regulation of OFRs. Many of these publications are focused on other topics and only mention regulatory information in passing; however, approximately a half-dozen provided a more focused look at regulatory trends.

Based on these sources, we created a fact sheet for each major government jurisdiction (state, federal/national, or Regional Economic Integration Organization (REIO, e.g., the European Union). Each

[21] We also attempted to identify legislation developed in China related to OFRs. Our literature review suggests China imposes some restrictions on OFRs, as discussed generally in Section 4.1.3.

fact sheet summarizes information about major legislation addressing OFRs. These fact sheets are provided in Volume 2, Appendix R.

4.1.2 U.S. REGULATORY TRENDS

According to data compiled from fact sheets provided in Volume 2, Appendix R, 15 U.S. states and the District of Columbia have existing laws restricting the use of OFR chemicals. An additional seven states have similar pending legislation. The majority of legislation restricts or prohibits manufacturing, selling, or distributing in commerce products that contain more than one tenth of one percent of identified hazardous chemicals, specifically when used in children's products, upholstered furniture, or mattresses. Other products identified are carpeting, window treatments, or residential textiles broadly.

In the past 20 years, the work done at the state level to restrict the use of harmful flame-retardant chemicals in consumer products has included the identification of these OFR chemicals, additional research on alternatives to OFR chemicals and potential exposure, use restrictions of OFRs in consumer products, especially children's products, and legislation requiring the reporting of use of OFR chemicals in consumer products. Using legislation, states have developed tools to report and share data reported for hazardous chemicals across state lines. In the legislation, a few states have encouraged federal agencies to do more to protect human health and the environment from the use of potentially hazardous OFR chemicals.

The earliest regulation of an OFR chemical in the United States occurred in the late 1970's with CPSC's attempt to ban brominated Tris (Tris(2,3-dibromopropyl)phosphate, CAS 126-72-2) from use in children's pajamas. After a period of relatively little new regulation in the 1980s and 1990s, state legislatures initiated efforts to regulate OFRs, focusing at first on polybrominated diphenyl ethers (PBDEs) and then later on a broader set of OFR chemicals.

These efforts are described below.

4.1.2.1 1960 – 1987: Brominated Tris

According to Cordner et al. (2013), the manufacture of chemical flame retardants began in the 1960s, and concerns about the health risks posed by these chemicals emerged shortly thereafter. As described in their paper, in 1973 in Michigan, polybrominated biphenyl flame retardants were accidentally substituted for cattle feed, poisoning livestock and leading to concerns about exposure for Michigan residents through the consumption of meat and dairy products.[22] This incident was followed by the discovery that an OFR commonly used in children's pajamas, brominated Tris (CAS 126-72-7) was mutagenic (Blum and Ames, 1977, as cited in Cordner et al., 2013). Based on these findings, CPSC banned the compound in children's sleepwear, and EPA ultimately restricted its use under a Significant New Use Rule pursuant to TSCA (CPSC 1977 and US EPA 1987, as cited in Cordner et al. 2013).[23] As a result, brominated Tris was thought to be no longer in use in the United States, however data compiled in this report indicate that this

[22] As of 2013, epidemiological studies of this population were still active (Egginton, J., 2009 and Michigan Department of Community Health, 2012, as cited in Cordner et al., 2013).

[23] CPSC's ban was overturned in Federal court, however it maintained the authority to pursue enforcement actions in federal courts related to brominated Tris (O'Brien 1987, as cited in Cordner et al. 2003).

chemical is on the TSCA active inventory and that its use was indicated in a single report as recently as 2019 (see Exhibit 3-8 and Appendix L).

4.1.2.2 Early 2000 - 2010: Polybrominated Diphenyl Ethers

Beginning in the 2000s, advocacy groups, legislators, and agencies began focusing attention on the health risks associated with polybrominated diphenyl ethers (PBDEs). Three specific compounds received significant attention, including pentaBDE (CAS 32534-81-9), octaBDE (32536-52-0), and decaBDE (1163-19-5). According to Cordner et al. (2013), pentaBDE was primarily used in furniture foam, octaBDE was primarily used in electronics plastics, and decaBDE was primarily used in plastic electronics enclosures and textiles.

As shown below in Exhibit 4-1, regulatory action primarily occurred at the state level, starting with California's 2003 legislation restricting the use of pentaBDE and octaBDE. In response, chemical manufacturers announced that they would voluntarily phase-out the use of the two chemicals beginning in 2004 (Cordner et al. 2013). US EPA subsequently regulated the two chemicals (Cordner et al. 2013).

At the same time, states also began researching the potential adverse health effects associated with decaBDE. In response, in 2009, the chemical industry announced it would phaseout production of the chemical over a 3-year timeline (Cordner et al. 2013). EPA enacted additional restrictions on the use of decaBDE in 2012 (U.S. EPA 2012, as cited in Cordner et al. 2013). In total, between 2003 and 2010, 12 states, accounting for approximately one-third of the U.S. population at the time, had passed legislation restricting the use of pentaBDE, octaBDE, and/or decaBDE.

4.1.2.3 2008 – Present: Additional OFR Chemicals

Beginning in 2008, state legislatures began considering additional OFR chemicals beyond PBDE compounds. Specifically, in 2008 and 2009, Maine, California, and Minnesota passed legislation establishing processes for state agencies to identify and prioritize chemicals of concern, including OFRs, in children's products and consumer products more generally (see Exhibit 4-1 and Appendix R Fact Sheets). Subsequently, from 2011 through 2021, 12 states and the District of Columbia passed laws restricting the use of a wide range of OFRs across a range of products. These states account for approximately 30 percent of the U.S. population (2010 Census). Seven additional states, including Alaska, Virginia, Georgia, Delaware, West Virginia, Iowa, and New Jersey, proposed new legislation between 2019 and 2021 restricting the use of OFRs. These bills are still pending.

4.1.2.4 Summary of U.S. Regulatory Trends

As shown in Exhibit 4-1, state regulation of OFRs has tended to focus primarily on the use of these chemicals in children's products, upholstered furniture, and mattresses. Twelve states and the District of Columbia have banned hazardous OFR chemicals from children's products and/or upholstered furniture, and seven states have banned the use of hazardous OFR chemicals in mattresses. Electronics products are less frequently mentioned, and the use of OFRs in transportation-related products is often exempted from the regulations (see Appendix R Fact Sheets). Some laws also specifically exclude recycled or reused products and replacement parts, likely to help shield less robust secondary markets from any regulatory disturbance and industry more broadly from liability associated with unknown chemical hazards posed by recycled plastics.

According to data compiled in this report, which can be found in Appendix R, eight states and the District of Columbia, have reporting or data sharing requirements for OFR chemicals.[24] U.S. states, like other legal geographies, compel reporting and data sharing in various forms through legislation, rather than relying on voluntary reporting. Broadly, the sharing of data reported to states helps improve the effectiveness of enacted legislation on potentially hazardous OFR chemicals and to address information asymmetries in the market. Increasingly, state legislation allows for reciprocal data-sharing agreements with trade associations, the Interstate Chemicals Clearinghouse, IC2 (theic2.org), or other independent third parties.

U.S. state legislation of hazardous OFR chemicals is becoming increasingly data driven. According to data compiled in this report, 11 states have legislated additional research on OFR chemicals. Additional research required by legislation includes requirements to determine the risks posed to human health by various OFR chemicals, to determine the availability of alternatives, and to report on the potential harm of the OFR and chemical alternatives. In some instances, state legislation of OFR chemicals includes a requirement for state agencies to identify and recommend other chemical flame retardants to be prohibited in the future, on a rolling 3-, or 4-year basis.

[24] These eight states and D.C. represent approximately 27 percent of the U.S. population.

EXHIBIT 4-1. STATE REGULATORY HISTORY

YEAR	STATE	REQUIREMENT	CHEMICALS[1]	RELEVANT PRODUCTS[2]
1986	California	• Identifies OFR as hazardous chemicals • Requires reporting or data sharing	96-13-9 108171-26-2 3296-90-0 2385-85-5 115-28-6 TBBPA (79-94-7) TDCPP (13674-87-8) 126-72-7 TCEP (115-96-8) PBBs Pentabromodiphenyl ether mixture [DE-71 (technical grade)] [3]	N/A (pertains to discharging chemicals to waterways)
2003	California	• Restricts use of OFRs • Requires additional research of OFRs	PentaBDE OctaBDE	All products or flame-retarded parts of products
2004	Washington	• Identifies OFRS as hazardous chemicals	PBDEs	N/A
	New York	• Restricts use of OFRs • Requires additional research of OFRs	PentaBDE OctaBDE DecaBDE	All products or flame-retarded parts of products
	California	• Restricts use of OFRs	PentaBDE OctaBDE	All products or flame-retarded parts of products
	Maine	• Restricts use of OFRs • Requires additional research of OFRs	PentaBDE OctaBDE	All products
	Hawaii	• Restricts use of OFRs	PentaBDE OctaBDE	All products or flame-retarded parts of products
2005	Oregon	• Restricts use of OFRs • Requires additional research of OFRs	PentaBDE OctaBDE	All products
	Maryland	• Restricts use of OFRs • Requires additional research of OFRs	PentaBDE OctaBDE DecaBDE	All products or flame-retarded parts of products
	Michigan	• Restricts use of OFRs • Requires additional research of OFRs	OctaBDE PBDEs	All products
	Michigan	• Restricts use of OFRs	PentaBDE	All products
2006	Illinois	• Restricts use of OFRs • Requires additional research of OFRs	PentaBDE OctaBDE DecaBDE	All products or flame-retarded parts of products
	Maine	• Requires additional research of OFRs	DecaBDE and alternatives	All products
	Rhode Island	• Restricts use of OFRs • Requires additional research of OFRs	PentaBDE OctaBDE DecaBDE	All products or flame-retarded parts of products

YEAR	STATE	REQUIREMENT	CHEMICALS[1]	RELEVANT PRODUCTS[2]
2007	Minnesota	• Restricts use of OFRs • Requires additional research of OFRs	PentaBDE OctaBDE DecaBDE	All products or flame-retarded parts of products
	Maine	• Restricts use of OFRs • Requires additional research of OFRs • Requires reporting or data sharing	PentaBDE OctaBDE DecaBDE	All products
	Washington	• Restricts use of OFRs • Requires additional research of OFRs	PBDEs DecaBDE DecaBDE alternatives	Non-edible products Mattresses
2008	Maine	• Identifies OFRs as hazardous chemicals • Requires reporting or data sharing	All chemicals	Children's product
	California	• Identifies OFRs as hazardous chemicals	71 distinct OFR chemicals	Consumer products
	Washington	• Restricts use of OFRs • Requires additional research of OFRs • Requires reporting or data sharing	TBBPA (79-94-7) TCEP (115-96-8) DecaBDE (1163-19-5) HBCD (25637-99-4) TDCPP (13674-87-8)[4]	Children's products
2009	Minnesota	• Identifies OFRs as hazardous chemicals • Requires reporting or data sharing	59 distinct OFR chemicals	N/A
	Vermont	• Restricts use of OFRs • Requires reporting or data sharing	PentaBDE OctaBDE DecaBDE	Mattresses Mattress pads Upholstered furniture Televisions Computers
2010	Oregon	• Restricts use of OFRs	DecaBDE	All products
	Hawaii	• Support of OFR restriction	DecaBDE All other PBDEs	N/A
	Maine	• Restrict use of OFRs • Requires reporting or data sharing	DecaBDE	Shipping pallets
	Maryland	• Restricts use of OFRs	DecaBDE	All products
2011	Maine	• Identifies OFRs as hazardous chemicals • Requires reporting or data sharing	TBBPA (79-94-7) HBCD (25637-99-4) DecaBDE (1163-19-5)	Children's products
	New York	• Restricts use of OFRs	TCEP	Children's products
2013	California	• Requires additional research	All OFRs	Insulation materials
	Maryland	• Restricts use of OFRs	TCEP	Children's products

YEAR	STATE	REQUIREMENT	CHEMICALS[1]	RELEVANT PRODUCTS[2]
	Vermont	• Restricts use of OFRs • Requires reporting or data sharing	PentaBDE OctaBDE DecaBDE TCEP (115-96-8) TCPP (13674-84-5) TDCPP (13674-87-8)	Children's products Mattresses Mattress pads Upholstered furniture Plastic shipping pallets
2014	California	• Identifies OFRs as hazardous chemicals • Requires reporting or data sharing	All OFRs	Flexible polyurethane foam or upholstered or reupholstered furniture
	Maryland	• Restricts use of OFRs	TDCPP	Children's products
	New York	• Restricts use of OFRs	TDCPP	Children's products
	Vermont	• Restricts use of OFRs • Requires reporting or data sharing	HBCD (25637-99-4) Short-chained chlorinated paraffins (85535-84-8) DBDPE (84852-53-9) TBBPA (79-94-7) BDE-209 DecaBDE (1163-19-5) TCEIP (11509608) TDCPP (13674-87-8) TCPP (13674-84-5) TDBPP (126-72-7) 38051-10-4 TBB (183658-27-7) TBPH (26040-51-7)	Children's products
2015	Minnesota	• Restricts use of OFRs • Requires additional research of OFRs	TDCPP (13674-87-8) TCEP (115-96-8) DecaBDE (1163-19-5) HBCD (25637-99-4)	Children's products Residential upholstered furniture
	Oregon	• Identifies OFRs as hazardous chemicals • Restricts use of OFRs • Requires reporting or data sharing	BDE-209 (1163-19-5) TBB (183658-27-7) SCCP (85535-84-8) TBBPA (79-94-7) TDCPP (13674-87-8) TCPP (13674-84-5) TCEP (115-96-8) HBCD (25637-99-4)	Children's products
2016	Washington, DC	• Restricts use of OFRs • Requires reporting or data sharing	TCEP (115-96-8) TCPP (13674-84-5) TDCPP (13674-87-8)	Children's products Residential upholstered furniture

YEAR	STATE	REQUIREMENT	CHEMICALS[1]	RELEVANT PRODUCTS[2]
	Washington	• Restricts use of OFRs • Requires additional research of OFRs	TDCPP (13674-87-8) TCEP (115-96-8) DecaBDE (1163-19-5) HBCD (25637-99-4) Additive TBBPA (79-94-7) TDBPP (126-72-7) TCPP (13674-84-5) V6 (38051-10-4) TBB (183658-27-7) TBPH (26040-51-7) DBDPE (84852-53-9) SCCP (85535-84-8) Chlorinated paraffins (108171-26-2)[5]	Children's products Residential upholstered furniture
2017	Maine	• Restrict use of OFRs	All OFRs	Upholstered furniture
	Rhode Island	• Restricts use of OFRs	All OFRs	Residential upholstered bedding and furniture
2018	California	• Restricts use of OFRs • Requires reporting or data sharing	All OFRs	Children's products Mattresses Upholstered furniture
2019	Minnesota	• Restricts the use of OFRs	All OFRs (with some exceptions)	Children's products Upholstered residential furniture Residential textiles Mattresses
	Washington	• Identifies OFRs as hazardous chemicals • Requires reporting or data sharing	All OFRs	Consumer products
	New Hampshire	• Restricts use of OFRs	All OFRs	Upholstered furniture
2019 (pending)	Alaska	• Restricts use of OFRs • Requires reporting or data sharing	All OFRs	Consumer products
2020	New York	• Restricts use of OFRs • Requires reporting or data sharing	All OFRs	Children's product
2020 (pending)	Virginia	• Restricts use of OFRs	TDCPP (13674-87-8) TCEP (115-96-8) TCPP (13674-84-5) TBBPA (79-94-7) DecaBDE (1163-19-5) HBCD (25637-99-4) TBPH (26040-51-7) TBB (183658-27-7)	Upholstered furniture Children's products

