UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MD 20814

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DATE: May 24, 2017

BALLOT VOTE SHEET

TO: The Commission
Todd A. Stevenson, Secretary

THROUGH: Mary T. Boyle, General Counsel
Patricia H. Adkins, Executive Director

FROM: Patricia M. Pollitzer, Assistant General Counsel
Matthew T. Mercier, Attorney, OGC

SUBJECT: Petition HP15-1, Requesting Rulemaking on Certain Products Containing Organohalogen Flame Retardants

BALLOT VOTE DUE Wednesday, May 31, 2017

CPSC staff is forwarding a briefing package to the Commission regarding a petition that requests that the Commission initiate rulemaking to declare four categories of consumer products containing additive organohalogen flame retardants (OFRs) to be "banned hazardous substances" under the Federal Hazardous Substances Act (FHSA). The petition was submitted by the American Academy of Pediatrics, American Medical Women's Association, Consumer Federation of America, Consumers Union, Earthjustice, 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 America National Hispanic Medical Association, and Worksafe (petitioners). In the attached briefing package, staff recommends that the Commission deny the petition.

Please indicate your vote on the following options:

I. Grant the petition and direct staff to begin developing a notice of proposed rulemaking or an advance notice of proposed rulemaking.

______________________________ ____________________
(Signature) (Date)

II. Defer the petition and direct the staff to conduct additional work. (Please specify.)

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__________________________ __________________
(Signature) (Date)

III. Deny the petition and direct staff to draft a letter of denial to the petitioner.

__________________________ __________________
(Signature) (Date)

IV. Take other action. (Please specify.)

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__________________________ __________________
(Signature) (Date)

Attachment: Staff Briefing Package for Petition HP15-1, Requesting Rulemaking on Certain Products Containing Organohalogen Flame Retardants

United States
Consumer Product Safety Commission

Staff Briefing Package

In Response to Petition HP15-1, Requesting Rulemaking on Certain Products Containing Organohalogen Flame Retardants

May 24, 2017

For further information contact:
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EXECUTIVE SUMMARY

The U.S. Consumer Product Safety Commission (CPSC or Commission) received a request from the American Academy of Pediatrics, American Medical Women's Association, Consumer Federation of America, Consumers Union, Earthjustice, 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 America National Hispanic Medical Association, and Worksafe (petitioners) to promulgate a rule under the Federal Hazardous Substances Act (FHSA) prohibiting certain products containing non-polymeric, additive organohalogen flame retardants (OFRs). Specifically, the Petition asks the Commission to declare that children's products, upholstered furniture, mattresses/mattress pads, and casings surrounding electronics are banned hazardous substances if they contain any non-polymeric, additive, OFR. The petitioners claim that, due to their inherent physico-chemical properties, additive OFRs as a class (1) are toxic, (2) migrate out of products regardless of how the product is used, leading to widespread human exposure, and therefore, (3) present a serious public health concern and risk of adverse health impacts. In addition, the petitioners claim that warning labels are not adequate to prevent or control exposure, and the use of these chemicals is not required by any legally binding flammability standard in the four product categories. The petitioners asked the CPSC to issue a rule under the FHSA, and staff provides a discussion of the FHSA requirements.

This briefing memorandum provides, to the extent available, existing or readily obtained information concerning the hazard, market, estimate of risk, annual cost to society, existing standards and activities, past agency action, feasibility of the petitioners' request, and a discussion of the Commission's options to grant, deny, or defer the Petition.

Staff considers OFRs to represent a broad class of chemicals defined largely by their functional use and the presence of a halogen, such as a bromine or chlorine (Tab B). The limited data on OFRs show varying toxicity and exposure potential among individual OFR compounds. These varying properties of individual OFR compounds indicate that OFRs, in fact, represent several subclasses of chemicals that should be examined separately. Due to the varying toxicological properties among OFR subclasses (and even within those subclasses) and because of the many data gaps relating to toxicity, staff believes that insufficient data exist to assess OFRs as a class under the FHSA, and one cannot conclude that they all would be considered "hazardous substances."

Although there are studies demonstrating human exposure to OFRs, most of the studies cited by the petitioners cannot be linked to specific products (Tab B). Human biomonitoring data (HBM) also demonstrate that exposure and uptake occur. However, the mere presence of a chemical (including those that may be considered toxic under the FHSA) in a person's blood or urine is not enough to demonstrate that an adverse health effect or disease may occur because levels may indicate exposures that are too low to cause these effects in humans. HBM and environmental data, such as dust, do not reveal the source of the exposure. Rather, both types of data represent exposure from all sources (including food and vehicles). Thus, it is not possible to determine that adverse health effects result from exposure to OFRs in the specific products in these categories that the petitioners identify.

The petitioners ask the Commission to conclude that OFRs, where limited or no data are available, possess the same toxicity and exposure potential as OFRs for which data exist and to use these conclusions to determine that products in these four product categories are "banned hazardous substances" if they contain any OFRs (Tab B). The Commission's chronic hazard guidelines discuss the use of surrogate data[1] in the context of exposure assessment. However, the guidelines do not address the use of surrogate data for determining toxicity of a chemical where no toxicity data are available. The guidelines indicate that surrogate exposure data may be used in limited circumstances including identifying whether more data are needed and whether additional studies are necessary; however, this data cannot be used to determine the exposure potential of an unstudied OFR for regulatory decision making because chemical specific data would be needed for a robust assessment to support a regulation. Currently, staff considers the tools available to assess the toxicity of a chemical, without data specific to that chemical, are too limited to allow surrogate data to be used for toxicological assessments for regulatory decisions. Therefore, since the limited toxicity and exposure data on OFRs show variation in toxicity under the FHSA and in exposure potential, OFRs could not be assessed at the class level by staff to conclude that all products defined by the petitioners with OFRs were hazardous substances under the FHSA.

Staff evaluated mandatory, voluntary, and international standards for the four product categories in the Petition. OFRs are not specifically required for any of the mandatory or voluntary standards reviewed (Tabs C and D). According to the petitioners, OFRs are used extensively in these four product categories. The petitioners cited a number of studies showing the presence of OFRs in products. Many of the studies cited by the petitioners are older studies. Additionally, staff has indications that OFR use is changing. Given recent state regulations and actions by the Environmental Protection Agency (EPA) and the European Union, statements by manufacturers about OFR use in some of these product categories, and results from current CPSC staff testing of children's products, OFRs may not be used in these product categories as extensively as the petitioners assert.

Staff discussed the complexity of developing test methods for an unknown set of OFRs and market survey and compliance testing feasibility in these four product categories (Tab E). As stated by the petitioners, the number and identities of all OFRs currently in use are unknown. Staff estimated that it could take years and considerable staff resources to develop test protocols to analyze OFRs and perform a marketplace survey to support rulemaking if the Petition were granted.

Staff considered the economic implications of the rule that the petitioners request (Tab F). With the vast number of OFRs and products potentially affected, staff does not have sufficient information to assess the possible economic impact of such a rule. However, staff notes that any rule that bans the use of these OFR chemicals in children's products would require manufacturers to certify based on third party testing that each children's product does not contain

[1] Exposure data derived from chemicals with similar properties, such as structure, reactivity, or volatility, as the chemical of interest.

these chemicals, regardless of whether OFRs were used in their products. Depending on the scope of the rule or testing requirements, third party testing costs could be high.
Staff evaluated the consumer incidents specifically associated with adverse health effects related to the presence of OFRs in the four product categories (Tab G). Insufficient data are available in CPSC's databases to evaluate consumer incidents associated with OFR use in these categories.

Staff Recommendation

Based on the available information provided by the petitioners and information presented in the briefing package, staff recommends that the Commission deny the Petition for the following reason:

- **Insufficient toxicological and exposure data supporting the Petition**. The petitioners assert that OFRs should be handled as a class because OFRs as a class have similar physico-chemical properties. However, even the limited data on OFRs show varying toxicity and exposure potential among individual OFR compounds. These varying properties of individual OFR compounds indicate that OFRs, in fact, represent several subclasses of chemicals that should be examined separately. However, even then, individual compounds within the same subclass may differ in the effects that they cause, their potency, mechanism of action, and bioaccumulation potential. Petitioners also assert that exposure to OFRs occurs through consumers' exposure to household dust. The presence of OFR chemicals in household dust does not establish a link to the four product categories that the petitioners identify. Petitioners have not submitted data establishing this connection, and staff is not aware of such information.