YEAR	STATE	REQUIREMENT	CHEMICALS[1]	RELEVANT PRODUCTS[2]
	New Jersey	• Identifies OFRs as hazardous chemicals • Restricts use of OFRs • Requires reporting or data sharing	HBCD (25637-9-4) SCCP (85535-84-8) Chlorinated paraffins (108171-26-2) DBDPE (84852-53-9) 79-94-7 DecaBDE (BDE-209)	Children's products
2021	Maryland	• Restricts use of OFRs	All OFRs	Children's products Mattresses Upholstered or reupholstered furniture
	Massachusetts	• Restricts use of OFRs • Requires additional research	TDCPP (13674-87-8) TCEP (115-1496-8) TCPP (13674-84-5) HBCD (25637-99-4) TBPH (26040-51-7) TBB (183658-27-7) Chlorinated paraffins (85535-84-8) PentaBDE OctaBDE TBBPA (79-94-7)	Children's products Residential upholstered furniture Bedding Carpeting Window treatment
	Maine	• Restricts use of OFRs	All OFRs	Upholstered furniture
	Nevada	• Restricts use of OFRs	All OFRs	Children's products Upholstered residential furniture Residential textiles Business textiles Mattresses
	New York	• Restricts use of OFRs • Requires reporting or data sharing	All OFRs	Upholstered furniture Mattresses Electronic displays
2021 (pending)	Georgia	• Restricts use of OFRs	TDCPP (13674-87-8) TCPP (13674-84-5) TCEP (115-96-8) HBCD (25637-99-4) TBPH (26040-51-7) TBB (183658-27-7) Chlorinated paraffins (85535-84-8) OctaBDE (32536-52-0) PentaBDE TBBPA (79-94-7)	Bedding Carpeting Children's product Residential upholstered furniture Window treatment

YEAR	STATE	REQUIREMENT	CHEMICALS[1]	RELEVANT PRODUCTS[2]
	Delaware	• Restricts use of OFRs	TBB (183658-27-7) TBPH (26040-51-7) Chlorinated paraffins (85535-84-8) DecaBDE (1163-19-5) HBCD (25637-99-7) TBBPA (79-94-7) TDCPP (13674-87-8) TCEP (115-96-8) TCPP (13674-84-5)	Children's products Upholstered furniture Mattresses
	West Virginia	• Restricts use of OFRs • Requires additional research of OFRs	DecaBDE PentaBDE HBCD TCEP TDCPP	Children's products Upholstered furniture
	New York	• Restricts use of OFRs	All OFRs	Residential upholstered furniture
	Iowa	• Restricts use of OFRs	All OFRs	Upholstered furniture

Source: IEc research.
Notes:

1. We generally list chemicals as they are identified in the relevant legislation (e.g., we include CAS numbers for chemicals when those numbers are identified by legislators).
2. In most cases, each piece of legislation includes exceptions to the applicability of the law to products included in this column.
3. Chemicals regulated by California's Safe Drinking Water and Toxic Enforcement Act of 1986 were listed in the following years:
    a. 1988: 2385-85-5, 126-72-7, PBBs
    b. 1989: 108171-26-2, 115-28-6
    c. 1992: TCEP (115-96-8)
    d. 1994: 96-13-9
    e. 1996: 3296-90-0
    f. 2011: TDCPP (13674-87-8)
    g. 2017: Pentabromodiphenyl ether mixture [DE-71 (technical grade)], TBBPA (79-94-7)
4. Chemicals regulated by Washington's Children's Safe Products Act (2008) were added to the list of Chemicals of High Concern for Children in the following years:
    a. 2011: TBBPA (79-94-7), TCEP (115-96-8), DecaBDE (1163-19-5), HBCD (25637-99-4)
    b. 2013: TDCPP (13674-87-8)
5. The following OFRs were added to Oregon's list of Chemicals of High Concern to Children in 2017: TDBPP (126-72-7), TCPP (13674-84-5), V6 (38051-10-4), TBB (183658-27-7), TBPH (26040-51-7), DBDPE (84852-53-9), SCCP (85535-84-8), Chlorinated paraffins (108171-26-2).

4.1.2.5 Additional Federal Regulation of OFR Chemicals

As discussed in the Appendix R Fact Sheet, TSCA authorizes EPA to test chemical substances to evaluate potential human health or environmental hazards. Section 5 of TSCA authorizes EPA to issue Significant New Use Rules (SNURs) when it identifies a significant new use that could result in exposure to, or release of, a substance of concern. Section 6 authorizes EPA to restrict or ban the manufacture, importation, processing, distribution, use, and/or disposal of any chemical substance that presents an unreasonable risk of injury to human health or the environment. Specifically, TSCA section 6(h) requires EPA to take expediated regulatory action for certain persistent, bioaccumulative, and toxic (PBT) chemicals.

In October 2014, EPA issued the TSCA Work Plan for Chemical Assessments. In the Work Plan, EPA developed criteria for identifying chemicals for further assessment and focused on chemicals that meet one or more of the following factors: (1) potentially of concern to children's health, (2) neurotoxic effects, (3) PBT, (4) probable or known carcinogens, (5) used in children's products, (6) detected in biomonitoring programs. Last updated in 2014, the Work Plan includes four "clusters" of flame retardant chemicals, including (West and Simon 2018):

- Chlorinated Phosphate Esters (e.g., TCEP, TCPP, TDCPP);
- Cyclic Aliphatic Bromides (e.g., HBCD);
- Tetrabromobisphenol A and Related Chemicals; and
- Brominated Phthalate (TBB, TBPH).

The four clusters include a total of 20 chemicals, and EPA's intent was to complete its assessments by 2016. Subsequently, the passage of the Frank R. Lautenberg Chemical Safety for the 21st Century Act in 2016 required EPA to designate 10 substances on the list as high priority for risk evaluation. HBCD was selected for that high priority list (West and Simon 2018). As a result, HBCD received a final risk evaluation in 2020 and risk management is ongoing starting in 2021.

Also in 2016, EPA identified five PBT chemicals for expedited action and issued a proposed rule in 2019 for the chemical flame retardant Decabromodiphenyl ether (CAS No. 1163-19-5), also called decaBDE. TSCA section 6(h), as amended by the Frank R. Lautenberg Chemical Safety for the 21st Century Act, includes a provision requiring EPA to take expedited action on specific PBT chemicals to reduce exposures to them. These chemicals are slow to degrade, and they accumulate in the environment and in exposed populations over time. As a result, they pose potential risks for exposed populations, including consumers and susceptible subpopulations, such as children.

EPA identified decaBDE as an additive flame retardant in plastic enclosures for televisions, computers, audio and video equipment, textiles and upholstered articles, wire and cables for communication and electronic equipment. EPA concluded that humans or the environment are likely exposed to decaBDE under various conditions and that hazards associated with the chemical include, but are not limited to, potential developmental and neurological effects, general development toxicity, liver effects, and carcinogenicity.

Since then, under TSCA section 6(h), as amended, EPA issued a final rule on January 6, 2021, that prohibits all manufacture (including import), processing and distribution in commerce of decaBDE (1163-

19-5) or decaBDE-containing products or articles, with some exclusions (U.S. EPA 2021).[25] In the rule EPA requires that all persons who manufacture, process, or distribute in commerce decaBDE and products containing decaBDE maintain ordinary business records, such as invoices and bills-of-loading, related to compliance. Exempted from the recordkeeping requirement are those persons that process and distribute in commerce products made from decaBDE containing recycled plastics.

4.1.3 INTERNATIONAL REGULATORY TRENDS

Internationally, other nations and REIOs have also undertaken efforts to limit exposure to certain OFRs. This section provides an overview of key agreements and regulations; however, it is not exhaustive. Many individual countries likely have regulations implementing international agreements, as discussed below.

4.1.3.1 2004 Stockholm Convention

The United Nations Environment Programme (UNEP) is "the global authority that sets the environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment" (UNEP undated). It has led the development of several multilateral environmental agreements, including the 2004 Stockholm Convention. This international treaty aims to "protect human health and the environment from persistent organic pollutants" (Stockholm Convention 2019). Currently, there are 152 signatories to the convention (Sharkey et al., 2020). Notably, the United States has not ratified the treaty.

The Stockholm Convention currently lists five groups of flame retardants. All are listed under Annex A, which requires parties to the convention to take measures to eliminate their production and use. These groups include:

- Hexabromobiphenyl (HBB);
- Hexabromocyclododecane (HBCDD);
- OctaBDE;
- PentaBDE; and
- DecaBDE.

The Stockholm Convention allows signatories to apply for certain exemptions from the restrictions included in the agreement. For example, for pentaBDE and OctaBDE congeners, exemptions are available for certain uses of these chemicals with regard to recycling of contaminated waste articles (Sharkey et al. 2020). For decaBDE, in contrast, exemptions are available for certain product types (e.g., specific parts for legacy vehicles, materials for building aircraft, etc.). Exhibit 4-2 summarizes the year each flame retardant was listed, whether exemptions are available, the countries that obtained exemptions, and the year the exemptions will expire.

[25] The rule includes an exclusion for the distribution in commerce of new products made from recycled plastics (i.e., plastic from products and articles that were originally made with decaBDE) that may still contain the chemical.

EXHIBIT 4-2. STOCKHOLM CONVENTION LISTED FLAME RETARDENTS

FLAME RETARDENT	YEAR LISTED	EXEMPTION(S) FOR USE	EXEMPTIONS(S) FOR PRODUCTION	COUNTRY (U/P)[1]	EXEMPTION EXPIRATION YEAR
Tetra/PentaBDE	2004	Y	N	Brazil (u), Japan (u), Turkey (u), Republic of Korea (u)	2030
Hexa/heptaBDE	2004	Y	N	Brazil (u), Japan (u), Turkey (u), Republic of Korea (u), Cambodia (u)	2030
DecaBDE	2019	Y	Y	Brazil (u), EU (u/p), Iran (u), New Zealand (u), Republic of Korea (u/p), Switzerland (u/p)	2036
HBCDD	2014	Y	Y	China (u/p), Republic of Korea (u)	2021
HBB	2004	N	N	none	2009

Source: Reproduced from Sharkey et al. (2020), Table 1.
Note:
1. U = use; p = production.

4.1.3.2 European Union Regulations

Three key regulations and directives implement the Stockholm Convention in the EU (Sharkey et al. 2020):

- **Regulation 2019/1021 on persistent organic pollutants:** This regulation identifies persistent organic pollutants (POPs) that must be restricted and/or prohibited within the EU.
- **Directive 2011/65/EU on the restriction of the use of certain hazardous (ROHs) substances in electrical and electronic equipment:** This directive works with regulation 2019/1021 to define concentration limits for flame retardants in consumer products, including for new products entering the market and in waste streams.
- **Regulation 1907/2006 "Registration, Evaluation, Authorisation and Restriction of Chemicals" (REACH):** REACH requires companies to identify and manage the risks linked to substances manufactured and marketed in the EU. Companies must demonstrate how the substance can be safely used, and they must communicate the risk management measures to users. If risks cannot be managed, the authorities may restrict the use of substance. Under REACH, the European Chemicals Agency (ECHA) evaluates information on substances and identifies Substances of Very High Concern (SVHC). Relevant restricted substances under REACH (Annex XVII) include:
    - Tris (2,3 dibromopropyl) phosphate (126-72-7);
    - Polybromobiphenyls, Polybrominatedbiphenyls (PBB) (59536-65-1);
    - Tetrabromo(tetrabromophenyl)benzene (27858-07-7);
    - Decabromo-1,1'-biphenyl (13654-09-6);

- 4-bromobiphenyl (92-66-0);
- 4,4'-dibromobiphenyl (92-86-4);
- 3-bromobiphenyl (2113-57-7);
- Hexabromo-1,1'-biphenyl (36355-01-8);
- Diphenyl ether, octabromo derivative (32536-52-0).[26]

4.1.3.3 Japan

In 1973, Japan enacted two laws intended to address hazardous substances, including:

- **Act on Control of Household Products Containing Harmful Substances (Act No. 112 of 1973):** This law authorizes regulators to designate products as containing harmful substances, and prohibits businesses from manufacturing, importing, or selling household products containing these substances. Currently, two relevant OFRs are identified as harmful substances, including:
  - Bis (2,3-dibromopropyl) phosphates [BDBPP] (5412-25-9); and
  - Tris (2,3-dibromopropyl) phosphate [TDBPP] (126-72-7).
- **Act on the Regulation of Manufacture and Evaluation of Chemical Substances (Act No. 117 of 1973):** Manufacturers or importers must notify regulators before new chemical substances are manufactured or imported. Class I chemicals cannot be manufactured or imported without permission. The current Class I list includes 53 relevant OFR compounds (see Volume 2: Appendix R fact sheet).

4.1.3.4 China

According to Sharkey et al. (2020), in 2016 China "'banned the produce, use, import, and export of HBCDD except for specific exemptions of production and use for EPS and XPS buildings' in line with exemptions set out in the Stockholm Convention." In addition, China established concentration limits for PBDEs in "'electronic information products' made from virgin plastics entering the marketplace" (Sharkey et al. 2020). However, it has not set a limit on decaBDE (Ibid.)

4.2 MARKET TRENDS

This section provides an overview of trends in OFR use based on four key data sources. First, we describe production activity in the United States, including the manufacture and importation of OFRs, based on periodic reporting to EPA under the Chemical Data Reporting (CDR) Rule. Then, we describe trends in reported OFR waste in the United States based on EPA's Toxic Release Inventory (TRI). We rely on the State of Washington and Oregon's High Priority Chemical Data System (HPCDS) to describe trends in the use of OFRs in children's products. Finally, we review trend information reported in multi-client reports produced by market research firms.

[26] PentaBDE and short chain chlorinated paraffins were removed from Annex XVII in 2011 and 2013, respectively.

4.2.1 PRODUCTION VOLUME TRENDS

OFR production (manufacturing and importing) activity in the United States has been periodically reported by industry to EPA under the CDR Rule, and its predecessor, the Inventory Update Rule (IUR). Reporting under these programs began in 1986.[27] While reporting under the CDR is currently required every four years, both the reporting frequency and the reporting criteria have changed over the years. The following summarizes the criteria for the various reporting periods:[28]

- **2016 CDR**. Detailed data are reported for the most recent year (2015), and total production volume (PV) is reported for the prior three years (2012-2014). Reporting is triggered if more than 25,000 pounds of a reportable chemical are onsite during any calendar year during the reporting period (2012-2015). Reporting thresholds are lower (2,500 pounds) for chemicals subject to certain TSCA actions.[29]
- **2012 CDR**. Detailed data are reported for the most recent year (2011) and PV is reported for the prior year (2010). Reporting is triggered if more than 25,000 pounds of a reportable chemical are onsite during the "principal reporting year", i.e., 2011. Reporting thresholds are lower (2,500 pounds) for chemicals subject to certain TSCA actions.
- **2006 IUR**. Aggregate PV per chemical across all reporters is reported by EPA in ranges, for 2005.[30] Reporting is triggered if more than 25,000 pounds of a reportable chemical are onsite during the "principal reporting year", i.e., 2005.
- **2002 IUR**. Data were not available from EPA from this reporting period.
- **1998 IUR**. Total PV is reported in ranges, for 1997.[31] Reporting is triggered if more than 25,000 pounds of a reportable chemical are onsite during the "principal reporting year", i.e., 1997.

CPSC determined that the reporting criteria from the most recent two reporting periods (2016 and 2012) were reasonably consistent and used the data to assemble a timeline of OFR PV for the period 2010 to 2015. Estimated OFR PV for 2005 and 1997, based on the prior IUR reporting criteria, are presented in Appendix Q.

Exhibit 4-3 shows the combined PV for all chemicals by OFR class for 2010 through 2015, as well as the annual average for each class, and Exhibit 4-4 shows this graphically for each OFR class. Over this period, PV was reported for 10 of the 14 OFR classes.

[27] For more details, see https://www.epa.gov/chemical-data-reporting/legislative-and-regulatory-authority-chemical-data-reporting.

[28] In all reporting periods up to and including 2016, there are reporting exemptions for small manufacturers.

[29] Typically, the number of chemicals subject to lower reporting thresholds is small. The number in 2016 was not readily available but for 2020, only nine chemicals were reportable at the lower threshold. None of those were OFRs.