  The FHSA requires consideration of the connection between the toxicity of a substance, exposure to that substance through customary and reasonably foreseeable use of a product, and resulting substantial personal injury or substantial illness associated with the exposure. In the absence of data showing toxicity of all of these OFRs under the FHSA and uniformity in exposure patterns relating to the use of products in these four categories, one cannot conclude that all products in the four categories containing any OFRs are "hazardous substances." Because petitioners have not submitted such data, and such data is not currently otherwise available, staff recommends that the Commission deny the petition and not proceed with the FHSA rulemaking that the petitioners request.

Based on other information provided in the Petition, additional reasons for staff's recommendation include ongoing market and regulatory changes affecting the potential presence of OFRs in these four product categories and the significant resources that would be required to develop the rule that the petitioners request. Independent of the Petition, staff has been working to assess the presence of and exposure to OFRs and will continue the ongoing FR work in the operating plan, with voluntary standards organizations, and coordinating with other federal agencies.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MARYLAND 20814

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Memorandum

May 24, 2017

TO	**:**	The Commission Todd A. Stevenson, Secretary
THROUGH	**:**	Mary T. Boyle, General Counsel Patricia H. Adkins, Executive Director DeWane Ray, Deputy Executive Director for Safety Operations
FROM	**:**	George A. Borlase, Ph.D., P.E., Assistant Executive Director Office of Hazard Identification and Reduction Melanie B. Biggs, Ph.D., Project Manager Directorate for Health Sciences
SUBJECT	**:**	Petition requesting rulemaking to protect against consumer products containing additive organohalogen flame retardants (HP 15-1)

1. Introduction

On July 1, 2015, the American Academy of Pediatrics, American Medical Women's Association, Consumer Federation of America, Consumers Union, Earthjustice, 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 America, National Hispanic Medical Association, and Worksafe (petitioners) petitioned the Commission to promulgate a rule prohibiting certain products containing organohalogen flame retardants (OFRs). The petitioners requested that the U.S. Consumer Product Safety Commission (CPSC or Commission) initiate rulemaking under the Federal Hazardous Substances Act (FHSA) declaring that children's products, furniture, mattresses/mattress pads, and casings surrounding electronics are banned hazardous substances if they contain any non-polymeric, additive, OFR. The Office of the General Counsel docketed the request as a Petition, HP 15-1 (see Tab A). The Commission published a request for public comment on this Petition in the *Federal Register* on August 16, 2015 (80 FR 50238). The Commission also published a notice of opportunity for oral presentation of comments in the *Federal Register* on October 26, 2015 (80 FR 65174). This *Federal Register* notice also extended the comment period from October 19, 2015 to January 19, 2016, in response to outside requests. Two more *Federal Register* notices were published for corrections to previous notices or providing more information (80 FR 75955 and 80 FR 77591).

CPSC staff prepared this briefing package in response to the Petition. The briefing package provides the Commission with information relevant to the Petition, including a review of the public comments received in response to the *Federal Register* notices, and a discussion of options for Commission consideration in light of existing data.

2. Issue

The petitioners claim that, due to their inherent physico-chemical properties, additive OFRs, as a class, (1) are toxic, (2) migrate out of products regardless of how the product is used, leading to widespread human exposure, and therefore, (3) present a serious public health concern and risk of adverse health impacts. The petitioners asked for a rule that covers four product categories (children's products, furniture, mattresses/mattress pads, and casings surrounding electronics). The petitioners state that these products are used daily by most consumers and that many of these products contain measurable OFRs. The petitioners claim that:

1. These flame retardants (FRs) must be regulated as a class when used in consumer products so that consumers are not exposed to regrettable substitutions, using one harmful FR for another.
2. Consumers cannot be advised on how to use these products in a way to eliminate exposures and that warning labels are not adequate to prevent or control exposure.
3. This exposure presents a serious public health concern because these chemicals have been associated with many adverse health impacts, such as reproductive impairment, endocrine disruption, and neurological impairment.
4. The use of these chemicals is not required by any legally binding flammability standard in the four product categories, and
5. Each foreseeable way that these four categories of products are used can pose a risk of harm to consumers if OFRs are added to them.

Based on these claims, the petitioners asked the Commission to promulgate regulations under the FHSA to declare:

- any durable infant or toddler product, children's toy, child care article or other children's product (other than children's car seats) that contains additive OFRs, is a "banned hazardous substance,"
- any article of upholstered furniture sold for use in residences and containing additive OFRs is a "hazardous substance" and a "banned hazardous substance,"
- any mattress or mattress pad with additive OFRs is a "hazardous substance" and a "banned hazardous substance," and
- any electronic device with additive OFRs in its plastic casing is a "hazardous substance" and a "banned hazardous substance."

3. The Framework for Considering a Petition

The Commission's petition regulations state factors for the Commission to consider when deciding whether to grant or deny a petition:

1) Whether the product that is the subject of the petition presents an unreasonable risk of injury;
2) Whether a rule is reasonably necessary to eliminate or reduce the risk of injury; and
3) Whether failure to initiate rulemaking would expose the petitioner or others to the risk of injury that the petitioner alleges the product presents.

These considerations are geared more towards the determinations that the Commission would make to issue a consumer product safety rule under the Consumer Product Safety Act (CPSA). For this Petition, however, the Commission should consider the determinations needed under the FHSA. The petition regulations also state that when considering these factors, the Commission will consider the petition in relation to the agency's priorities as stated in the CPSC's Policy on Establishing Priorities and the Commission's resources available for rulemaking. 16 C.F.R.§ 1051.9(a).

4. Product Description

The four product categories associated with this Petition are children's products, furniture, mattresses/mattress pads, and casings surrounding electronics. Petitioners define these products as follows: Children's products include any durable infant or toddler product,[2] children's toy,[3] child care article/or other children's product,[4] other than children's car seats. Furniture includes any article of upholstered furniture[5] sold for use in residences. Mattresses[6] includes products intended or promoted for sleeping upon whose ticking is filled with a resilient material. A mattress pad[7] is a thin mat, cushion, or ticking filled with resilient material that is used on the top of a mattress. Electronics includes any consumer electronic device with a plastic casing surrounding it.

FRs are chemicals added to natural and synthetic materials to improve their resistance to ignition, reduce flame spread or burning rate after ignition occurs.[8] Thus, FRs reduce the risk of injury from fires, and in many situations, provide additional time to escape from fires.[9] FRs are used in many consumer products, such as building materials, furniture, plastics, electronics equipment, and textiles. Additive FRs are typically applied to foams, textiles, and polymers before, during, or after production, and before manufacturing of the end product. Additive FRs are not chemically bound to the substrate and may be released from the product, thereby leading to potential human and environmental exposures. The petitioners are concerned with additive

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[2] As it is defined in 15 U.S.C. § 2056a(f).
[3] As it is defined in 15 U.S.C. § 2057c(g)(1)(B).
[4] As it is defined in 16 C.F.R. § 1200.2(a)(1).
[5] As it is defined in the CPSC's notice of proposed rulemaking proposing a "Standard for the Flammability of Residential Upholstered Furniture,"73 Fed. Reg. 11702 (March 4, 2008), Proposed 16 C.F.R. § 1634.2(a).
[6] As it is defined in 16 C.F.R. § 1632.1(a).
[7] As it is defined in 16 C.F.R. § 1632.1(b).
[8] WHO, 1998. Environmental Health Criteria, 209. ISBN 92-4-157209-4; 209 (0). 1998
[9] IPCS, 1997. Environmental health criteria for flame retardants: A general introduction. Vol. 192; WHO, 1998. Environmental Health Criteria, 209.

FRs that contain halogens, such as bromine or chlorine. This Petition covers these four product categories that contain non-polymeric, additive, OFRs.

5. FHSA[10]

The petitioners asked the CPSC to promulgate a rule under the FHSA to declare that children's products, upholstered furniture, mattresses/mattress pads, and casings surrounding electronics are banned hazardous substances if they contain any non-polymeric, additive, OFR. The FHSA requires cautionary labeling for hazardous substances intended or packaged in a form suitable for use in the household or by children. Under the FHSA, to ban a substance, the Commission must determine that the hazard posed by the presence or use of the substance in the product is such that the labeling required by the FHSA would not protect the public health and safety. However, a toy or other article intended for use by children that is, bears, or contains a hazardous substance that a child can access is a "banned hazardous substance" under the FHSA, regardless of labeling. 15 U.S.C. § 1261(q)(1). To be considered a "hazardous substance" under the FHSA, a substance or product must satisfy a two-part definition. First, the substance or product must be "toxic," as defined under the FHSA, or present one of the other hazards enumerated in the statute.[11] Second, the substance or product must have the potential to cause substantial personal injury or substantial illness during or as a result of customary or reasonably foreseeable handling or use, including ingestion by children. 15 U.S.C. § 1261(f)(1)(A). In other words, the determination that an item is a "hazardous substance" is risk based. When assessing whether a household product is a hazardous substance under the FHSA (and thus, would require cautionary labeling), CPSC staff considers the customary and reasonably foreseeable use of the product, the formulation of the product, and any adverse health effects associated with the exposure, including toxicity.

The use of surrogate exposure data when no exposure data exist for a chemical is discussed in the Commission's chronic hazard guidelines (CPSC, 1992). The guidelines indicate that surrogate exposure data may be used in limited circumstances, including identifying if more data are needed and whether additional studies are necessary. These guidelines do not address the use of surrogate data for determining toxicity of a chemical where no toxicity data are available. Surrogate exposure data have not been used extensively by the Commission, and the chronic hazard guidelines state it "should only be used when data concerning a chemical of interest is sparse or unavailable and when there is a reasonable assurance that the surrogate data will accurately represent the chemical of interest" (CPSC, 1992).

6. Health Sciences Assessment (TAB B)

The Directorate for Health Sciences (HS) staff provides a discussion on how the CPSC addresses risk to consumers from exposure to substances in consumer products under the FHSA. HS staff also discusses assessing OFRs as a class, in terms of toxicity and exposure information on studied OFR chemicals, existing data gaps in this information, and the scope of the Petition. The

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[10] See Tab B.

[11] Other hazards enumerated in the statute include corrosive, an irritant, a strong sensitizer, flammable or combustible, or generates pressure through decomposition, heat or other means.

first step in the risk assessment process is hazard identification, that is, to review the available toxicity data for each chemical under consideration and determine whether the chemical is “toxic” under the FHSA. The FHSA defines the term “toxic” to apply to any substance that has the capacity to produce personal injury or illness through ingestion, inhalation, or absorption through any body surface. 15 U.S.C. § 1261(g). Thus, the FHSA applies to both acute and chronic toxicities. If a substance is determined to be “toxic” under the FHSA due to acute or chronic toxicity, then a quantitative assessment of exposure and risk is performed to determine whether the chemical may be a “hazardous substance” under the FHSA, which includes consideration of dose response, bioavailability, and exposure.

<u>OFRs as a Class of Chemicals</u>

Staff considers that OFRs represent a broad class of chemicals defined largely by their functional use and the presence of a halogen, such as a bromine or chlorine. The limited data on OFRs show varying toxicity and exposure potential among individual OFR compounds. These varying properties of individual OFR compounds indicate that OFRs, in fact, represent several subclasses of chemicals, and one cannot conclude that they all would be considered “hazardous substances” under the FHSA. Examples of these subclasses are discussed in Tab B, and include polybrominated diphenyl ethers (PBDEs), brominated aromatic FRs, brominated aliphatic FRs, and chlorinated alkyl phosphates.

<u>*Toxicity Data*</u>

Petitioners state that exposure to any chemical in the OFR class poses human health risks, and they present information about specific OFRs that present risks to human health. However, to ban products containing OFRs as a class, the Commission would need to conclude that every OFR is toxic under the FHSA.

Under CPSC’s chronic hazard guidelines, a conclusion that a chemical is “probably toxic to humans” must be supported by either sufficient evidence in animal studies or limited evidence in humans. When examining OFRs at the class or subclass level, however, toxicological properties of individual OFRs are not uniform and show variation in their potential health effects and in their potential toxicity under the FHSA. As shown in Table 2 in Tab B, OFRs that are structurally similar affect different endpoints and have greater or lesser toxicity under the FHSA, For example, while most brominated FRs show effects on the thyroid at high doses, the toxicological effects of chlorinated alkyl phosphate OFRs are varied in animal experiments, with some being suspected carcinogens and others showing thyroid hormone disruption or neurotoxicity. OFRs also vary in their bioaccumulation potential[12] among and within subclasses. For example, although PBDEs (representing certain brominated OFRs) have a relatively high bioaccumulation potential, other brominated OFRs, such as tetrabromobenzoate (TBB) and tetrabromobisphenol A (TBBPA), show a low potential for bioaccumulation. Additionally, a chlorinated alkyl phosphate OFR, V6,[13] is not considered bioaccumulative. Furthermore, as

[12] Accumulation of a substance in an organism.
[13] 2,2-bis (chloromethyl)propane-1,3-diyl tetrakis(2-chloroethyl)bis (phosphate)

illustrated in Table 2, Tab B, toxicity data are incomplete, limited, or lacking for this subset of OFR compounds. Due to the varying toxicological properties among OFR subclasses (and even within those subclasses) and the many data gaps relating to toxicity, available data indicate that one cannot consider OFRs as a class under the FHSA because one cannot conclude that every OFR would meet the toxicity prong of the FHSA's definition of "hazardous substance." Staff's memo at Tab B discusses in greater detail the varying characteristics of OFRs for which staff has information.

Exposure Data

Based on their physico-chemical properties, most OFRs are classified as semi-volatile organic compounds (SVOCs) and slowly emit from products over time during normal use and tend to adsorb to dust particles. This persistence in the indoor environment causes them to redistribute from their original source and separate into air, dust, and onto surfaces leading to potential exposure. The likelihood of exposure to chemicals is specific for each person and impacts the amount of chemical someone may be exposed to. Furthermore, the extent of exposure to a given OFR will depend on the specific product containing that OFR because different exposure pathways, such as inhalation, ingestion, or dermal contact, and varying contributions of those exposure pathways will exist for each product based on its use. Additionally, the potential for exposure may vary among different OFR chemicals. For example, some studies have suggested that inhalation exposure to chlorinated OFRs is more of an issue than for PBDEs, due to their high water solubility and lower hydrophobicity.

Although some studies demonstrate human exposure to OFRs, most of the studies cited by the petitioners cannot be linked to specific products, and most of the environmental data on OFRs is from dust or air in the indoor environment. Petitioners assert that exposure to OFRs occurs through consumers' exposure to household dust. Because many studies have small sample sizes and different collection methodologies, assessment and comparison of these studies is difficult. Another form of data, human biomonitoring data (HBM) (*i.e.* blood or urine) also demonstrate that exposure and uptake occurs. Petitioners state that, according to the Centers for Disease Control and Prevention (CDC), 97 percent of people living in the United States have measurable quantities of OFRs in their blood. However, the mere presence of a chemical (including those that may be considered toxic under the FHSA) in a person's blood or urine is not enough to demonstrate that an item containing that chemical is a "hazardous substance" under the FHSA because levels may indicate exposures that are too low to cause these effects in humans. HBM and environmental data do not reveal the source of the exposure. Rather, both types of data represent exposure from all sources (including food and vehicles). Thus, it is not possible to determine that adverse health effects result from exposure to OFRs in the specific products in these categories that the petitioners identify, and these data are not an accurate measure of OFR exposure concerning those enumerated product categories. For the Commission to issue the regulation that the petitioners request based on exposure to dust or HBM data, the Commission would need to determine a connection between the four product categories covered in the Petition and OFRs measured in household dust or blood or urine. Petitioners have not submitted data establishing these connections, and staff is not aware of such information. In the absence of exposure data relating to the specified product categories in the Petition, it would be difficult for the Commission to determine that those categories of products that contain OFRs are "hazardous substances."