[30] The ranges are as follows, in pounds: <500,000, 500,000 to <1 million; 1 million to <10 million; 10 million to <50 million; 50 million to <100 million

[31] The ranges are as follows, in pounds: 10,000 to 500,000; >500,000 to 1 million; >1 million to 10 million; >10 million to 50 million; 50 million to 100 million

PV was reported for five OFR classes in each of the six years captured: (1) polyhalogenated alicycles, (2) polyhalogenated aliphatic chains, (3) polyhalogenated bisphenol aliphatics and functionalized, (4) polyhalogenated organophosphates, and (5) polyhalogenated diphenyl ethers. PV was reported in only some years for the following OFR classes: (1) polyhalogenated carbocycles (five years), (2) polyhalogenated benzene aliphatics and functionalized (five years), (3) polyhalogenated phthalates/benzoates/imides (four years), (4) polyhalogenated phenol derivatives (two years), and (5) polyhalogenated triazines (one year). Lack of reporting for the remaining four OFR classes indicates that either no manufacturing or importing occurred, or that no manufacturers or importers met the reporting thresholds described above.

In each year, the largest PV reported was for the polyhalogenated aliphatic chains OFR class. The annual average PV for this class is over 81 million pounds, representing more than half the reported PV of all OFRs. The next highest-volume OFR classes are: polyhalogenated organophosphates (54 million pounds); polyhalogenated alicycles (7.1 million pounds), and polyhalogenated phthalates/benzoates/imides (5.8 million pounds). Notably, PV has been reported for this last OFR class in only the last four years and the PV reported in the most recent year (2015) was 9.6 million pounds.

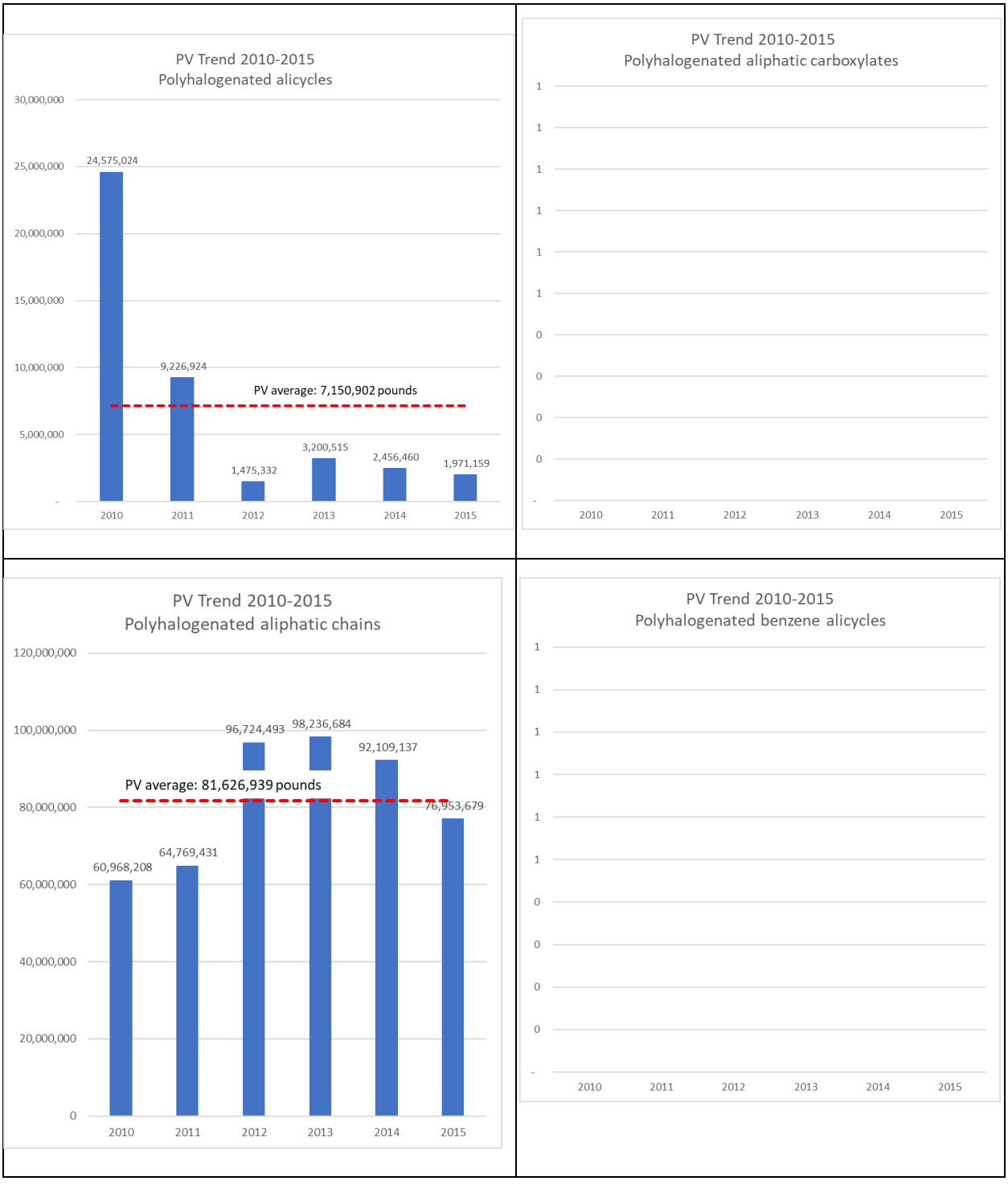
While not directly comparable due to the reporting changes described above, data from the 2006 and 1998 IUR suggest that the OFR PVs presented here show some large decreases compared to earlier years. While the total PV for all OFRs averaged 151 million pounds from 2010-2015, Appendix Q estimates that the combined PV for all OFRs was 752 million in 2005, and 1.4 billion pounds in 1997. In 2005, the three OFR classes with the highest estimated PV were polyhalogenated bisphenol aliphatics and functionalized (305 million pounds), polyhalogenated organophosphates (121 million pounds), and polyhalogenated diphenyl ethers (75 million pounds). In 1997, the three highest volume OFR classes were polyhalogenated diphenyl ethers (767 million pounds), polyhalogenated bisphenol aliphatics and functionalized (261 million pounds), and polyhalogenated organophosphates (119 million pounds). Thus, there is evidence of both a general decrease in the manufacturing and importing volume of OFRs over this extended time period as well as some shifting among the various OFR classes.

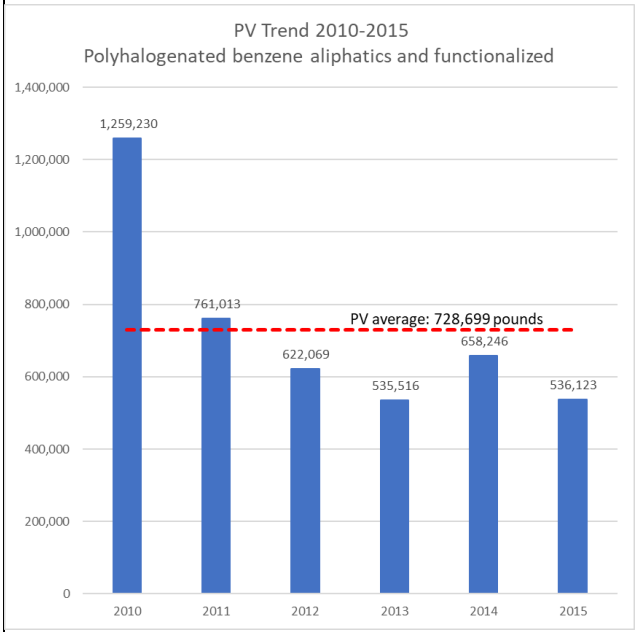
EXHIBIT 4-3. REPORTED PRODUCTION VOLUME BY OFR CLASS, 2010-2015

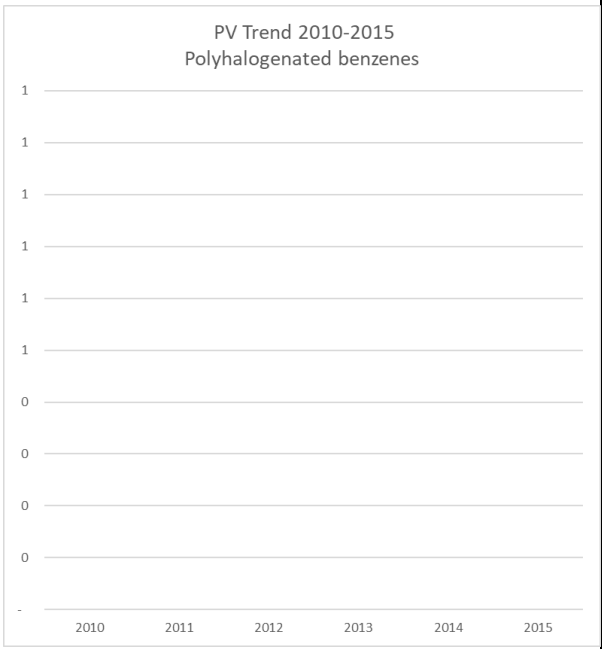
OFR CLASS	REPORTED PV (POUNDS)						
	2010	2011	2012	2013	2014	2015	2010-2015 AVERAGE
Polyhalogenated alicycles	24,575,024	9,226,924	1,475,332	3,200,515	2,456,460	1,971,159	**7,150,902**
Polyhalogenated aliphatic carboxylates	-	-	-	-	-	-	**-**
Polyhalogenated aliphatic chains	60,968,208	64,769,431	96,724,493	98,236,684	92,109,137	76,953,679	**81,626,939**
Polyhalogenated benzene alicycles	-	-	-	-	-	-	**-**
Polyhalogenated benzene aliphatics and functionalized	1,259,230	761,013	622,069	535,516	658,246	536,123	**728,699**
Polyhalogenated benzenes	-	-	-	-	-	-	**-**
Polyhalogenated bisphenol aliphatics and functionalized	579,516	564,799	80,248	26,646	69,555	78,704	**233,245**
Polyhalogenated carbocycles	680,000	822,409	1,389,706	1,265,139	1,238,759	802,482	**1,033,083**
Polyhalogenated diphenyl ethers	251,733	542,112	64,167	275,413	284,330	573,192	**331,825**
Polyhalogenated organophosphates	33,306,973	46,078,478	58,227,373	59,892,351	65,058,589	64,266,362	**54,471,688**
Polyhalogenated phenol derivatives	-	-	-	276	-	27,557	**4,639**
Polyhalogenated phenol aliphatic ethers	-	-	-	-	-	-	**-**
Polyhalogenated phthalates/benzoates/imides	-	60,000	7,943,212	8,121,647	8,982,680	9,647,334	**5,792,479**
Polyhalogenated triazines	1,245,337	760,991	-	-	-	-	**334,388**
TOTAL	**122,866,020**	**123,586,157**	**166,526,600**	**171,554,187**	**170,857,756**	**154,856,592**	**151,707,885**

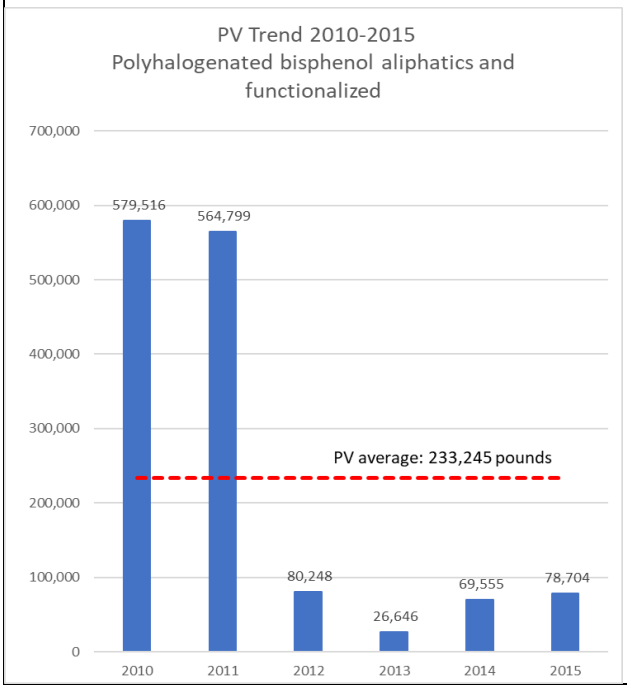
Source: U.S. EPA CDR (2012 and 2016).

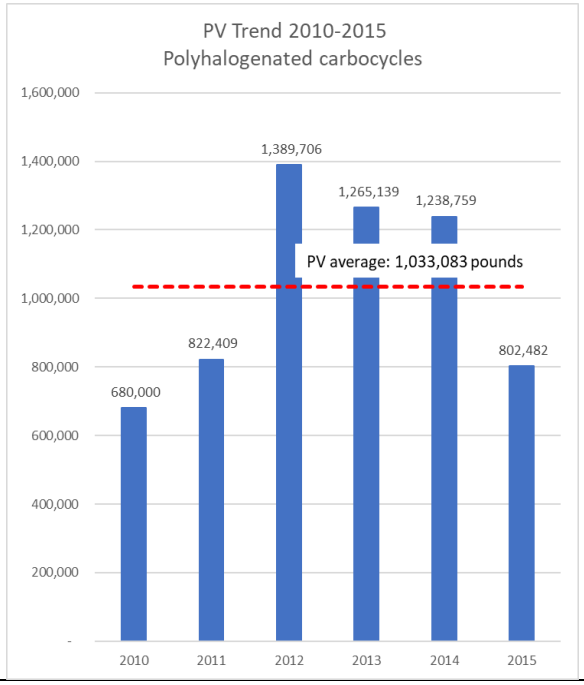
EXHIBIT 4-4. PRODUCTION VOLUME TRENDS BY CLASS (2010 - 2015)

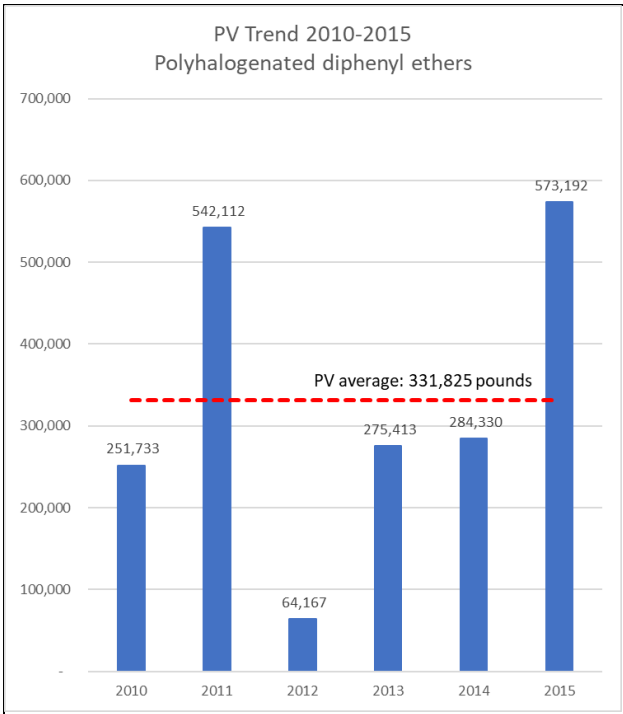


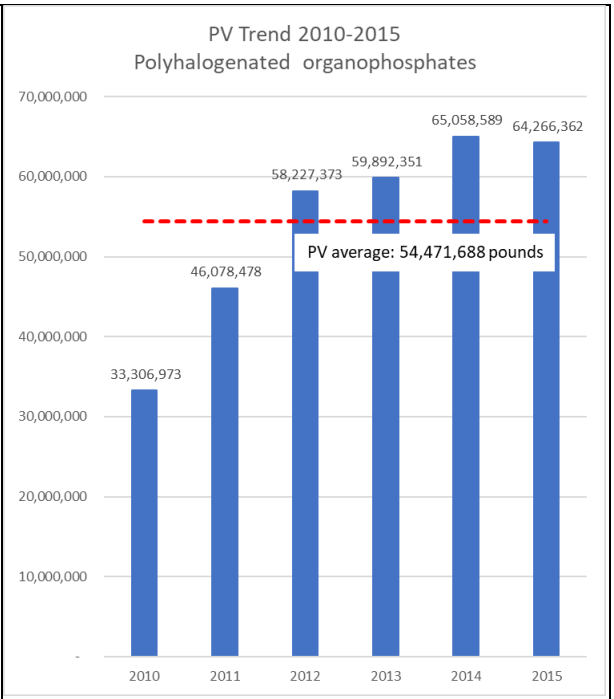

PV Trend 2010-2015
Polyhalogenated benzene aliphatics and functionalized
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1,259,230
761,013
622,069
535,516
658,246
536,123
PV average: 728,699 pounds
2010
2011
2012
2013
2014
2015