Use of Surrogate Data

Although many data gaps exist concerning the toxicity and exposure data for OFRs, the petitioners are asking the Commission to conclude that OFRs, where limited or no data are available, possess the same toxicity and exposure potential as OFRs where data exist. The petitioners ask the Commission to use these conclusions to determine that products in these four product categories are "banned hazardous substances" if they contain any OFRs. The Commission's chronic hazard guidelines (16 C.F.R. §1500.135) discuss the use of surrogate data in the context of exposure assessment. The guidelines indicate that surrogate exposure data may be used in limited circumstances, including identifying whether more data are needed and whether additional studies are necessary; however, this data cannot be used to determine the exposure potential of an unstudied OFR for regulatory decision making. The guidelines indicate that surrogate exposure data may be used in limited circumstances, including identifying if more data are needed and whether additional studies are necessary. Staff notes that the guidelines do not address the use of surrogate data for determining toxicity of a chemical where no toxicity data is available. Currently, staff considers the tools available to assess the toxicity of a chemical, without data specific to that chemical, are too limited to allow surrogate data to be used for toxicological assessments for regulatory decisions. Therefore, OFRs could not be assessed at the class level by staff under the FHSA.

Scope of the Petition

The petitioners ask for a uniform rule that covers a range of products and a vast number of chemicals, the actual numbers and identities of which are unknown [14] and are not in fact uniform. Additionally, information on the uses of OFRs is largely unknown because manufacturers of consumer products are not required to report the inclusion of these substances to CPSC before manufacturing their products. It is difficult to conclude that all OFRs when used in the four product categories are "hazardous substances" and should be removed from commerce due to the variations in the toxicity of these OFRs and varying exposure patterns of use concerning these different products.

7. Organohalogen Flame-Retardant Usage in Four Product Categories[15]

According to the petitioners, OFRs are used extensively in children's products, upholstered furniture, mattresses/mattress pads, and plastic casings surrounding electronics. The petitioners cite a number of studies showing the presence of OFRs in these products. However, the extent to which OFRs are actually used in these product categories is unclear. Recent state regulations and actions by the Environmental Protection Agency (EPA) and the European Union appear to be having an effect on how and in what products OFRs are being used. Thus, many of the

[14] CPSC-2015-0022-0135.
[15] See Tabs B, C, and F.

studies the petitioners cite are outdated and may not reflect the current usage of OFRs in these product categories. In addition, new OFRs are being introduced, and analytical standards are not available to identify these FRs.

Several commenters stated that OFRs are not used in upholstered furniture, mattresses/mattress pads, or some children's products, such as jewelry. According to the American Home Furnishing Alliance (AHFA), FRs were used in upholstered furniture to meet the open-flame requirements of the California flammability standard Technical Bulletin (TB) 117. However, TB 117 was amended in 2013, and FRs are no longer required to meet the standard. Consequently, the AHFA claims that there has already been a significant reduction in the use of FRs in upholstered furniture, and the use of FRs in upholstered furniture "will soon be very low or non-existent."[16] At this time, CPSC staff does not have the data to confirm or negate this statement on the reduction of FR use in upholstered furniture. Another commenter stated that FRs are not needed in upholstered furniture because barrier fabrics or inherently flame-resistant materials are available to meet fire safety standards.[17]

Mattress manufacturers have numerous technologically feasible and viable solutions that do not involve added FRs, including fiber and fabric barriers, for meeting the requirements set forth in the CPSC's flammability standards, 16 C.F.R. part 1632 and 16 C.F.R. part 1633. Therefore, OFRs are not needed to meet federal mattress flammability standards.[18] According to the International Sleep Product Association (ISPA), the trade association for the mattress industry, the United States mattress industry does not spray finished mattresses with any FR chemicals to meet federal standards for residential mattresses, and ISPA opposes any standards that require the use of FRs.

The mandatory and voluntary standards for children's products do not require the use of FRs for these products to satisfy the standards. According to one commenter, toy manufacturers typically do not add FRs to toys[19]; however, OFRs may be present in circuit boards, which are excluded in this Petition. Current work is being performed by CPSC staff on commonly used children's products, such as upholstered chairs, crib mattresses, and soft carriers, to determine FR presence. Thus far, staff has detected OFRs in about 22 percent of the children's products tested that contained polyurethane foam, which is a lower frequency of detection than in many of the reported studies in the literature.

Given the recent state regulations and actions by the EPA and the European Union regarding OFRs, statements by manufacturers of OFR use in some of these product categories, and current CPSC staff children's products testing, OFRs may not be as pervasive in these product categories as the petitioners' state. To determine OFR presence in these four product categories, staff would need to conduct additional studies to identify which FRs are being used in these products.

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[16] CPSC-2015-0022-0077.
[17] Public Meeting (PM) 28.
[18] CPSC-2015-0022-0179.
[19] CPSC-2015-0022-0176.

8. Laboratory Sciences Engineering Assessment (TAB C)

The Directorate for Laboratory Sciences Engineering (LSE) reviews existing mandatory, voluntary, and international flammability standards relating to upholstered furniture, mattresses and mattress pads, and children's products. LSE staff also discusses OFR use in these standards. None of the mandatory or voluntary standards reviewed require OFRs. The mandatory CPSC standards that apply to mattresses and children's products are performance standards and not design standards. The standards do not require the use of any specific design features, methods of assembly, or specific components, including the use of any FR chemicals or treatments. Voluntary standards for children's products do not require the use of FRs for these products to satisfy the standards. The applicable voluntary standards and California's revised TB 117 (TB 117-2013) requirements for upholstered furniture are performance based and do not require the use of FRs. The mattress and upholstered furniture industries have provided information to CPSC stating that OFRs are not used in their products.

9. Engineering Sciences Electrical Engineering Assessment (TAB D)

The petitioners have expressed concern of OFR use in "electronic casings." Staff clearly distinguishes "electronic" device casings from "electrical" device casings, with consumer electronic devices being a subset of electrical devices. The Directorate for Engineering Sciences Electrical Engineering (ESEE) staff provides a definition of "consumer electronics" as products classified as information technology and audio and video equipment. Examples of such equipment are personal computers and computer displays, cell phones, televisions, power adapters, cameras, and similar electronic products. Electronic product enclosures are designed to provide a level of protection against electric shock, excessive temperatures, radiation, implosion, mechanical hazards, and fire to reduce the likelihood of a fire spreading from a product or to provide resistance against ignition due to external flame sources, such as candles. There are no mandatory federal requirements for the use of OFRs in the construction of electronic device casings. The applicable voluntary standards for consumer electronic products do not require the construction of electronic casings with plastics, and the use of plastics is an optional approach. However, when manufacturers choose to use plastics, OFRs appear to be the preferred FRs used in product casings to meet current flammability requirements in these voluntary standards. An economic analysis would be needed to understand the financial impact of moving from plastic fire casings dependent on OFRs to fire casings formed from metal or a casing consisting of two-part constructions before proceeding with FHSA rulemaking.

10. Laboratory Sciences Chemistry Assessment (Tab E)

The Laboratory Sciences Chemistry (LSC) staff provides a discussion on the complexity of developing test protocols for an unknown set of OFRs, a marketplace survey, and compliance testing feasibility in these four product categories if the Petition were approved and the Commission issued the rule that the petitioners' request. The Petition requests that all OFRs added as FRs be prohibited; therefore, dozens of test methods would need to be developed and certified to cover the multitude of organohalogen compounds that may be used as an FR. Multiple test methods would be required due to the range of properties of the many different OFRs. Additionally, the petitioners state that the requested rule would only apply to OFRs if they are intentionally added. It is unclear how "additive OFRs" would be defined, as laboratories cannot test to distinguish additive use, and the petitioners ask the Commission to determine an appropriate detection level. LSC staff explains the numerous practical and resource challenges they would encounter establishing a program to support the rule that the petitioners request.

11. Economic Analysis Assessment (TAB F)

The Directorate for Economic Analysis (EC) staff reviews the use of OFRs in these four product categories and the economic impact if the Commission grants the Petition and ultimately issues the rule petitioners' request. Flexible polyurethane foam (FPF) can be used in a variety of consumer applications, including mattresses and mattress pads and upholstered furniture. FPF can also be used as padding in many durable infant and toddler products and stuffed toys. Although additive OFRs can be used in FPF, not all polyurethane foam contains FR chemicals. In the past, OFRs may have been used in polyurethane foam of upholstered furniture to meet California's TB 117 flammability standard; however, manufacturers of other consumer products, such as mattresses and mattress pads and many children's products, may also have used this treated foam. TB 117 was amended in 2013 to reduce the use of FRs to comply, and some states have also passed laws regulating specific OFRs. Based on the amendment of TB 117 and public comments from trade associations, staff believes that OFR use is greatly reduced and that OFRs are not commonly used in upholstered furniture, mattresses and mattress pads, and most children's products. The extent to which FR chemicals are used in the plastic casings of electronics devices is unknown; however, electrical manufacturers have stated that OFRs are used in these plastic casings to mitigate the potential fire hazard within the devices.[20]

Staff does not have sufficient information to evaluate the societal cost of injuries or illnesses associated with the use of OFRs. However, a rule that banned the use of these chemicals in children's products would require that manufacturers certify that their products do not contain the chemicals based on third party testing. Depending on the scope of the rule or testing requirements, third party testing costs could be high.