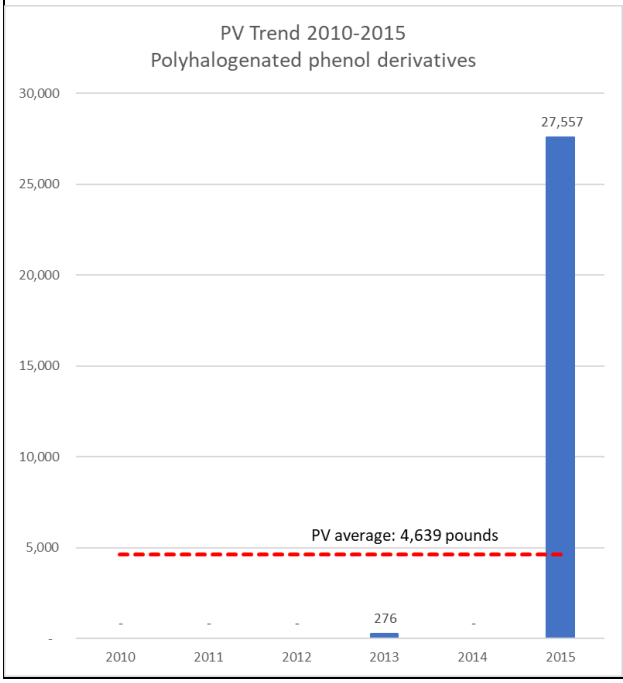

PV Trend 2010-2015
Polyhalogenated benzenes
1
1
1
1
1
1
0
0
0
-
2010
2011
2012
2013
2014
2015


PV Trend 2010-2015
Polyhalogenated bisphenol aliphatics and functionalized
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
579,516
564,799
80,248
26,646
69,555
78,704
PV average: 233,245 pounds
2010
2011
2012
2013
2014
2015

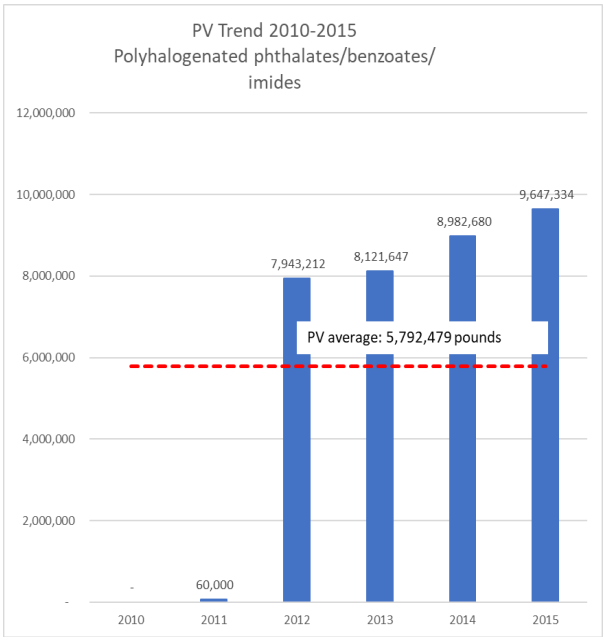

PV Trend 2010-2015
Polyhalogenated carbocycles
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
-
680,000
822,409
1,389,706
1,265,139
1,238,759
802,482
PV average: 1,033,083 pounds
2010
2011
2012
2013
2014
2015

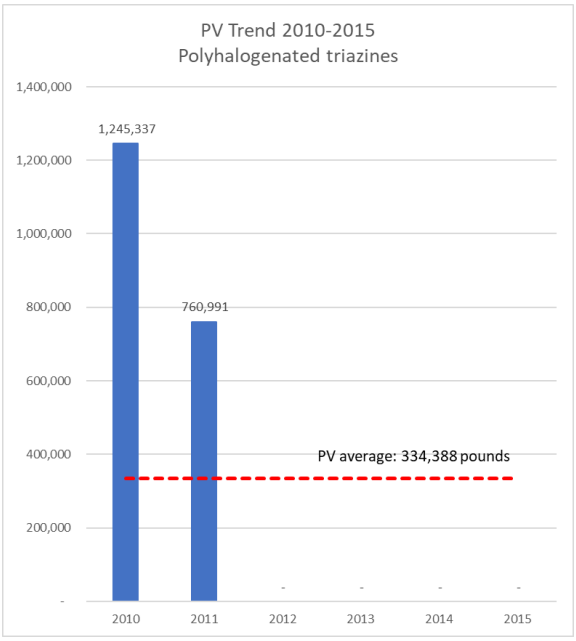

PV Trend 2010-2015
Polyhalogenated diphenyl ethers
700,000
600,000
500,000
400,000
300,000
200,000
100,000
-
251,733
542,112
64,167
275,413
284,330
573,192
PV average: 331,825 pounds
2010
2011
2012
2013
2014
2015


PV Trend 2010-2015
Polyhalogenated organophosphates
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
-
33,306,973
46,078,478
58,227,373
59,892,351
65,058,589
64,266,362
PV average: 54,471,688 pounds
2010
2011
2012
2013
2014
2015


PV Trend 2010-2015
Polyhalogenated phenol derivatives
30,000
25,000
20,000
15,000
10,000
5,000
-
-
-
-
276
-
27,557
PV average: 4,639 pounds
2010
2011
2012
2013
2014
2015


PV Trend 2010-2015
Polyhalogenated phenol aliphatic ethers
1
1
1
1
1
1
0
0
0
0
-
2010
2011
2012
2013
2014
2015





Source: EPA Chemical Data Reporting (CDR), 2012 and 2016 reporting periods.
Note: The reporting criteria differ slightly for 2010-2011 compared to 2012-2016. In 2010 and 2011, chemicals were reportable if there was more than 25,000 pounds onsite during the principal reporting year, 2011. For 2012-2016, reporting was required if the same quantity was onsite during any calendar year within the reporting period.

4.2.1.1 PV and PV Changes for Individual Chemicals

We also examined PV and PV changes for individual chemicals over this period. We first categorized individual chemical PVs as low, medium, or high based on the 2010-2015 average PV for each chemical, as follows:

- High: in excess of 1 million lbs/year
- Medium: 100,000 to 1 million lbs/year
- Low: less than 100,000 lbs/year

Exhibit 4-5 shows all OFR chemicals, by class, ranked in terms of PV and assigned to each of these PV categories. Of the 27 OFRs that were reportable over the 2010-2015 timeframe, eight are classified as "high" PV, six are "medium" PV, and 13 are "low" PV chemicals. Across OFR classes, the polyhalogenated aliphatic chains class accounts for the most "high" PV chemicals (three) as well as the most "medium" PV chemicals (four).

EXHIBIT 4-5. OFRS REPORTABLE DURING 2010-2015, BY PV CATEGORY

OFR CLASS	CAS NO.	AVERAGE PV 2010-2015	CATEGORY
Polyhalogenated alicycles	77-47-4	6,872,948	High
	3194-55-6	248,374	Medium
	25637-99-4	29,580	Low
Polyhalogenated aliphatic chains	63449-39-8	64,411,442	High
	68527-02-6	8,885,143	High
	61788-76-9	7,638,276	High
	68527-01-5	352,507	Medium
	3296-90-0	213,265	Medium
	36483-57-5	208,521	Medium
	85535-85-9	132,276	Medium
Polyhalogenated benzene aliphatics and functionalized	84852-53-9	728,699	Medium
Polyhalogenated bisphenol aliphatics and functionalized	79-94-7	182,399	Medium
	25327-89-3	102,108	Medium
	4162-45-2	16,810	Low
Polyhalogenated carbocycles	115-27-5	968,138	Medium
	13560-89-9	77,933	Low
Polyhalogenated diphenyl ethers	1163-19-5	331,825	Medium
Polyhalogenated organophosphates	13674-84-5	43,295,924	High
	13674-87-8	10,551,937	High
	76025-08-6	570,918	Medium
	115-96-8	79,364	Low
Polyhalogenated phenol derivatives	42757-55-1	4,639	Low
Polyhalogenated phthalates/benzoates/imides	26040-51-7	4,601,790	High
	632-79-1	875,487	Medium
	20566-35-2	295,202	Medium
	117-08-8	20,000	Low
Polyhalogenated triazines	25713-60-4	1,003,164	High

Note: All other OFRs not shown in this table had zero reportable PV over the 2010-2015 period.
Source: EPA CDR, 2012 and 2016.

Exhibit 4-6 shows OFRs whose PV increased or decreased *by more than one million pounds* between 2010 and 2015. The largest increase in PV over this period was for CAS No. 63449-39-8, a member of the polyhalogenated aliphatic chains OFR class. Its PV rose from 28.3 million pounds in 2010 to 68.7 million pounds in 2015, an increase of 40.2 million pounds. Other chemicals with PV increases of one million pounds or more over this period include:

- CAS No. 13674-84-5 (OFR class: polyhalogenated organophosphates), increase of 15.3 million pounds
- CAS No. 13674-87-8 (OFR class: polyhalogenated organophosphates), increase of 14.7 million pounds
- CAS No. 26040-51-7 (OFR class: polyhalogenated phthalates/benzoates/imides), increase of 7.0 million pounds
- CAS No. 632-79-1 (OFR class: polyhalogenated phthalates/benzoates/imides), increase of 1.3 million pounds
- CAS No. 20566-35-2 (OFR class: polyhalogenated phthalates/benzoates/imides), increase of 1.1 million pounds

The largest decrease in PV over this period was for CAS No. 77-47-4, a member of the polyhalogenated alicycles OFR class. Its PV decreased from 24.5 million pounds in 2010 to 1.3 million pounds in 2015, a decrease of 23.3 million pounds. Other chemicals with PV decreases of one million pounds or more over this period include:

- CAS No. 61788-76-9 (OFR class: polyhalogenated aliphatic chains), decrease of 19.9 million pounds
- CAS No. 68527-02-6 (OFR class: polyhalogenated aliphatic chains), decrease of 4.8 million pounds
- CAS No. 25713-60-4 (OFR class: polyhalogenated triazines), decrease of 1.2 million pounds

EXHIBIT 4-6. OFRS WITH PV CHANGES OF 1 MILLION POUNDS OR MORE, 2010-2015

CAS NO.	OFR CLASS	PV 2010	PV 2015	2010-2015 PV CHANGE
2010-2015 PV increase of 1 million pounds or more				
63449-39-8	Polyhalogenated aliphatic chains	28,306,718	68,730,493	40,423,775
13674-84-5	Polyhalogenated organophosphates	33,306,973	48,662,701	15,355,728
26040-51-7	Polyhalogenated phthalates/benzoates/imides	--	7,095,602	7,095,602
632-79-1	Polyhalogenated phthalates/benzoates/imides	--	1,266,832	1,266,832
20566-35-2	Polyhalogenated phthalates/benzoates/imides	--	1,174,900	1,174,900
2010-2015 PV decrease of 1 million pounds or more				
77-47-4	Polyhalogenated alicycles	24,575,024	1,257,515	(23,317,509)
61788-76-9	Polyhalogenated aliphatic chains	19,876,707	10,355	(19,866,352)
68527-02-6	Polyhalogenated aliphatic chains	12,221,977	7,400,000	(4,821,977)
25713-60-4	Polyhalogenated triazines	1,245,337	--	(1,245,337)

4.2.2 WASTE MANAGEMENT TRENDS

The Toxics Release Inventory (TRI) tracks the management of certain toxic chemicals that may pose a threat to human health and the environment. U.S. facilities in different industry sectors must report annually how much of each chemical is released to the environment and/or managed through recycling, energy recovery and treatment, subject to certain reporting thresholds. Currently, 770 toxic chemicals are reportable to the TRI, including nine OFRs:[32]

TRI tracks the following for all reportable chemicals:

a) On-site disposal or other releases of the chemical, include emissions to the air, discharges to bodies of water, disposal to land including disposal in underground injection wells at the facility;

b) Off-site disposal or releases of the chemical, including off-site disposal to landfill or other treatment facility, transfers to a publicly-owned treatment works (POTW);

c) Off-site transfers for recycling or energy recovery; and

d) On-site reuse, recycling, or energy recovery.

EXHIBIT 4-7. LIST OF ALL TRI-REPORTABLE OFRS, 2001-2019

CAS NO.	CHEMICAL NAME	OFR CLASS	FIRST YEAR REPORTABLE	REPORTING THRESHOLD (LBS)[B]
25637-99-4[a]	Hexabromocyclododecane	Polyhalogenated alicycles	2017	100
77-47-4	Hexachlorocyclopentadiene	Polyhalogenated alicycles	1987	25,000 / 10,000
3296-90-0	Pentaerythritol dibromide	Polyhalogenated aliphatic chains	2011	25,000 / 10,000
85535-84-8	C10-13 chloro alkanes	Polyhalogenated aliphatic chains	1995	25,000 / 10,000
59536-65-1	Polybrominated biphenyls (PBB)	Polyhalogenated benzenes	1987	25,000 / 10,000
79-94-7[a]	3,3',5,5'-Tetrabromobisphenol A	Polyhalogenated bisphenol aliphatics and functionalized	2000	100
2234-13-1	1,2,3,4,5,6,7,8-Octachloronaphthalene	Polyhalogenated carbocycles	1987	25,000 / 10,000
1163-19-5	1,1'-Oxybis[2,3,4,5,6-pentabromobenzene] (DecaBDE)	Polyhalogenated diphenyl ethers	1987	25,000 / 10,000
126-72-7	Tris(2,3-dibromopropyl) phosphate	Polyhalogenated organophosphates	1987	25,000 / 10,000

Notes:
[a] Chemical of special concern.
[b] For chemicals of special concern, the reporting threshold is the same for all activities (manufacture, processing, and otherwise use); for all other chemicals, the manufacture and processing threshold is 25,000 lbs./year and the otherwise use threshold is 10,000 lbs./year.

[32] Chapter 3 presents more detailed information about TRI reporting, including further trends analysis for 2015-2019.

TRI waste quantities reported are an imperfect indicator of the quantities of OFR chemicals used. As further explained in Chapter 3, TRI waste quantities represent the minimum amount of chemical used at facilities. Trends in waste quantities may also reflect general trends in use.

The "waste factor" (waste as a percentage of total chemical used) may vary substantially from industry to industry and use to use. It is beyond the scope of this study, however, to assess whether waste factors in industries using OFRs are high or low relative to other chemicals or industries.

It is important to note that TRI defines recycling (whether onsite or offsite) to mean the chemicals are being recovered for reuse. Thus, in the exhibits and discussion below, we subtract the "recycled" amount from the total production-related waste. The quantities of OFRs recycled ranged from about 120,000 to 660,000 pounds from 2001 through 2018, but increased to over 2.27 million pounds in 2019, due to one facility reporting 2.2 million pounds of TBBPA being recycled in 2019.

Exhibit 4-8 shows the number of TRI reports submitted, by chemical, over the period 2001-2019. From the data available, we find that OFR chemicals have been reported through TRI on an annual basis for approximately two decades. Three OFR chemicals have been reported to TRI in every year dating back to 2001: CAS Nos. 1163-19-5 (DecaBDE), 79-94-7 (TBBPA), and 77-47-4 (HCCPD). From 2001 through 2013, the greatest number of reports submitted, an average of 124 per year, was for CAS No. 1163-19-5 (DecaBDE). Beginning in 2014, however, the number of reports for DecaBDE drop to an average of only 24 per year. CAS No. 79-94-7 (TBBPA) then becomes the most commonly-reported OFR chemical, with between 52 and 59 reports submitted per year from 2014 through 2019. Reports for CAS No. 77-47-4 (HCCPD) also remained consistent over the period, ranging from 5 to 10 annually. Three OFR chemicals, CAS Nos. 85535-84-8, 59536-65-1, and 115-28-6, have been reportable over the entire 2001-2019 period but reports for one (CAS No. 85535-84-8) only started showing up in 2015 and only a single report has been submitted for another (CAS No. 59536-65-1), that coming in 2019. No reports for CAS No. 115-28-6 have been submitted over the entire 2001-2019 period.

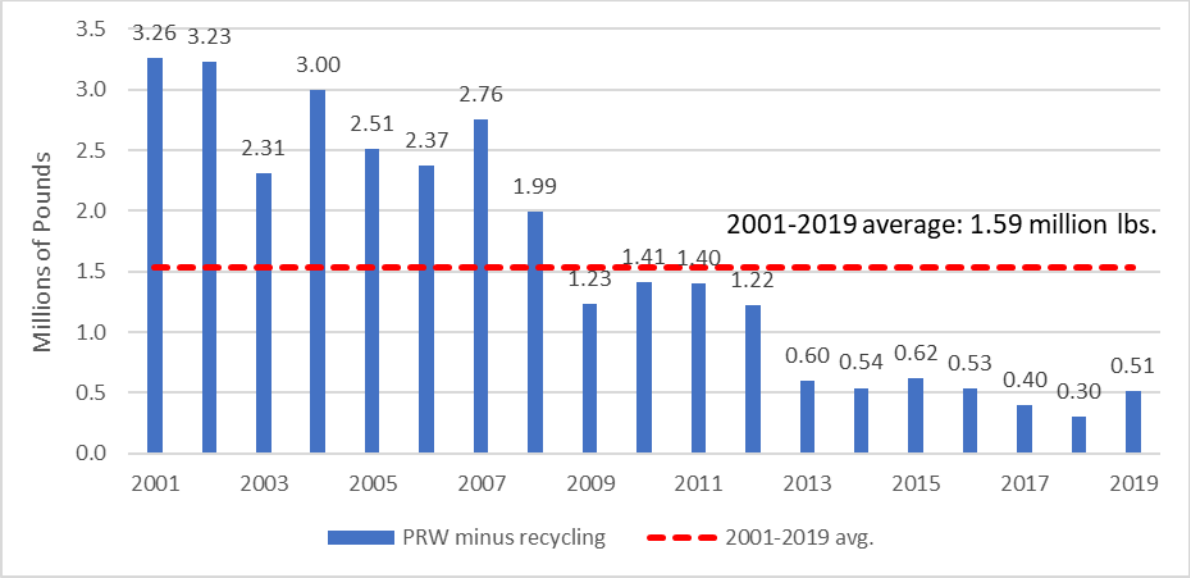
EXHIBIT 4-8. OFRS REPORTABLE TO THE TOXICS RELEASE INVENTORY, ANNUAL NUMBER OF REPORTS, 2001-2019

CAS NO.	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1163-19-5	143	136	131	145	140	147	133	128	115	120	112	97	76	37	30	24	16	15	10
126-72-7	2	1	2	1	2	2	1	1	1	1			1		1	1	1	1	1
2234-13-1						1	1	1	1	1	1	1	1	1					1
3296-90-0	Reportable beginning in 2011										2	3	2	2	2	2	2	3	3
77-47-4	7	8	10	7	6	8	10	8	8	8	9	7	7	8	8	8	6	5	6
79-94-7	52	49	49	45	47	45	44	49	48	50	50	55	52	56	56	59	55	52	56
25637-99-4	Reportable beginning in 2017																4	1	3
85535-84-8															7	4	2	9	6
59536-65-1																			1
115-28-6																			
TOTAL	**204**	**194**	**192**	**198**	**195**	**203**	**189**	**187**	**173**	**180**	**174**	**163**	**139**	**104**	**104**	**98**	**86**	**86**	**87**

Source: U.S. EPA, TRI Basic Data Files, 2001-2019. Accessible at: https://www.epa.gov/toxics-release-inventory-tri-program/tri-basic-data-files-calendar-years-1987-present

Trends in the amounts of "production-related waste" (PRW) reported to TRI[33] are shown in Exhibits 4-9 and 4-10. PRW for all OFRs (Exhibit 4-9) has fallen from 3.2 million pounds per year in 2001 to below one million pounds in all years since 2013. Exhibit 4-10 shows PRW amounts for each reportable OFR over the same period.

EXHIBIT 4-9. PRODUCTION-RELATED WASTES REPORTED TO THE TRI (EXCLUDING RECYCLING), 2001-2019: ALL OFRS



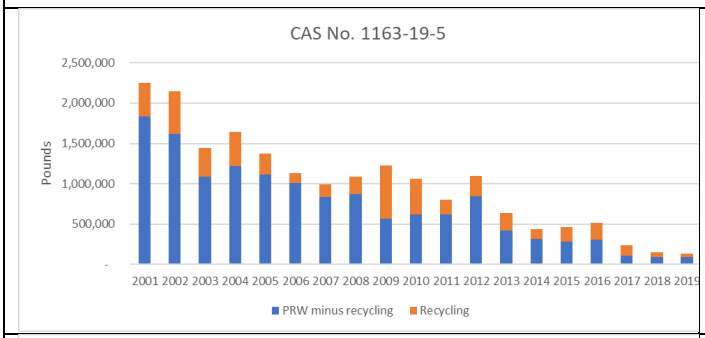
Note: Not all OFRs were reportable to TRI in all years. Reporting for CAS No. 3296-90-0 began in 2011 and reporting for CAS No. 25637-99-4 began in 2017. Changes in the TRI reporting universe may impact multi-year trend analyses or year-to-year comparisons of TRI data.[34] The number of TRI reporters declined over this period.[35]

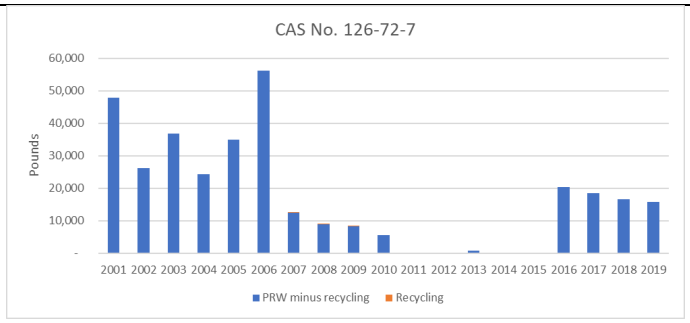
[33] As noted above, this is the total amount of waste reported, less the amount reported as being recycled (reused).

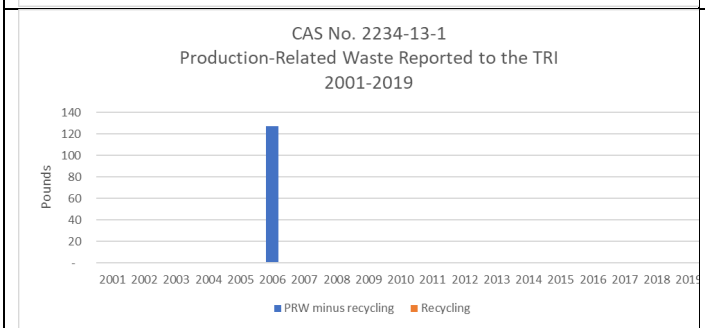
[34] For more details, see https://www.epa.gov/system/files/documents/2022-02/factorstoconsider_approved-by-opa_1.25.22-copy.pdf

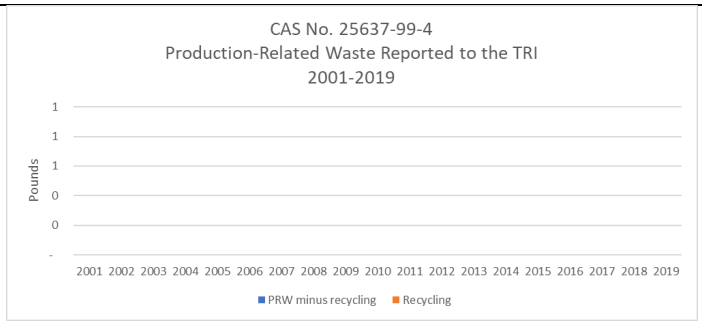
[35] For more information, see https://www.epa.gov/sites/default/files/2019-03/documents/factors_to_consider_march_2019.pdf

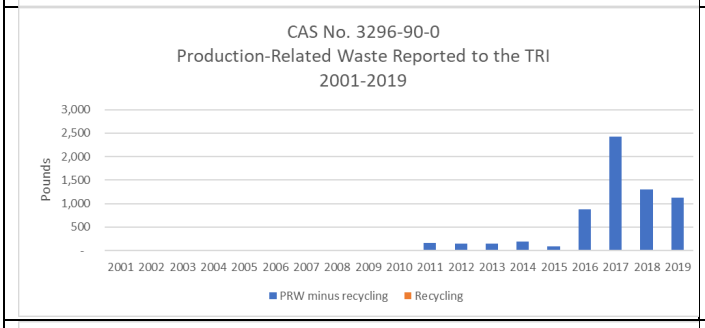
EXHIBIT 4-10. PRODUCTION-RELATED WASTES REPORTED TO THE TRI (EXCLUDING RECYCLING), 2001-2019: ALL OFRS

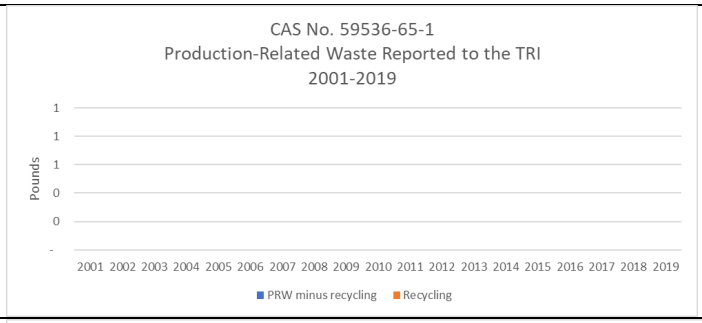


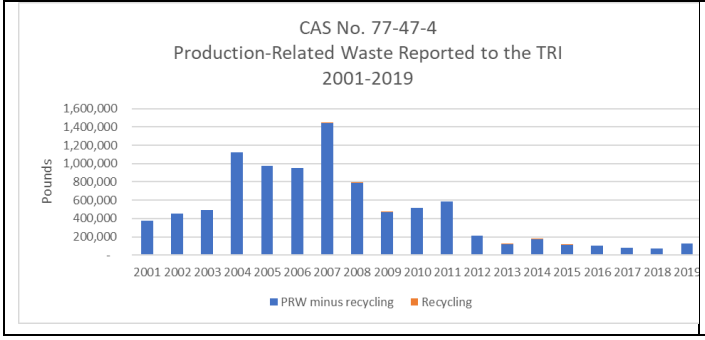


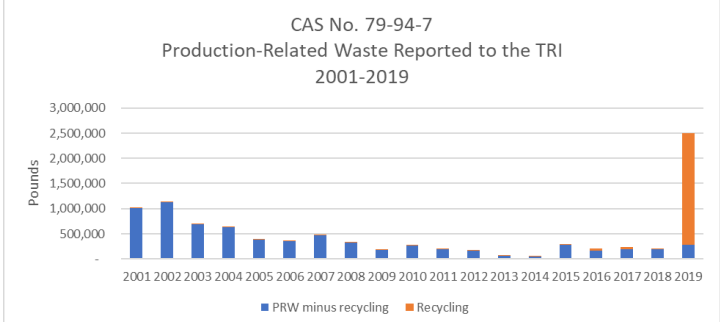


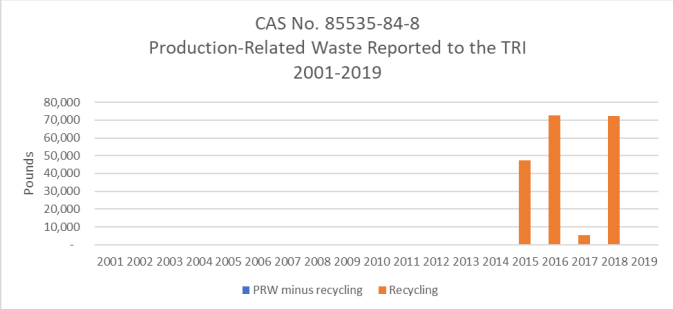












Note: TRI defines recycling as "a variety of methods through which toxic chemicals in waste can be recovered, such as solvent recovery and metals recovery. To be reported as recycling under TRI, the chemicals or the waste containing the chemicals must undergo a recovery step prior to being used again, such as removing impurities from a solvent. The choice of the recycling method depends on the chemical. Once they have been recycled, these chemicals may be reused at the facility or made available for use in commerce." Source: EPA "Common TRI Term." Available at: https://www.epa.gov/toxics-release-inventory-tri-program/common-tri-terms

EXHIBIT 4-11. PRODUCTION-RELATED WASTE QUANTITIES (LESS AMOUNT RECYCLED) REPORTED TO TRI, 2001-2019

CAS NO.	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1163-19-5	1,837,490	1,617,596	1,089,632	1,221,716	1,115,852	1,011,288	837,702	873,023	568,511	621,852	618,206	842,157	423,995	316,580	279,992	311,779	110,264	87,438	87,410
126-72-7	47,935	26,278	36,747	24,359	34,863	56,260	12,406	8,901	8,369	5,545	-	-	762	-	14	20,477	18,410	16,669	15,748
2234-13-1	-	-	-	-	-	127	-	-	-	-	-	-	-	-	-	-	-	-	-
3296-90-0	Reportable beginning in 2011										162	145	144	198	94	875	2,428	1,294	1,121
77-47-4	373,902	453,332	492,516	1,125,750	976,973	948,006	1,439,701	789,685	469,361	516,644	587,694	209,190	117,098	174,731	110,025	100,329	81,337	74,694	127,680
79-94-7	1,004,056	1,133,467	689,577	628,147	384,548	358,820	466,387	320,618	184,757	264,413	193,600	167,741	56,104	46,759	276,829	168,567	191,622	196,799	276,464
25637-99-4	Reportable beginning in 2017																-	-	-
85535-84-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(47,235)	(72,600)	(5,400)	(72,155)	-
59536-65-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
115-28-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**3,263,383**	**3,230,673**	**2,308,471**	**2,999,972**	**2,512,236**	**2,374,501**	**2,756,196**	**1,992,227**	**1,230,998**	**1,408,454**	**1,399,662**	**1,219,233**	**598,102**	**538,268**	**619,719**	**529,427**	**398,661**	**304,738**	**508,423**

Looking at Exhibits 4-10 and 4-11, the key trends that emerge from the TRI reporting data include:

- The quantity of waste managed for CAS No. 1163-19-5 (decabromodiphenyl oxide) averages 730,131 pounds per year over the period 2001-2019. It falls steadily over this period, however, from around 1.8 million pounds in 2001 to 87,000 pounds in 2019. This represents over 60 percent of the total decline across all OFRs over the same period.
- A steady decline can also be seen in PRW for CAS No. 79-94-7 (Tetrabromobisphenol A). In 2001, PRW for this OFR was 1 million pounds, but this declines to just 238,000 pounds by 2019. The average quantity of waste managed over this time period is 368,909 pounds.
- Reported PRW quantities for CAS No. 77-47-4 (Hexachlorocyclopentadiene) increased over the period 2001 to 2007, rising from 373,000 pounds to over 1.4 million pounds. PRW has since decreased, however, to between 75,000 and 130,000 pounds in the most recent two-year period (2018 and 2019).The average quantity of waste managed over 2001-2019 is 482,560 pounds.