12. Epidemiology Assessment (TAB G)

The Directorate for Epidemiology Hazard Analysis (EPHA) evaluates consumer incidents specifically associated with adverse health effects related to the presence of OFRs in the four product categories that the Petition asks the Commission to regulate. EPHA staff searched two databases: the National Electronic Injury Surveillance System (NEISS) and the Consumer Product Safety Risk Management System (CPSRMS). Neither NEISS nor CPSRMS databases reports cases of adverse health effects related to the presence of OFRs in children's products, plastic casings surrounding electronic devices, mattresses or mattress pads, or upholstered furniture. Therefore, due to insufficient data, staff could not provide the requested evaluation.

[20] CPSC-2015-0022-0060.

13. Staff Response to Comments Received on the Petition and at Public Meeting (Tab H)

The Commission published a request for public comment on this Petition (CPSC-2015-0022) in the *Federal Register* on August 16, 2015. The comment period ended on October 19, 2015, but the Commission extended the comment period to January 19, 2016, in response to outside requests. The Commission received a total of 204 comments from domestic and international bodies. However, some comments included multiple supporter signatures or letters within the comment. The majority of the 204 comments received support granting the Petition, with consumer advocate groups submitting the bulk of these comments. A total of 16 comments support denying the Petition, and most of these comments were submitted by trade associations.

The Commission also published a notice of opportunity for oral presentation of comments in the *Federal Register* on October 26, 2015. The public meeting was held at the CPSC on December 9, 2015, or by telephone, and 28 panelists spoke. Panelists from government, advocacy groups, academia, trade associations, and industry presented to the CPSC Commissioners at the public meeting. The presenters included 10 panelists from organizations representing the Petitioners and 14 representing affiliations that also submitted written comments to the docket.

Many written comments included statements from commenters regarding their concern about toxic chemicals in consumer products, the health effects associated with this class of chemicals, FR migration out of chemicals and into dust, and preventing child exposure to toxic chemicals. Panelists reiterated the Petition's points and also discussed the broad nature of the Petition, that any work on these chemicals must be risk-based, fire safety, state actions on OFRs, and studies that measured OFRs in some of these products categories.

Other commenters and panelists provided discussions on a variety of topics, including:

- OFR use in certain product categories and exemptions should the Petition be granted,
- Fire safety and voluntary standards,
- Other government actions on OFRs,
- Economic burden should the Petition be granted,
- Fire science, toxicity and exposure studies, and
- Information on chemical mixtures regulation.

Tab H presents the issues raised by the comments and staff's responses. The major issues are summarized below.

CPSC Authority Under the FHSA

Several commenters discussed CPSC's authority under the FHSA to grant the Petition. Some stated that the petitioners' requested rulemaking is inconsistent with the requirements of the FHSA, an inappropriate application of the FHSA, and the FHSA requires that a substance cannot be banned unless the CPSC evaluates the substance as it is intended to be used in a household. CPSC staff has considered the petitioners' request in light of the Commission's regulations regarding petitions for rulemaking, and requirements for rulemaking under the FHSA. The FHSA requires consideration of the connection between a substance, exposure to that substance through use of a product, and the resultant injury or illness. The Commission has the legal authority to address the Petition under the FHSA. This briefing package discusses the available information that would (or would not) support the rulemaking petitioners request and points out resource and other limitations that the Commission might consider when determining whether to grant the Petition.

Commenters also discussed labeling of products containing OFRs. Some stated that labeling is insufficient to protect children and families from OFR risk, while others discussed how cautionary labeling is required under the FHSA on these products and that no determination has been made that "labeling is inadequate to protect public health and safety." The FHSA requires cautionary labeling on the immediate container of hazardous substances that are intended or packaged in a form suitable for use in the household. This labeling informs consumers how to safely store and use those products and gives consumers information about immediate first aid steps to take if an accidental exposure occurs. Cautionary labeling is required if the household product meets the FHSA definition of "hazardous substance."

Overly Broad Petition

Many commenters asserted that the Petition is overly broad with respect to chemicals and products included, and that CPSC must regulate based on science and data. They encouraged the CPSC to clearly define the Petition's scope as it relates to products and FR chemicals included and to thoroughly review and evaluate the chemicals within this organohalogen class. Staff considers that OFRs represent a broad class of chemicals defined largely by their functional use and the presence of either a bromine or chlorine. The limited data on OFRs show varying toxicity and exposure potential among individual OFR compounds. These varying properties of individual OFR compounds indicate that OFRs in fact represent several subclasses of chemicals that should be examined separately, and one cannot conclude that they all would be considered "hazardous substances" under the FHSA (see Tab B, Section 4). The FHSA requires consideration of the connection between the toxicity of a substance, exposure to that substance through customary and reasonably foreseeable use of a product, and resulting substantial personal injury or substantial illness associated with the exposure.

Risk-Based Approach Should Be Taken for Assessment

Many commenters stated that a risk-based approach should be taken when examining each member in this class of chemicals, which includes determining exposure potential and hazard and performing rigorous risk assessments. Others discussed how exposure should be assessed when evaluating these chemicals and how the presence of a chemical does not indicate exposure. The FHSA applies to "hazardous substances." Under the FHSA, any substance or mixture of substances that is "toxic," as defined in FHSA regulations, is considered to be a "hazardous substance," if such substance or substances may cause substantial personal injury or substantial illness during or as a result of reasonable foreseeable handling or use. 15 U.S.C. § 1261(f)(1)(A). Therefore, when assessing potential chemical hazards under the FHSA, CPSC staff considers not only the toxicity of the substance, but also exposure and the risk of any adverse health effects associated with the exposure.

Commenters discussed the science behind banning an entire chemical class; some deemed it unscientific, while others stated that regulating these chemicals together makes scientific sense, due to their similar physico-chemical properties, structure, and environmental fate characteristics. The use of surrogate exposure data (such as data derived from chemicals of similar structure or reactivity as the chemical of interest) when no exposure data exist for a chemical is discussed in the Commission's chronic hazard guidelines. 16 C.F.R. § 1500.135. These guidelines do not address the use of surrogate data for determining toxicity of a chemical where no toxicity data are available. Surrogate exposure data have not been used extensively by the Commission, and it "should only be used when data concerning a chemical of interest is sparse or unavailable and when there is a reasonable assurance that the surrogate data will accurately represent the chemical of interest."

Many commenters discussed how the presence of a chemical in a person's blood or urine does not equate to adverse health effects or disease. The mere presence of a chemical (including those that may be considered toxic under the FHSA) in a person's blood or urine is not enough to demonstrate that an item containing that chemical is a "hazardous substance" under the FHSA because levels may indicate exposures that are too low to cause these effects in humans. Under the FHSA, to be a "hazardous substance" (and potentially subject to regulation) a substance or mixture of substances that is "toxic," must also cause substantial personal injury or substantial illness during or as a result of reasonable foreseeable handling or use. 15 U.S.C. § 1261(f)(1)(A). Human biomonitoring data do not reveal the source of the exposure; rather it represents exposure from all sources. Accordingly, these data are not an accurate measure of OFR exposure concerning those enumerated product categories.

Organohalogen Flame-Retardant Use in Products

Commenters discussed OFR use within these product categories, and they stated that manufacturers of upholstered furniture, mattresses, and children's jewelry do not use OFRs. These statements are consistent with industry information provided to staff regarding the lack of use of OFRs in these products. No federal standards require specific components for fire performance and fire safety. TB 117-2013 is the current standard for furniture sold in the state of California, and it is a performance-based standard that does not require the use of FR chemicals. While the previous version of TB 117 did not state that FRs must be used to meet the standard, it did contain an open-flame flammability performance test that was usually met by using FR chemicals. Mattress prototypes must comply with open-flame and smoldering ignition mandatory standards 16 C.F.R. parts 1633 and 1632, respectively. The standards are performance based and do not require specific FR components. Mattress manufacturers meet the performance requirements of the standards with the use of fiber technologies and barriers, rather than with chemical treatments. Children's jewelry products do not have to satisfy flammability standards.