4.2.3 OFRS IN CHILDREN'S PRODUCTS

The High Priority Chemical Data System (HPCDS) contains reports that are submitted by manufacturers or importers of products intended for use by children and for sale in Washington or Oregon state. Reports must identify, among other things, the function of the chemical in the product and its concentration in the product.

Reporting data is available from the HPCDS for 13 OFR chemicals for the period 2012 to 2020. The exhibits below show the number of reports submitted each year, by OFR chemical.[36] Exhibit 4-12 shows the total number of reports and reflects use of the chemical for any function and at any concentration. Exhibit 4-13 shows only reports that indicated the function of the chemical was "flame retardant," and Exhibit 4-14 shows reports where the function was "flame retardant" and the concentration in the final product exceeded 0.1 percent.

In terms of total reports for OFRs, Exhibit 4-12 shows that across all years, CAS 79-94-7 accounts for 246 reports, the most among all OFRs, and CAS Nos. 1163-19-5 (DecaBDE) and 85535-84-8 (C10-13 chloro alkanes) account for the next most reports. For multiple chemicals, the number of reports peaked in 2017 and has fallen since, although reports for CAS No. 85535-84-8 peaked two years later, in 2019.

When reports are restricted to use as a flame retardant (Exhibit 4-14), across all years CAS No. 1163-19-5 accounts for 91 reports, the most among all OFRs. This is followed by CAS No. 79-94-7 with 84 reports. A number of chemicals appear to be used more frequently for uses other than flame retardancy, as the number of reports dropped significantly for them. These include CAS Nos. 85535-84-8 (falling from 163 to 4 reports), 79-94-7 (falling from 246 to 84 reports), and 1163-19-5 (falling from 186 to 91 reports).

Finally, when we focus only on OFRs used as a flame retardant at concentrations above 0.1 percent (Exhibit 4-16), the total number of reports across all years falls to 46. That represents 11 percent of all flame retardant use reports and 4 percent of all use reports irrespective of chemical function. Here, CAS Nos. 79-94-7 and 13674-84-5 account for the largest share of these reports with 12 each. Limited trends

[36] It is important to note that reports for Washington are submitted annually, while reports for Oregon are submitted biennially (in even-numbered years) and cover the current and prior year. Thus, year to year comparisons of the number of reports submitted may not be indicative of trends.

can be observed, other than the number of reports for CAS No. 79-94-7 falling from 10 in 2013 to only one in each of the years 2018 and 2019.

EXHIBIT 4-12. NUMBER OF REPORTS SUBMITTED TO HPCDS: ANY CHEMICAL FUNCTION, ANY CONCENTRATION (2012-2020)

OFR CLASS AND CAS NO.	2012	2013	2014	2015	2016	2017	2018	2019	2020[1]	TOTAL
POLYHALOGENATED ALICYCLES		2	16	1	29	63	4	8	3	126
25637-99-4		2	16	1	29	63	4	8	3	126
POLYHALOGENATED ALIPHATIC CHAINS						5	50	105	46	206
108171-26-2						2	9	22	10	43
85535-84-8						3	41	83	36	163
POLYHALOGENATED BENZENE ALIPHATICS AND FUNCTIONALIZED							7	10	5	22
84852-53-9							7	10	5	22
POLYHALOGENATED BISPHENOL ALIPHATICS AND FUNCTIONALIZED		25	28	13	40	71	20	40	9	246
79-94-7		25	28	13	40	71	20	40	9	246
POLYHALOGENATED DIPHENYL ETHERS	1	7	27	10	30	82	8	17	4	186
1163-19-5	1	7	27	10	30	82	8	17	4	186
POLYHALOGENATED ORGANOPHOSPHATES		1	21	6	55	129	20	38	12	282
115-96-8		1	18	4	31	65	5	7	4	135
126-72-7								1		1
13674-84-5							11	19	5	35
13674-87-8			3	2	24	64	4	5	3	105
38051-10-4								6		6
POLYHALOGENATED PHTHALATES/BENZOATES/IMIDES							16	8	1	25
183658-27-7							9	6		15
26040-51-7							7	2	1	10
Total	1	35	92	30	154	350	125	226	80	1,093

[1] Not a complete reporting year.
Source: High Priority Chemical Data System, Interstate Chemicals Clearinghouse (2021).

EXHIBIT 4-13. CHILDREN'S PRODUCTS IDENTIFIED IN REPORTS SUBMITTED TO HPCDS: OFR CHEMICALS, ANY CHEMICAL FUNCTION, ANY CONCENTRATION (2012-2020)

PRODUCT BRICK	NUMBER OF REPORTS (2012-2020)
Shirts/Blouses/Polo Shirts/T-shirts [10001352]	121
Overalls/Bodysuits [10001332]	93
Pants/Briefs/Undershorts [10001347]	87
Toys/Games Variety Packs [10005186]	49
Toys/Games - Other [10006899]	48
Sportswear - Upper Body Wear [10001344]	45
Toy Vehicles - Non-ride (Powered) [10005194]	35
Dolls/Soft Toys (Non Powered) [10005142]	33
Sportswear - Full Body Wear [10001342]	33
Jackets/Blazers/Cardigans/Waistcoats [10001350]	27
Sportswear - Lower Body Wear [10001343]	20
Socks [10001348]	19
Action Figures (Non Powered) [10006395]	18
Baby Car/Booster Seats [10000792]	17
Arts/Crafts Variety Packs [10001760]	16
Headwear [10001329]	15
Belts/Braces/Cummerbunds [10001326]	15
Artists Painting/Drawing Supplies Other [10001685]	14
Pens [10001235]	14
Dresses [10001333]	14
Artists Accessories [10001682]	14
Shoes - General Purpose [10001077]	13
Jewelry Craft Materials [10001717]	12
Personal Accessories Variety Packs [10001389]	12
Fancy Dress Costumes [10005172]	11
Skirts [10001334]	11
Fancy Dress Accessories (Non Powered) [10005175]	10
Dolls/Soft Toys (Powered) [10005143]	9
Baby Carrier [10000502]	9
Necklaces/Necklets [10001090]	9
Blankets/Throws (Non Powered) [10002224]	9
Board Games (Non Powered) [10005133]	9
Bath/Pool Water Toys [10005155]	9
Full Body Wear Variety Packs [10001355]	9
Indoor/Outdoor Games [10005181]	9
Viewing Toys (Powered) [10005171]	7

PRODUCT BRICK	NUMBER OF REPORTS (2012-2020)
Baby Feeding - Bibs [10000732]	7
Role Play - Housekeeping/Gardening/DIY Toys [10005684]	7
Occasion Supplies Variety Packs [10001218]	7
Camping Tents [10002069]	7
Bracelets [10001084]	6
Handwear [10001328]	6
Sleepwear Variety Packs [10001358]	6
Occasion Supplies Other [10001217]	6
Outdoor Games/Play Structures Other [10005180]	6
Clothing Accessories Variety Packs [10001354]	6
Outdoor Play Structures [10005182]	6
Upper Body Wear/Tops Variety Packs [10001361]	6
Night Dresses/Shirts [10001339]	5
Table Games (Non Powered) [10005183]	4
Prams/Pushchairs/Strollers [10000793]	4
Developmental/Educational Toys Other [10005159]	4
Indoor Footwear - Fully Enclosed Uppers [10001078]	4
Sweaters/Pullovers [10001351]	4
Jewelry Craft Supplies Other [10001720]	4
Toy Building Blocks (Non Powered) [10005166]	4
Musical Toys Other [10005179]	4
Dolls Buildings/Settings [10005147]	4
Fancy Dress Costumes/Accessories Other [10005173]	4
Trousers/Shorts [10001335]	4
Pantyhose/Stockings [10002425]	4
Board Games/Cards/Puzzles - Accessories/Replacement Parts [10005135]	4
Card Games (Non Powered) [10005138]	3
Action Figures (Powered) [10006396]	3
Dolls/Puppets/Soft Toys Other [10005144]	3
Measuring/Geometrical Equipment [10001231]	3
Practical Jokes [10005443]	3
Board Games/Cards/Puzzles Other [10005136]	2
Toy Building Blocks (Powered) [10005167]	2
Tiaras [10001093]	2
Rings [10001092]	2
Artists Painting Surface Agents [10001678]	2
Jewelry Other [10001387]	2
Clothing Variety Packs [10002102]	2
Earrings/Body-piercing Jewelry [10001087]	2

PRODUCT BRICK	NUMBER OF REPORTS (2012-2020)
Basketry Craft Materials [10001721]	2
Baby Safety Protection (Non Powered) [10000503]	2
Toy Vehicles - Non-ride (Non Powered) [10005193]	2
Car/Train Sets (Powered) [10005191]	2
Toys - Ride-on (Non Powered) [10005187]	2
Baby Feeding Accessories [10000492]	2
Watches [10001105]	2
Fancy Dress Costumes/Accessories Variety Packs [10005174]	2
Baby Hygiene Products [10000505]	2
Bean Bags/Pouffes/Ottomans [10002197]	1
Baby Hygiene/Grooming Other [10000826]	1
Toys - Ride-on (Powered) [10005188]	1
Pram/Pushchair/Stroller Accessories [10000797]	1
Athletic Footwear - General Purpose [10001070]	1
Dressing Gowns [10001338]	1
Brooches [10001085]	1
Toy Drawing Boards/Accessories [10005442]	1
Developmental/Educational Toys Variety Packs [10005160]	1
Toy Making Accessories [10001711]	1
Action Figure Accessories [10006397]	1
Toy Model Construction (Non Powered) [10005168]	1
Baby Swings [10000803]	1
Role Play - Kitchen Toys [10005250]	1
Baby Play Pens/Dens [10000788]	1
Puzzles (Non Powered) [10005140]	1
Source: High Priority Chemical Data System, Interstate Chemicals Clearinghouse (2021).	

EXHIBIT 4-14. NUMBER OF REPORTS SUBMITTED TO HPCDS: CHEMICAL FUNCTION = FLAME RETARDANT, ANY CONCENTRATION (2012-2020)

OFR CLASS AND CAS NO.	2012	2013	2014	2015	2016	2017	2018	2019	2020[1]	GRAND TOTAL
POLYHALOGENATED ALICYCLES					2	59	1	1		63
25637-99-4					2	59	1	1		63
POLYHALOGENATED ALIPHATIC CHAINS						2		2	6	10
108171-26-2						1		2	3	6
85535-84-8						1			3	4
POLYHALOGENATED BENZENE ALIPHATICS AND FUNCTIONALIZED								6	4	10
84852-53-9								6	4	10
POLYHALOGENATED BISPHENOL ALIPHATICS AND FUNCTIONALIZED		13	1	3	1	61	3	2		84
79-94-7		13	1	3	1	61	3	2		84
POLYHALOGENATED DIPHENYL ETHERS	1	1	6	4	3	66	3	7		91
1163-19-5	1	1	6	4	3	66	3	7		91
POLYHALOGENATED ORGANOPHOSPHATES		1	4	2	2	119	13	20	2	163
115-96-8		1	2	1	1	61	3	4		73
126-72-7								1		1
13674-84-5							8	9	1	18
13674-87-8			2	1	1	58	2	3	1	68
38051-10-4								3		3
POLYHALOGENATED PHTHALATES/BENZOATES/ IMIDES								2	1	3
183658-27-7								1		1
26040-51-7								1	1	2
Total	1	15	11	9	8	307	20	40	13	424

[1] Not a complete reporting year.
Source: High Priority Chemical Data System, Interstate Chemicals Clearinghouse(2021).

EXHIBIT 4-15. CHILDREN'S PRODUCTS IDENTIFIED IN REPORTS SUBMITTED TO HPCDS: CHEMICAL FUNCTION = FLAME RETARDANT, ANY CONCENTRATION (2012-2020)

PRODUCT BRICK	NUMBER OF REPORTS (2012-2020)
Shirts/Blouses/Polo Shirts/T-shirts [10001352]	106
Overalls/Bodysuits [10001332]	70
Pants/Briefs/Undershorts [10001347]	70
Sportswear - Upper Body Wear [10001344]	21
Baby Car/Booster Seats [10000792]	15
Arts/Crafts Variety Packs [10001760]	10
Sportswear - Lower Body Wear [10001343]	10
Belts/Braces/Cummerbunds [10001326]	10
Dolls/Soft Toys (Non Powered) [10005142]	8
Toys/Games - Other [10006899]	7
Camping Tents [10002069]	6
Toy Vehicles - Non-ride (Powered) [10005194]	6
Artists Painting/Drawing Supplies Other [10001685]	6
Shoes - General Purpose [10001077]	6
Socks [10001348]	6
Viewing Toys (Powered) [10005171]	6
Outdoor Play Structures [10005182]	6
Skirts [10001334]	5
Headwear [10001329]	5
Artists Accessories [10001682]	5
Prams/Pushchairs/Strollers [10000793]	4
Dolls Buildings/Settings [10005147]	3
Toys/Games Variety Packs [10005186]	3
Personal Accessories Variety Packs [10001389]	3
Outdoor Games/Play Structures Other [10005180]	3
Fancy Dress Costumes/Accessories Variety Packs [10005174]	2
Indoor/Outdoor Games [10005181]	2
Card Games (Non Powered) [10005138]	2
Baby Safety Protection (Non Powered) [10000503]	2
Baby Feeding Accessories [10000492]	2
Role Play - Housekeeping/Gardening/DIY Toys [10005684]	2
Occasion Supplies Other [10001217]	2
Fancy Dress Costumes [10005172]	1
Fancy Dress Accessories (Non Powered) [10005175]	1
Baby Swings [10000803]	1
Baby Play Pens/Dens [10000788]	1

PRODUCT BRICK	NUMBER OF REPORTS (2012-2020)
Toys - Ride-on (Powered) [10005188]	1
Puzzles (Non Powered) [10005140]	1
Baby Carrier [10000502]	1
Toy Drawing Boards/Accessories [10005442]	1
Bean Bags/Pouffes/Ottomans [10002197]	1
Toy Vehicles - Non-ride (Non Powered) [10005193]	1
Source: High Priority Chemical Data System, Interstate Chemicals Clearinghouse (2021).	

EXHIBIT 4-16. NUMBER OF REPORTS SUBMITTED TO HPCDS: CHEMICAL FUNCTION = FLAME RETARDANT, CONCENTRATION >= 1,000 PPM (2012-2020)

OFR CLASS AND CAS NO.	2013	2014	2015	2016	2017	2018	2019	2020[1]	TOTAL
POLYHALOGENATED ALICYCLES				2		1			3
25637-99-4				2		1			3
POLYHALOGENATED ALIPHATIC CHAINS								4	4
108171-26-2								2	2
85535-84-8								2	2
POLYHALOGENATED BENZENE ALIPHATICS AND FUNCTIONALIZED							1	2	3
84852-53-9							1	2	3
POLYHALOGENATED BISPHENOL ALIPHATICS AND FUNCTIONALIZED	10					1	1		12
79-94-7	10					1	1		12
POLYHALOGENATED DIPHENYL ETHERS		1	1	1		2	3		8
1163-19-5		1	1	1		2	3		8
POLYHALOGENATED ORGANOPHOSPHATES		1	1		2	5	6	1	16
115-96-8					1				1
13674-84-5						5	6	1	12
13674-87-8		1	1		1				3
Total	10	2	2	3	2	9	11	7	46

[1] Not a complete reporting year.
Source: High Priority Chemical Data System, Interstate Chemicals Clearinghouse(2021).

EXHIBIT 4-17. CHILDREN'S PRODUCTS IDENTIFIED IN REPORTS SUBMITTED TO HPCDS: CHEMICAL FUNCTION = FLAME RETARDANT, CONCENTRATION >= 1,000 PPM (2012-2020)

PRODUCT BRICK	NUMBER OF REPORTS (2012-2020)
Toy Vehicles - Non-ride (Powered) [10005194]	6
Arts/Crafts Variety Packs [10001760]	6
Dolls/Soft Toys (Non Powered) [10005142]	5
Outdoor Play Structures [10005182]	4
Shoes - General Purpose [10001077]	3
Artists Painting/Drawing Supplies Other [10001685]	3
Camping Tents [10002069]	3
Baby Feeding Accessories [10000492]	2
Role Play - Housekeeping/Gardening/DIY Toys [10005684]	2
Artists Accessories [10001682]	2
Baby Car/Booster Seats [10000792]	2
Toy Vehicles - Non-ride (Non Powered) [10005193]	1
Baby Swings [10000803]	1
Baby Play Pens/Dens [10000788]	1
Toys/Games - Other [10006899]	1
Toys - Ride-on (Powered) [10005188]	1
Fancy Dress Accessories (Non Powered) [10005175]	1
Baby Safety Protection (Non Powered) [10000503]	1
Baby Carrier [10000502]	1
Source: High Priority Chemical Data System, Interstate Chemicals Clearinghouse (2021).	

From the available data, we see that children's shirts (shirts/bouses/polo shirts/T-shirts [10001352]) are the most commonly reported children's product known to contain OFR chemicals (see Exhibit 4-13). This is also true when we select for children's products containing OFR chemicals identified for their flame-retardant chemical function. The HPCDS data show that OFRs are used as flame retardants in children's shirts in small concentrations (see Exhibit 4-15). However, when we select for OFR chemicals used as flame retardants in children's products in concentrations greater than 1,000 ppm, the most commonly reported children's products are powered, non-riding toy vehicles [10005194] and arts and crafts variety packs [10001760] (see Exhibit 4-17).

4.2.4 OTHER MARKET TRENDS IDENTIFIED

In this section we briefly present some broader perspectives on the flame retardant chemicals market, and trends within that market. This information comes from a variety of sources. A number of market research firms provide analysis of the flame retardant market through multi-client reports that they prepare and update periodically. While the purchase of fully-licensed copies of such reports was beyond the scope and budget of this project, report extracts are available for public use and these contain some relevant findings.

Asia (China) dominates the global market. The global market for flame retardants, in terms of both production and consumption, is dominated by China specifically, and Asia-Pacific more broadly.

- "Asia-Pacific was [the] leading producer accounting for 50% of the total market volume in 2020" (Grandview Research, 2020).
- "The Asia Pacific region is dominating the global market with the highest market share of about 47.3% in 2020" (Reports and Data, 2020).

Flame retardant demand is a derived demand. Flame retardant consumption is linked to its use in electronics, automobiles, construction products, and textiles.

- "Asia Pacific is the major hub of electrical & electronics and occupies the largest flame retardant market share. The presence of major electronics industries, and rising construction activities, will drive the market in this region." (Fortune Business Insights, 2020).
- "Asia Pacific is a substantially large market for flame retardants due to high demand for the product from end-use markets such as automotive, electrical & electronics, construction, and others." (Grandview Research, 2021).
- "The Asia-Pacific region dominated the global market share. Flame retardant chemicals are extensively used in the construction sector in developing insulation, structural elements, cables, and electrical wires." (Mordor Intelligence, 2020).

Standards and regulations drive the use of flame retardants. Fire safety considerations have historically been the main stimulus for the use of flame retardants and remain so today.

- "Various fire standards around the world are driving the market for flame retardants. In Europe, all materials for building and construction (including rigid PU foams) have to meet the fire requirements according to EN 13501. Building materials in the United States have to be tested according to ASTM E 84." (Mordor Intelligence, 2020).
- "Consumption of flame retardants in Europe, the Middle East, and Africa is driven primarily by regulations in many industries, such as the building and construction (including housing, public, and commercial buildings) and transportation industries (automobiles and buses)." (IHS Markit, 2020).

At the same time, regulations are also driving shifts within the market. Health and environmental concerns surrounding the use of flame retardants has led to restrictions and the search for more benign substitutes.

- "In Mainland China, flame retardants have been experiencing rapid development following growth in the plastics market and also as a result of policy requirements. Brominated flame retardants

were once the largest flame retardants segment consumed in mainland China. However, as a result of environmental issues, the use of brominated compounds has been restricted gradually in recent years. Production and consumption of and trade in hexabromocyclododecane (HBCD) have been banned since 2016 except for some applications. The mainland Chinese government has highlighted the importance of halogen-free flame retardants, which is affecting flame retardants market in mainland China." (IHS Markit, 2020).

- "The drive to change from halogenated FRP's [flame retardant polymers], due to toxicology and environmental concerns, came about in the middle of the last decade driven by the introduction of three new regulations, RoHS (Restriction of Hazardous substances), REACH (Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals), specifically SVHC (substances of very high concern) and the WEEE (Waste Electric and Electronical Equipment)." (Mitchell, 2014).
- "The low environmental impact of ATH [alumina trihydrate], combined with strict regulations over the use of halogen compounds will increase the demand for ATH compound, thereby helping this segment emerge as the leading section in the forecast period." (Fortune Business Insights, 2020).
- "The demand for environmentally friendly flame retardants such as non-halogenated flame retardants is growing at a rapid pace. The Asia Pacific, North American, and European regions have emerged as the largest consumers of these non-halogenated flame retardants owing to the presence of stringent environmental sustainability policies and rising awareness for fire safety among consumers." (Grandview Research, 2020).
- "Although some brominated flame retardants are voluntarily withdrawn or banned from use by manufacturers, existing and emerging brominated flame retardants continue to be utilized in heavily industrialized countries such as China and Brazil." (Grandview Research, 2020).

CHAPTER 5 | SUMMARY AND CONCLUSIONS

This report provides class-based market use profiles of OFR chemicals in consumer products. Specifically, NASEM (2019) defines 14 subclasses of OFRs. For each of these classes, we identify and characterize the relevant chemical properties of chemicals in the class, describe their current and historical presence in consumer products in the United States, and characterize regulatory and market trends related to OFR use.

This information is intended for use by CPSC as it responds to a stakeholder petition (HP 15-1) requesting the CPSC initiate rulemaking under the FHSA to ban the use of non-polymeric, additive OFRs in several types of consumer products (infant and toddler products, residential upholstered furniture, mattresses and mattress pads, and the plastic casing of electronic devices). The market use profiles will provide data and information for use by CPSC in its exposure and risk assessment.

5.1 IDENTIFYING AND CHARACTERIZING RELEVANT OFRS IN EACH CLASS

As a first step, we constructed a relational database to combine and standardize information on OFR compounds of interest to CPSC. The database includes 467 chemical compounds identified by CPSC in Attachment 1 to the Request for Quotation (RFQ) for this effort. Our search process identified 21 additional relevant compounds, for a total of 488. Applying expert judgment to the chemical information described below, and in consultation with CPSC staff, we assigned each of the 21 additional chemicals to one of the 14 OFR classes defined by NASEM.

For each compound, the database provides standard identifiers including CAS number, EC number (based on EU REACH), CID (based on PubChem), and DTSXID (based on EPA CompTox). It also identifies the following additional information, including:

- Common names and synonyms;
- Predicted or experimental chemical properties (e.g., boiling point, flash point, Henry's Law constant, LogKoa, vapor pressure);
- Presence of substances on lists of concern (e.g., ECHA Plastic Additives Initiative, NORMAN Suspect List Exchange Classification);
- Structure-activity and Structure-use predictions;
- Links to full text within PubChem and Patent records;
- Patent information filtered by relevant OFR keywords.

This information was collected from 16 databases maintained by various U.S. and European agencies, as well as a network of reference laboratories, research centers, and related organizations. For details, please see Exhibit 2-1 of this report. The database was provided to CPSC as a separate attachment to this report.

From a chemical perspective, many of the OFR chemicals are industrial mixtures. A regulation described as controlling pentaBDE, for example, may also be interpreted to include specific structural isomers of pentaBDE with their own CAS numbers (e.g., 2,2',4,4',5-pentabromodiphenyl ether) or it may refer only to the chemical mixture. Within an OFR class, the compounds often can also be grouped into "homologues," which would be a core compound (e.g., a diphenyl ether) with varying levels of halogenation (e.g., the pentaBDEs or pentabromodiphenyl ethers all have the same core with five substituted bromines, the hexaBDEs have the same core but with six substituted bromines). Similarly, particularly in the polyhalogenated aliphatics, an OFR substance may be a chemical mixture specified by a range of carbons and a percent of the weight that comes from halogen atoms. While level of halogenation is not always tied to use and toxicity, this is a good general guide for the OFR chemicals.

Stereoisomers are also present within the set of OFR compounds. These chemicals have identical chemical connectivity but may be mirror images or other rotations around specific points in the molecule. For example, the majority of the polyhalogenated alicycles class are isomers of hexabromocyclododecane, HBCD, including specific stereoisomers with their own CAS numbers such as (+)-alpha-Hexabromocyclododecane and (1R,2S,5S,6S,9S,10R)-1,2,5,6,9,10-Hexabromocyclododecane. Many of these are not manufactured independently but may be found in environmental or health surveys.

The findings within this report are described at the level at which they are reported. As an example, waste reports under TRI are collected for CAS No. 85535-84-8, C10-13 chloro alkanes, but not for the specific C10 compound 2,3,4,5,6,8-Hexachlorodecane (CAS No. 1852481-27-6), which may be contained within that mixture. Similarly, the regulatory reports are compiled at the level at which the compounds are described (Section 5.3). When unclear, regulations have not been evaluated as to whether they apply to specific individual compounds within a general homologue group or chemical mixture.

5.2 MARKET RESEARCH APPROACH AND FINDINGS

5.1.1 APPROACH

Next, using the list of chemicals provided in the database, along with their CAS numbers and synonyms, we collected information about the use of these chemicals in products of interest to CPSC. Relevant products include, but are not limited to upholstered furniture, mattresses, home furnishings, consumer electronics, appliances, children's products, building materials, and other household products. To collect this information, we followed these general steps:

- We reviewed the results of the initial data and literature search conducted by CPSC and characterized the identified sources of information in terms of their relevance to the task and the OFRs they covered.
- We extended the search to additional sources such as flame retardant reference books and chapters in engineering handbooks focused on flame retardants;
- We searched U.S. and foreign chemical inventories and registries to determine whether each OFR is, or has previously been, in commerce;
- We conducted general literature searches using standard search engines tools and searches of commercial online literature databases; and
- We contacted a select number of industry experts for additional information.

The results of these data collection efforts are summarized below. Importantly, information from U.S. and European sources is more readily-available than information from other countries, particularly in Asia. Given the dominance of Asian manufacturers in products that incorporate flame retardants (e.g., electronics, textiles, automobiles and components), this limits our understanding of the potential presence of OFRs in products imported from outside of the United States.

5.1.2 FINDINGS

While their exact purpose, scope, and application may vary from region to region, registries and inventories maintained by government organizations generally help define "existing" or "active" chemicals (i.e., chemicals that are presently manufactured in or imported into a country or region.) We reviewed six major inventories (U.S. TSCA, EU REACH, Canada DSL, Japan CSCL, and China IECSC) and found that only 40 percent of the 488 chemicals on our list appear on any registry. Japan lists 35.5 percent of OFRs, while the remaining countries/regions list between 4.7 percent and 18.9 percent. The OFR class with the highest number of substances on any list is polyhalogenated diphenyl ethers.

5.1.2.1 Current Uses

Based on the information in the registries described above, we draw the following conclusions about the current uses of OFRs.

- **Actively Used Substances:** According to the TSCA Inventory, 92 OFR substances are designated as active, meaning they have been in commerce at some point in the United States since June 2016. An additional 42 substances are designated as inactive, meaning that as of June 2016, they were determined to no longer be in commerce. A further 354 substances, or 72.5 percent of total, do not appear on the non-CBI portion of the TSCA Inventory. The active chemicals span all 14 OFR classes.
- **Production Volume (manufacturing and importing):** The CDR tracks information about U.S. production and import activity for active substances on the TSCA Inventory. As of the 2016 CDR reporting year, the most recent year available, manufacturers submitted 26 notifications of manufacturing activity for OFR substances, two notices of both manufacturing and importing activity, and 56 notices of importing activity. An additional 25 notices claimed the activity (manufacturing or importing) as CBI, and there were 11 reports for which a description of the activity was not available. The reports spanned 11 OFR classes, with the highest number of reports in the polyhalogenated organophosphates and polyhalogenated aliphatic chains classes. The highest volume chemical reported was chlorinated paraffins (CAS 63449-39-8).
- **Waste Management:** TRI requires U.S. facilities meeting certain reporting requirements to report whether it manufactures, processes, or otherwise uses TRI-listed chemicals above certain reportable quantity thresholds. In 2019, 83 forms were filed for TRI-listed OFR chemicals, for 10 OFR chemicals in seven OFR classes. Fifty-four forms were received from facilities reporting the release of TBBPA, 11 forms for decaBDE, and 6 forms each for HCCPD and certain chlorinated paraffins. The most common uses of the chemicals were processing as a reactant, processing as a formulation component, processing as an article component, and otherwise use (ancillary or other uses). Facilities in the chemical manufacturing sector (NAICS 325) reported for OFR chemicals more than any other sector, representing 41 percent of all forms filed for those chemicals from

2015 to 2019. Over half were plastics material and resin manufacturing sector (NAICS 325111) and custom compounding of purchased resins sector (NAICS 325991).

- **General Use Information:** Data reported to EPA in the CDR requires submitters to identify how and where the substances they manufacture and import are used, to the extent they have knowledge of such uses. In 2015, 172 use reports were submitted for 37 OFR substances spanning 11 OFR classes. The majority of uses (110 of 172) involved incorporation of the substance into a formulation, mixture, or reactant product. An additional 23 reports involved incorporation of the substance into an article, and 19 involved processing as a reactant. "Industrial Function" for CDR substances refers to the function the substance serves, and not surprising, "Flame Retardant" is the most common industrial function reported, accounting for 115 of 172 reports.
- **Use in Children's Products:** The CDR and HPCDS provide information about the use of chemicals in products intended for children. In 2015, there were 34 reports to the CDR of OFR use in consumer products and 6 reports of use in children's products (this likely undercounts the actual number of child product uses for a variety of reasons). The reports spanned seven OFR classes and many types of products (e.g., electrical and electronic products, foam seating and bedding, etc.). The HPCDS identifies substantially more uses of OFR chemicals in children's products than are reported in the CDR. Substances with the highest number of reports include Alkanes, C10-13, chloro (CAS No. 85535-84-8), Tetrabromobisphenol A (CAS No. 79-94-7), Chlorinated paraffins (CAS No. 108171-26-2), and Tris(1-chloro-2-propyl) phosphate (CAS No. 13674-84-5). As with the CDR, "flame retardant" is the most commonly-reported function in the HPCDS.

5.1.2.2 Market Research Findings

In this report we have identified five "high" production volume OFR subclasses and six "high" supply capacity OFR subclasses. OFR subclasses with high production volumes indicate that OFR chemicals in the subclass are in commerce and are used domestically in large volumes. OFR subclasses with high supply capacity are considered to be in commerce, available globally (specifically in China), and may enter the United States as raw chemical, chemical incorporated into a semi-finished good, or in finished products.