Upholstered Furniture

Commenters discussed the role of upholstered furniture in fires in the United States and noted that upholstered furniture is the leading item involved in home fire deaths. They also emphasized finding ways to maintain fire safety, while also protecting human and environmental health, and urged the Commission not to dismiss the human, economic, and environmental impact of fire when assessing this Petition. CPSC staff is aware of the hazard that upholstered furniture presents in home fires. The CPSC is currently in rulemaking under the Flammable Fabrics Act (FFA) to create a flammability standard for upholstered furniture. Petitioners have requested rulemaking under the FHSA to address potential adverse health effects associated with four classes of products containing OFRs. In conducting FHSA rulemaking to address potential adverse health effects associated with products containing OFRs, the Commission would assess this potential hazard, while also considering costs and benefits of implementing the requested rule, including those related to flammability and fire safety.

Electronic Devices

Many commenters discussed the use of OFRs in electronic devices to meet mandatory standards. Some commenters stated that flame and heat resistance are inherently necessary characteristics of these devices, and argued that banning the use of these FRs in electronics could increase consumer exposure to immediate dangers in the home, which are not present today due to the use of these chemicals. There are no mandatory standards that require the use of OFRs for electronic device casings, but there are increased flammability requirements for various electrical components used in buildings to comply with state and local electrical codes. However, the Petitioners limited their request to the plastic casings for electronic devices, excluding the casings for electrical products. The use of a flame-resistant plastic casing (enclosure) is not required by the applicable voluntary standards UL 60950, "Information Technology Equipment" and UL 60065, "Audio, Video and Similar Electronic Apparatus," but it is optional. Other methods exist for creating an electronic casing, such as use of metal. An economic analysis would be necessary to understand the costs/benefits of other methods for creating a casing, instead of using a casing made of flame-resistant plastics.

Standards

Many commenters stated that the Commission should favor performance-based safety standards and should refrain from setting prescriptive standards like those requested by the petitioners. Some commented that prescriptive standards stifle innovation, which could negatively impact the manufacturer's ability to implement new safety advances efficiently. Other commenters stated that relying on voluntary standards groups to proactively address risks when they become evident is a prudent way for CPSC to regulate, by allowing the regulated community to address hazards in a flexible manner. In the Petition, petitioners seek FHSA rulemaking regarding OFRs to address adverse human health impacts resulting from the presence of these FRs in the petitioner-specified product categories. Accordingly, the relevant inquiry regarding this potential hazard would be to examine the presence of voluntary standards that would eliminate or adequately reduce adverse human health impacts associated with the presence of OFRs in the enumerated classes of consumer products. The Commission would further examine this issue, should it proceed in the future with rulemaking, to address potential adverse health impacts relating to consumer products that contain specific OFRs.

Economic Burden

Many commenters discussed the potential burden on the supply chain to procure and integrate viable alternatives for compliance of these product categories, should the Commission ban certain products containing OFRs as requested by petitioners. The commenters noted that chemical alternatives may not be available in some instances, such as in enclosures for electronic devices. Other commenters stated that CPSC, along with EPA, must investigate any identified alternatives to OFRs for use in these products, and some commenters cited examples of companies that redesigned and reengineered their products to satisfy flammability tests without FRs. Commenters remarked that manufacturers are ready, able, and willing to eliminate the use of OFRs. If the Commission grants the Petition and proceeds with rulemaking, Commission staff would need to prepare a regulatory analysis that examines the costs and benefits of the rule. In order to perform this analysis, Commission staff would need to conduct additional analysis to determine the extent that OFR chemicals are used in consumer products, the benefits of eliminating the chemicals in certain applications, and the costs that could be associated with eliminating the OFR chemicals from certain products where they are used. This could involve investigating the costs of not using any FRs in the products, using inherently FR materials, or the potential costs and risks associated with substitute chemicals and potential alternative chemicals.

Several commenters noted that if the agency proceeds with rulemaking under the FHSA, the Commission must consider the relationship between costs and benefits in a proposed rule. If the Commission grants the Petition and proceeds with rulemaking, staff must conduct an economic analysis that considers the costs and benefits of the proposed rule, as well as alternatives to the rule. CPSC staff would also be required to conduct an analysis under the requirements of the Regulatory Flexibility Act to determine the potential impact on small entities.

Many commenters expressed concern about the impact of potential third party testing costs on firms if CPSC promulgated a rule to ban chemicals listed in the Petition, and some commenters provided estimates of these costs. According to Section 14 of the CPSA, manufacturers, importers and private labelers of children’s products must certify that their products comply with all applicable children’s product safety rules, based upon third party testing. Therefore, if the scope of any rule resulting from this Petition included children’s products, those manufacturers, importers, or private labelers would have to obtain third party tests of their products showing that they complied with the regulations. If the Commission promulgated a rule banning OFRs in children’s products, the cost of the third party testing could be significant for some companies.

Fire Safety

Several commenters discussed fire safety and OFRs, with some stating that there is no meaningful fire safety benefit for OFR use in any of the product categories in the Petition. Other commenters discussed a possible decrease in fire safety with a ban of OFRs. The petitioners have requested rulemaking under the FHSA to address potential adverse health effects associated with various classes of products containing OFRs. In conducting FHSA rulemaking to address potential adverse health effects associated with products containing OFRs, the Commission would assess this potential hazard and also consider costs and benefits of implementing the requested rule, including those related to flammability and fire safety.

Other Government Action on OFRs

Commenters discussed redundancy of this Petition noting that the EPA is assessing FR chemicals (some are OFRs) under the Toxics Substances Control Act (TSCA). Other commenters countered that this work would not be redundant because, although EPA has started looking at clusters of OFRs, this work could take years, and EPA would be unable to ensure that new chemicals developed as replacements for OFRs do not pose their own risks. Currently, EPA is evaluating FRs, including OFRs. CPSC and EPA staff are working together to coordinate activities to share information and prevent duplication of effort.

Commenters discussed regulatory actions taken by states on OFRs. Commenters asserted that the state actions can only go so far, and suggested that CPSC could facilitate this process. CPSC may consider the benefit of a federal regulation to provide consistency across states that already have requirements for certain commodities.

14. Options

A. Grant the Petition

The Commission could grant the Petition if it believes that available information indicates that the products identified by the petitioners that contain OFRs are "hazardous substances" as defined in the FHSA and that, by the end of the rulemaking process, the Commission could determine that such products are "banned hazardous substances," as defined in the FHSA, *i.e.*, either:

- the product is intended for use by children and is, bears, or contains a hazardous substance accessible to a child to whom the article is entrusted, or
- the product is intended or packaged in a form suitable for use in the household and, notwithstanding cautionary labeling, the presence or use of the substance in the household presents such a hazard that a ban is necessary to protect the public health and safety.

Granting a Petition does not mean that the Commission would necessarily issue a rule in the specific form requested in the Petition.

B. Deny the Petition

The Commission could accept the staff's recommendation and deny the Petition based on the information presented in this briefing package.

C. Defer Decision on the Petition

If the Commission concludes that more information is necessary before the Commission can decide whether to grant or deny the Petition, the Commission may defer a decision and direct staff to collect additional information or take other action.

15. Staff Conclusions and Recommendations

CPSC staff recommends that the Commission deny the Petition. From the data provided in the Petition and other available data, staff has determined that declaring products in these categories to be "banned hazardous substances" if they contain any non-polymeric, additive, OFR, cannot be addressed as written in the Petition. The reason for this recommendation is that the limited OFR toxicity and exposure data and variations in this data do not support assessing OFRs at the class level by staff to conclude that all products defined by the petitioners with OFRs are hazardous substances under the FHSA. Other reasons for this recommendation include lack of OFR use in these product categories, current regulatory measures for OFRs, economic burden, and staff resources.

Under the FHSA, for a substance or product to be considered a "hazardous substance," it must be "toxic" as defined by the FHSA, or it must present one of the other hazards enumerated in the statute. Additionally, it must have the potential to cause substantial personal injury or illness during, or as a result of, reasonably foreseeable handling and use of the product. The petitioners assert that OFRs should be handled as a class because OFRs as a class have similar physico-chemical properties. However, the limited data on OFRs show varying toxicity and exposure potential among individual OFR compounds. These varying properties of individual OFR compounds indicate that OFRs, in fact, represent several subclasses of chemicals that should be examined separately. Although these data gaps exist concerning the toxicity and exposure data for OFRs, the petitioners are asking the Commission to conclude that OFRs, where limited or no data are available, possess the same toxicity and exposure potential as OFRs where data exist. This constitutes a "surrogate data" approach. The Commission's chronic hazard guidelines (16 C.F.R. §1500.135) discuss the use of surrogate data in the context of exposure assessment. The guidelines indicate that surrogate exposure data may be used in limited circumstances, including identifying whether more data are needed, and whether additional studies are necessary; however, these data cannot be used to determine the exposure potential of an unstudied OFR for regulatory decision making because chemical specific data would be needed for a robust assessment to support a regulation. Staff notes that the guidelines do not address the use of surrogate data for determining toxicity of a chemical where no toxicity data are available. Currently, staff considers the tools available to assess the toxicity of a chemical, without data specific to that chemical, are too limited to allow surrogate data to be used for toxicological assessments for regulatory decisions. Therefore, because the limited toxicity and exposure data on OFRs show such variation OFRs could not be assessed at the class level by staff to conclude that all products defined by the petitioners with OFRs were hazardous substances under the FHSA.

From the exposure studies discussed in the Petition, most are not quantitative and not linked to specific products. HBM and environmental data also do not reveal the source of the exposure. Rather, both types of data represent exposure from all sources (including food and vehicles) and not just from the products on which the petitioners request regulation. Accordingly, these data are not an accurate measure of OFR exposure relating to those enumerated categories. Thus, it is not possible to determine that adverse health effects result from exposure to OFRs in the specific products in these categories that the petitioners identify. The presence of OFR chemicals in people's blood and the presence of OFRs in household dust do not establish a link to the four product categories that the petitioners identify, which would be necessary for the Commission to issue the regulation that the petitioners request. Petitioners have not submitted data establishing these connections, and staff is not aware of such information. It would be difficult or impossible for the Commission to determine that a certain product that contains OFRs is a "hazardous substance" without being able to relate the exposure to specific products.

The petitioners state that OFRs are used extensively in these four categories. However, regulations promulgated by domestic and international governments appear to be having an effect on reducing the use of OFRs in certain products. A CPSC study on children's products to determine OFR use demonstrates this because OFRs were detected in a smaller percentage of samples containing polyurethane foam than in many of the reported studies in the literature. Additionally, the mandatory CPSC standards and voluntary standards for products in these categories are performance based and do not require the use of any specific components, such as FRs. The revision of a California standard for upholstered furniture in 2013 may have implications on OFR use in polyurethane foam in these product categories because FR chemicals may no longer be used to meet the revised standard. Previously, many manufacturers made their foam with FR chemicals to meet the TB 117 open-flame performance requirements. Manufacturers of products other than upholstered furniture may have used that foam or foam made in the same factory, which may explain detection of FR chemicals in products other than furniture.

Staff estimates that it could take years and considerable staff resources to develop test protocols to analyze OFRs and perform a marketplace survey to support the rule that the petitioners request. Determining which OFRs are present in these products would potentially require the development and certification of dozens of test methods to cover the multitude of organohalogen compounds that may be used as FRs. Additionally, the availability of standard reference materials to be used in these methods and the uncertainty of how test labs will determine the purpose of any organohalogen found while testing would be challenging.

Therefore, based on the above information, staff recommends that the Commission deny the Petition. The petitioners' proposal lacks feasibility under the FHSA for the following reasons:

- The limited data on OFRs show varying toxicity and exposure potential among individual OFR compounds indicating that not all chemicals in this class have the same toxicity under the FHSA or the same exposure potential.
- The presence of OFR chemicals in household dust does not establish a link to the four product categories that the petitioners identify. Petitioners have not submitted data establishing this connection, and staff is not aware of such information.
- The FHSA requires consideration of the connection between the toxicity of a substance, exposure to that substance through customary and reasonably foreseeable use of a product, and resulting substantial personal injury or substantial illness associated with the exposure. Given the varying properties of OFRs and lack of a connection between OFR measurements in environmental media and use in products in the Petition, support is lacking to conclude that products containing any OFR are all hazardous substances under the FHSA.

Based on other information provided in the Petition, other reasons for staff's recommendation are ongoing market and regulatory changes that indicate the presence of OFRs in these four product categories may be declining and the significant resources that would be needed to develop the rule that the petitioners request.

Staff will continue: (1) assessing FRs in children's products; (2) working with voluntary standards organizations that already exist for upholstered furniture, children's products, and electronic devices; (3) monitoring mattress compliance with federal flammability standards; and (4) working closely with EPA to coordinate activities on FR chemicals, including OFRs.

TAB A: Petition for Rulemaking to Protect Against Consumer Products Containing Additive Organohalogen Flame Retardants

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EARTHJUSTICE

ALASKA CALIFORNIA FLORIDA MID-PACIFIC NORTHEAST NORTHERN ROCKIES
NORTHWEST ROCKY MOUNTAIN WASHINGTON, D.C. INTERNATIONAL

Received CPSC
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Office of the Secretary
FOI

July 1, 2015

VIA EMAIL – tstevenson@cpsc.gov

Mr. Todd Stevenson, Secretariat
U.S. Consumer Product Safety Commission
4330 East West Highway
Bethesda, MD 20814

Re: *16 C.F.R. § 1051 Petition for Rulemaking to Protect Against Consumer Products Containing Additive Organohalogen Flame Retardants*

Dear Mr. Stevenson –

In response to a May 19, 2015 letter from Patricia Pollitzer to me, attached please find a revised Petition for Rulemaking under 16 C.F.R. section 1051, and supporting statements.

If you would like hard copies of these documents, we'd be happy to provide them.

Thank you very much for your assistance.

Sincerely,

Eve C. Gartner

Eve Gartner

Cc: Ms. Patricia Adkins, Executive Director
Mr. Scott Wolfson, Communications Director

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UNITED STATES CONSUMER PRODUCT SAFETY COMMISSION

In re: 16 CFR § 1051 Petition for Rulemaking

No. HP 15-1

Petitioners:

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
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June 30, 2015

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PETITION FOR RULEMAKING

Petitioners 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 America, National Hispanic Medical Association, and Worksafe ("Petitioners"), hereby petition the Consumer Product Safety Commission ("CPSC") to adopt rules to protect consumers and children from the health hazards caused when toxic flame retardant chemicals are used in four categories of household products. Due to their inherent physico-chemical properties, additive organohalogen flame retardants 1) are toxic and 2) migrate out of products *regardless of how the product is used*; thus there is a nexus between the mere presence of products containing these chemicals and exposures that put consumers at risk of harm. To protect consumers from this risk, we ask the CPSC to promulgate regulations under the Federal Hazardous Substances Act ("FHSA") declaring that children's products, furniture, mattresses and the casings surrounding electronics are banned hazardous substances if they contain any non-polymeric, additive organohalogen flame retardant.

I. Introduction

When used in non-polymeric,[1] additive[2] form, organohalogen flame retardants[3]

[1] Due to their high molecular weights, polymeric organohalogen flame retardants are believed to be not readily bioavailable, and thus may be less likely to be harmful to humans. Therefore,

migrate from consumer products, leading to widespread human exposures. These exposures occur because of the semi-volatile property of these chemicals that results in migration of the chemicals and the chemicals' adsorption into house dust; there is no way to direct consumers to use affected products in a way that would eliminate exposures. As a result, 97 percent of people living in the United States have measurable quantities of organohalogen flame retardants in their blood, as estimated from the national biomonitoring program conducted by the Centers for Disease Control and Prevention ("CDC").[4]

This presents serious public health concerns because all organohalogen flame retardant chemicals, as a class, are toxic due to their physical, chemical and biological properties. These chemicals have been associated with many adverse human health impacts, including: reproductive impairment (e.g., abnormal gonadal development, reduced number of ovarian follicles, reduced sperm count, increased time to pregnancy); neurological impacts (e.g., decreased IQ in children, impaired memory, learning deficits, altered motor behavior, hyperactivity); endocrine disruption and interference with thyroid hormone action (potentially contributing to diabetes and

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they are not addressed by this petition. The term "organohalogen flame retardants" will be used henceforth in this petition to refer to non-polymeric chemicals only.