Using the 2010-2015 annual averages reported under the CDR reporting program, U.S. production volumes (manufacturing plus importing) for OFR subclasses ranged from a low of zero for three subclasses (polyhalogenated aliphatic carboxylates, polyhalogenated benzene alicycles, and polyhalogenated benzenes) to a high of 81.6 million pounds (polyhalogenated aliphatic chains). Using the high/medium/low PV categorization scheme in Section 4.2.1.1 above, the five subclasses with a "high" average PV over this period are, in decreasing order of PV:

- Polyhalogenated aliphatic chains (PHACs)
- Polyhalogenated organophosphates (PHOPs)
- Polyhalogenated alicycles (PHAs)
- Polyhalogenated phthalates/benzoates/imides (PHPBIs)
- Polyhalogenated carbocycles (PHCCs)

Global supply capacities for OFR substances (and chemicals generally) are not readily available, but for purposes of this report are proxied by examining capacity data for OFRs reported by companies listed as OFR suppliers on the Alibaba e-commerce platform.[37] By aggregating capacity listings by supplier, we determined capacity exceeds 5,000 tonnes per month and is thus considered "high" for six OFR classes. These include, in decreasing order of capacity:

- Polyhalogenated phenol derivatives (PHPDs)
- Polyhalogenated organophosphates (PHOPs)
- Polyhalogenated aliphatic chains (PHACs)
- Polyhalogenated phthalates/benzoates/imides (PHPBIs)
- Polyhalogenated benzenes (PHBs)
- Polyhalogenated alicycles (PHAs)

Thus, four of the five OFR classes classified as "high" domestic PV are also classified as "high" global supply capacity classes: PHACs, PHOPs, PHAs, and PHPBIs. The following provides further market details about these classes:

- **PHACs**. According to 2015 CDR data available from EPA, industry reported both manufacturing and importing PHACs into the United States. Data compiled in this report indicate that PHACs are both high production volume OFRs and high supply capacity OFRs. A single substance, chlorinated paraffins (CAS No. 63449-39-8), accounted for close to 90 percent of the reported PHAC manufacturing and importing. According to EPA, industry identified 54 processing and use activities for PHAC substances, of which the majority involved processing or use as a flame retardant. Flame retardant uses for PHACs included use in plastics products manufacturing, paint and coating manufacturing, rubber product manufacturing, adhesive manufacturing, textiles, apparel, and leather manufacturing, and furniture manufacturing. For the two high supply capacity OFRs identified in this subclass, CAS Nos. 36483-57-5 and 3296-90-0, industry reported domestic manufacturing activity as well. Therefore, PHACs are used in products found in the United States for their flame-retardant properties. Products that contain PHACs may enter the country as finished goods, semi-finished goods, and as raw chemical. (See Appendix E for additional detail).
- **PHOPs**. Data compiled in this report indicate that PHOPs are both high production volume OFRs and high supply capacity OFRs. CDR data from EPA indicate that reportable PVs of PHOP chemicals have increased and that these chemicals have been produced in very large quantities, each year, for over a decade. In 2015, two substances (CAS Nos. 13674-84-5 and 13674-87-8) accounted for most of the PHOP manufacturing and import volume. In the literature, PHOP chemicals are generally considered high production volume chemicals as well. Processing and use activities reported for PHOP chemicals include use as a flame retardant in construction products, plastic materials and resins, plastic products, furniture, and textiles/apparel. The three high supply capacity PHOPs identified in this report are also the most referenced PHOP chemicals in consumer products, according to the literature reviewed: CAS No. 13674-87-8 (44 sources), CAS No. 115-96-8 (27 sources) and CAS No. 13674-84-5 (24 sources). Several sources report the

[37] Further details about Alibaba.com listings can be found in Section 3.2.6.4.

results of product testing, and these indicate PHOPs have been found in a variety of consumer and/or children's products, such as furniture foam, secondhand toys, baby chairs and carriers, curtains and wallpaper, and textiles/foam and baby products. (See appendix L for additional detail).

- **PHAs**. A single chemical, HPCD (CAS No. 3194-55-6), accounts for most of the PHA manufacturing and importing volume reported to EPA in 2015 and is also the highest supply capacity PHA chemical identified in this report. Historical data indicates CAS Nos. 3194-55-6 and 77-47-4 have been manufactured or imported in the United States at high volumes for many years. Information available from the literature indicates several PHA chemicals (CAS Nos. 3194-55-6, 77-47-4, 25495-98-1, and 25637-99-4) are high production volume chemicals globally. In the United States, PHAs are reported to be used as flame retardants in construction products, plastic materials and resins, and plastic products. PHAs have been found in a variety of consumer and/or children's products that may be imported into the United States including, upholstery fabric and other textiles, synthetic polymers used in children's products, and other materials. (See Appendix C for additional detail).
- **PHPBIs**. According to 2015 CDR data, industry reported both manufacturing and importing PHPBI chemicals in the United States. One substance, CAS No. 26040-51-7, accounted for 73 percent of the total PV reported for PHPBI chemicals. Historical data from EPA indicate that PVs of PHPBI chemicals have decreased over time. From industry reporting to EPA, PHPBI uses as a flame retardant include plastics product manufacturing, furniture, and plastic materials and resins. Some consumer or consumer/commercial uses have also been reported by industry. While not a high PV chemical in the United States, CAS No. 117-08-8 is classified in this report as a high supply capacity OFR, with the highest estimated supply capacity among all PHPBIs. PHPBIs have been found in a variety of consumer and children's products, including gymnastic pit foam, baby products and polyurethane furniture foam. (See Appendix O for additional detail).

Since 2010, the combined annual PV for all OFRs has fluctuated, from a high of 172 million pounds in 2013 to a low of 155 million pounds in 2015. On net, total production volume for OFRs increased by 30 million pounds between 2010 and 2015. Four classes showed a decline in PV, while six showed an increase. These increases were led by PHOPs, PHACs, and PHPBIs. In addition to seeing the largest increases in production during the period, these classes also account for nearly all (97 percent) of total OFR production in 2015.

Individual chemicals seeing PV increases of more than one million pounds include:

- Hexachlorocyclopentadiene (CAS No. 77-47-4), increase of 23 million pounds;
- Chloroalkanes (CAS No. 61788-76-9), increase of 20 million pounds;
- Alkenes, C12-24, chloro (CAS No. 68527-02-6), increase of 5 million pounds; and
- 2,4,6-Tris-(2,4,6-tribromophenoxy)-1,3,5-triazine (CAS No. 25713-60-4), increase of 1 million pounds.

Waste management trends in the United States suggest large overall declines in the use of TRI-listed OFRs. Data show a large decline in the number of reports from 2001 through 2019, mainly driven by a decline in reports for decaDBE (Cas No. 1163-19-5). The number of reports for the next most commonly-

reported chemical, TBBPA (CAS No. 77-47-4), remain steady at between 44 and 59 per year throughout this period. Reports for all remaining chemicals (7 total chemicals) are sporadic throughout the period. Production-related wastes for all OFRs also declined significantly over this time period, from 3.2 million pounds in 2001 to 500,000 pounds in 2019. This decline is driven primarily by the decline in production-related waste for decaDBE (Cas No. 1163-19-5).

Data available in the HPCDS provide information about the use of OFRs as flame retardants in products intended for use by children and for sale in Washington and Oregon. These data indicate OFRs in seven subclasses have been used in products intended for use by children: PHOPs, PHBAFs, PHACs, PHDEs, PHAs, PHPBIs, and PHBzAFs. Over the period 2012 to 2019, 13 different OFRs were reported being used in children's products. Of these, TBBPA (CAS No. 79-94-7) accounted for the highest number of reports. OFR chemicals are used by suppliers in children's products for their flame retardant properties, but uses other than flame retardancy are reported, as is the presence of OFRs as a contaminant only. Limited trend information is observable from these data. Focusing on HPCDS uses where the function of the OFR is specified as "flame retardant" and the concentration in the product exceeds 1,000 ppm (and is thus unlikely to be a contaminant), the number of reports decreases substantially and are dispersed across nine individual OFRs, none of which account for a large share of the total. Products identified in these reports include toy vehicles, arts and crafts products, dolls and soft toys, outdoor play structures, shoes, and camping tents. Within these products, the component containing the flame retardant is most often listed as synthetic polymers (synthetic rubber, plastics, foams etc.), textiles (synthetic fibers and blends), and surface coatings (paints, plating, waterproofing etc.)

In contrast to the United States, the global market for flame retardants, in terms of both production and consumption, is dominated by China specifically, and Asia-Pacific more broadly. According to multi-client reports produced by market research firms, Asia-Pacific was the leading producer of OFRs, accounting for approximately 50 percent of total market volume in 2020 (Grandview Research, 2020; Reports and Data 2020). In addition to being produced in Asia-Pacific, flame retardants are also used extensively in this region in the manufacture of electronics, automobiles, construction products, and textiles. In this context, the Asia-Pacific region also dominates the global market share for OFRs (Grandview Research, 2021; Mordor Intelligence, 2020).

5.1.2.3 Price Information

We also made efforts to identify chemicals in commerce by determining their availability on several chemical B2B or e-commerce sites. Of the four sites we attempted to obtain data from, we were successful with three (Buyersguidechem.com, Chemnet.com, and Alibaba.com). From Buyersguide.com and Chemnet.com, we obtained the identity, country, and website of OFR suppliers. From Alibaba.com, we obtained the name and website of OFR supplies (but not the country), as well as some data on quantities available and pricing.[38] Overall, we found 255 unique suppliers across these sites, who collectively have 1,772 listings for 261 OFRs. China accounts for the majority of the supply listings; the United States, Canada, and Europe are also represented, but to a much lesser degree.

Listings on Alibaba.com include pricing data for most chemicals. Pricing is generally presented in ranges along with a minimum purchase quantity. The most common minimum purchase quantity quoted is 1 kg

[38] Alibaba is open to both Chinese companies and non-Chinese companies, although Chinese suppliers make up the vast majority of suppliers.

(approximately 46 percent of listings). Pricing at quantities of 25 kg or more are not uncommon, accounting for 47 percent of listings, and there are 55 listings that quote prices for purchases of one ton or greater. Our review of the Alibaba.com price data, however, raises some questions about the reliability of the data and whether the prices quoted reflect actual purchasing conditions. Another interpretation of the data is that the chemicals listed for sale on the site (in English) are available in global commerce, and that B2B solutions for supplying OFR chemicals are likely available to U.S. businesses importing from China. Currently, OFR chemicals are available at a variety of prices and quantities, including those that are hazardous.[39]

5.3 REGULATORY TRENDS

The use of OFRs in consumer products has been driven by fire safety standards and regulations. For example, in the United States, California Furniture Flammability Standard Technical Bulletin 117 (TB117), implemented in 1975, addressed flammability of polyurethane foam in juvenile products and upholstered furniture. According to Babrauskas *et al.* (2014), this state standard became a *de facto* national standard due to a desire to avoid maintaining multiple inventories and protection against liability. However, California implemented an updated standard (TB117-2013) that replaced the open flame test with a smolder standard. As a result of this change, many furniture products conform to the stand without the use of flame retardant chemicals. Subsequently, in 2021, CPSC issued a final rule to codify the statutory requirement that requires conformance with TB117-2013. Thus, this is now the national standard by federal law.[40]

Building materials in the United States must be tested for flammability according to ASTM E 84 (Mordor Intelligence, 2020). In 2000, the U.S. National Association of State Fire Marshals (NASFM) first proposed flammability requirements for home electronics, and the International Electrotechnical Commission Technical Committee 108 (IEc TC 108) developed requirements for enclosures of electronic housings (Babrauskas *et al.*, 2014).Given these standards, it is not surprising that various market research firms conclude fire safety concerns and standards are the main stimulus for the use of flame retardants globally (Mordor Intelligence, 2020; IHS Markit, 2020).

In the United States, regulation of the use of OFRs has been driven by state legislation. In the early 2000s, states focused significant attention on the regulation of polybrominated diphenyl ethers (PBDEs), including penta BDE (CAS 32534-81-9), octaBDE (32536-52-0), and decaBDE (1163-19-5). As a result, these chemicals have largely been phased out of use in the United States, consistent with the market use trends data provided in Section 5.2. Subsequently, state legislatures began considering other OFRs. From 2011 through 2021, 12 states and the District of Columbia passed laws restricting the use of a wide range of OFRs across a range of products. The restrictions primarily focused on children's products, upholstered furniture, and mattresses. Electronics products are less frequently mentioned, and the use of OFRs in transportation-related products is often exempted.

[39] In Appendix S, we provide pricing data for 75 OFR chemicals collected by CPSC staff from the website of Sigma Aldrich, a subsidiary of Merck that provides chemicals for analytical and laboratory uses. CPSC converted the listed prices, which are for laboratory quantities, to dollars per gram using the assumptions shown in the appendix. While these data may highlight differences in the relative price of producing these chemicals in a laboratory setting, this information should not be used to infer prices for commercially-relevant quantities from commercial suppliers.

[40] For more information, see https://www.cpsc.gov/Business--Manufacturing/Business-Education/Business-Guidance/Upholstered-Furniture.

At a global level, health and environmental concerns surrounding the use of flame retardants has led to restriction and the search for more benign substitutes. EU Directive 2011/65/EU on the restriction of certain hazardous (ROHs) substances in electrical and electronic equipment, the EU's Regulation on Registration, Evaluation, and Authorization and Restriction of Chemicals (REACH), and the EU's Waste Electric and Electronical Equipment (WEEE) have incentivized manufacturers to move away from halogenated flame retardants (Mitchell, 2014). The mainland Chinese government has also highlighted the importance of halogen-free flame retardants, which is affecting the flame retardants market in mainland China (IHS Markit, 2020). As a result, the demand for non-halogenated flame retardants is growing at a rapid pace worldwide (Grandview Research, 2020). However, existing and emerging brominated flame retardants continue to be utilized in heavily industrialized countries such as China and Brazil (*Ibid*).

5.4 CONCLUSION

This report presents a significant amount of information and data related to the potential presence of OFR chemicals in consumer products used in the United States. This information was collected through extensive searches of publicly-available data sources. However, our review also reveals significant data gaps. The primary reasons for these data gaps include:

- Reporting of OFR use is not consistently required by law;
- Information sharing among actors within the supply chain (from production to end-use) may be incomplete, hindering industry's ability to report OFR uses;
- Industry information may not be publicly-available due to concerns about the release of proprietary business information; and
- Wide-spread product testing or labeling is not consistently required.

As a result, manufacturers of products may be unaware of the presence of OFR chemicals in materials used in production, importers may be unaware of the presence of these chemicals in retail products sold in the United States, and consumers may be unaware of the presence of these chemicals in products purchased in the United States or abroad.

Ideally, information about the use of OFR chemicals in consumer products sold in the United States would be available through a labeling or reporting system, such as the Scan4Chem app launched in the EU in response to REACH legislation. Successful implementation of such a system would require better information sharing among actors within the supply chain about the materials used in the production of goods. Currently, such systems do not exist in the United States. This report has not evaluated the potential costs or benefits of implementing such a system.

The available information presented in this report suggests that OFR use in the United States may have declined in the past 20 years. However, evidence suggests OFR chemicals in 12 of 14 subclasses are still in use. No current uses were identified for chemicals in the polyhalogenated aliphatic carloxylate and polyhalogenated benzene alicycles classes (the two classes with the fewest chemicals). The decline in the overall use of OFRs appears to be correlated in time with regulatory activity by U.S. states and the European Union.

Information about OFRs in consumer products imported from other countries, particularly China and Asia Pacific, is sparse. Existing reporting systems are not designed to capture data on the chemical content of consumer products imported into the United States from other countries. While the mainland Chinese government has highlighted the importance of halogen-free flame retardants, the pace at which these chemicals are being removed from products or replaced with other types of flame retardants is uncertain. Brominated flame retardants continue to be utilized in heavily industrialized countries such as China and Brazil. Further complicating the issue, the toxic recycling of plastics containing brominated flame retardants into newly fabricated consumer products means that OFR chemicals are introduced into products unintentionally.

This report also highlights the heterogeneity in available data for specific chemicals within each OFR subclass. While a considerable amount of information exists for certain OFR chemicals, data related to the current or potential use of other OFR chemicals is limited. Current or potential uses of OFR chemicals can be considered proprietary, even when OFR chemicals are potentially hazardous.

Our synthesis of OFR chemical data, patent and literature sources, industrial manufacturing and use data, and market and regulatory trends allows for the comparison and evaluation of data-rich and data-poor chemicals within given classes, to help identify and close existing information gaps. The data synthesis by OFR subclass will help CPSC to quickly filter and identify similarities between OFR chemicals in order to prioritize new toxicity and consumer product studies, and to help CPSC protect the public from unreasonable risks associated with the use of OFR chemicals in consumer products.

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