[2] Additive (as opposed to reactive) flame retardants are not chemically bound to the products containing them, thus they can migrate out of products, resulting in human exposure.

[3] Organohalogen chemicals are created by combining carbon molecules with one of the halogen elements. Organohalogen flame retardants (also referred to as halogenated flame retardants) contain bonds between carbon and the elements bromine or chlorine. This class includes brominated and chlorinated phosphate ester flame retardants.

[4] Factual statements in this Introduction are addressed with citations in the accompanying statements and in the body of this Petition below.

obesity); genotoxicity; cancer; and immune disorders. These chemicals also have a disproportionately negative health effect on vulnerable populations, including children.

The use of flame retardants in the four product categories at issue is not required by any legally binding flammability standard. In addition, exposures to flame retardants that migrate from consumer products into homes cannot be adequately prevented or controlled with warning labels. Migration of these semi-volatile chemicals from common household products cannot be prevented, and knowledge that these toxic chemicals migrate from products into the indoor environment does not give consumers the ability to take meaningful measures to avoid exposures.

To stop future exposures and minimize the resulting health risks, we ask the CPSC to declare, under its FHSA authority, that

- any durable infant or toddler product,[5] children's toy,[6] child care article,[7] or other children's product[8] (other than children's car seats) that contains additive organohalogen flame retardants, is a "banned hazardous substance"; and
- any article of upholstered furniture[9] sold for use in residences and containing additive organohalogen flame retardants is a "hazardous substance" and a "banned hazardous substance"; and
- any mattress[10] or mattress pad[11] with additive organohalogen flame retardants is a "hazardous substance" and a "banned hazardous substance"; and

[5] We use the term "durable infant or toddler product" as it is defined in 15 U.S.C. § 2056a(f).

[6] We use the term "children's toy" as it is defined in 15 U.S.C. § 2057c(g)(1)(B).

[7] We use the term "child care article" as it is defined in 15 U.S.C. § 2057c(g)(1)(C).

[8] We use the term "children's product" as it is defined in 16 C.F.R. § 1200.2(a)(1).

[9] We use the term "upholstered furniture" as it is defined in the CPSC's Notice of Proposed Rulemaking proposing a "Standard for the Flammability of Residential Upholstered Furniture," 73 Fed. Reg. 11702 (March 4, 2008), Proposed 16 C.F.R. § 1634.2(a).

- ➢ any electronic device with additive organohalogen flame retardants *in its plastic casing* is a "hazardous substance" and a "banned hazardous substance."

It is imperative that CPSC's regulation cover all organohalogen flame retardants as a class when used in consumer products. This class of chemicals is foreign to the mammalian body and inherently toxic, due to its physical, chemical and biological properties. Industry has historically responded to the dangers posed by one organohalogen flame retardant by replacing it with one or more other organohalogens that are, by virtue of their chemical properties, also harmful. This exposes consumers to a series of "regrettable substitutions" from one harmful flame retardant to another, as explained below. The way to end this cycle of toxicity is to ban all products in the categories at issue here if they contain any organohalogen flame retardant. We believe it is appropriate for the ban on these products to apply only if the additive organohalogen flame retardant has been intentionally added and is not present as a contaminant from the manufacturing process. However we leave it to the expertise of the Commission to determine the appropriate detection level for its regulation.

This petition is supported by the following statements, which we submit with this Petition:

Human Exposures from Presence in Consumer Products

- Miriam Diamond, Ph.D., Professor in the Department of Geography, Chemical Engineering and Applied Chemistry, University of Toronto, on the mechanisms and evidence for the migration of organohalogen flame retardants from consumer products when used in additive form.

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[10] We use the term "mattress" as it is defined in 16 C.F.R. § 1632.1(a).

[11] We use the term "mattress pad" as it is defined in 16 C.F.R. § 1632.1(b).

- Ruthann Rudel, M.S., Director of Research at the Silent Spring Institute, and Research Associate in the Brown University Department of Pathology and Laboratory Medicine, on human exposure to organohalogen flame retardants from consumer products.

Known Human Health Risks Associated with Organohalogen Flame Retardants

- Kim Harley, Ph.D., Associate Adjunct Professor in Maternal and Child Health and Associate Director for Health Effects, Center for Environmental Research and Children's Health at UC Berkeley, on effects associated with the widely used organohalogen flame retardant pentabromodiphenyl ether (pentaBDE) in low-income Mexican-American children and their mothers in the Salinas Valley, California.
- Julie Herbstman, Ph.D., Assistant Professor in the Department of Environmental Health Sciences at the Columbia University Mailman School of Public Health, on the impact of prenatal exposure to pentaBDE on children's thyroid hormone levels, neurodevelopment, and IQ.
- Ted Schettler, MD, MPH, physician and the Science Director of the Science and Environmental Health Network, on the human health concerns associated with organohalogen flame retardants.
- Susan Kasper, Ph.D., Associate Professor in Environmental Health, University of Cincinnati College of Medicine, on the reproductive and carcinogenic effects of organohalogen flame retardants used as polybrominated diphenyl ethers (PBDE) replacements.

Hazards and Class Characteristics of Organohalogen Flame Retardants

- David Eastmond, Ph.D., Professor and Chair of the Department of Cell Biology and Neuroscience, and Research Toxicologist at UC Riverside, on hazardous properties of 83 non-polymeric organohalogen flame retardants.
- Terry Collins, Ph.D., Teresa Heinz Professor of Green Chemistry and Director of the Institute for Green Science at Carnegie Mellon University, on the intrinsic chemical properties of organohalogen flame retardants that result in a high potential for adverse human health effects.
- Rolf Halden, Ph.D., Director of the Center for Environmental Security at the Biodesign Institute, Professor in the Ira A. Fulton School for Sustainable Engineering and the Built Environment, Senior Sustainability Scientist in the Global Institute of Sustainability at Arizona State University, and adjunct faculty at the Johns Hopkins Bloomberg School of Public Health, on the characteristic hazards of organohalogen flame retardants and the need to regulate them as a class.

- David Epel, Ph.D., Jane and Marshall Steel Jr. Professor Emeritus of Biological and Marine Sciences at the Hopkins Marine Station of Stanford University, on the mechanisms through which most organohalogen flame retardants bypass cellular defenses, permeate cell membranes, and avoid metabolism and elimination.

Toxicity and Health Risks from Burning Organohalogen Flame Retardants

- Donald Lucas, Ph.D., scientist at the Lawrence Berkeley National Laboratory and Researcher in the School of Public Health at UC Berkeley (retired), on increased chronic and acute fire toxicity when organohalogen flame retardants are present in products that burn.
- Sharyle Patton, Director of the Commonweal Environmental Health Program in Bolinas, California, on biomonitoring studies of firefighters' levels of organohalogen flame retardants, dioxins and furans, possibly linked to higher cancer incidence in these workers.
- Roland Weber, Ph.D., independent consultant at POPs Environmental Consulting, on end-of-life concerns for products containing organohalogen flame retardants, including the production of dioxins and furans.

II. Interests of Petitioners

This petition is brought by the following physician and organizations on behalf of their patients, members and the entire United States population, virtually all of whom are exposed to hazardous flame retardant chemicals in the organohalogen class as a result of their use in consumer products.

Medical and Learning Disabilities Petitioners

The American Academy of Pediatrics is a non-profit professional organization of 62,000 primary care pediatricians, pediatric medical sub-specialists, and pediatric surgical specialists dedicated to the health, safety and well-being of infants, children, adolescents, and young adults.

The American Medical Women's Association ("AMWA") is an organization that functions at the local, national, and international level to advance women in medicine and improve women's health. Founded in 1915, AMWA is the oldest multi-specialty organization of women physicians. As the vision and voice of women in medicine for nearly a century, AMWA empowers women to lead in improving health for all, within a model that reflects the unique perspective of women.

Philip J. Landrigan, M.D. is a pediatrician, epidemiologist and Director of the Children's Environmental Health Center at Mt. Sinai School of Medicine in New York.

The Learning Disabilities Association of America ("LDA") is the country's oldest volunteer-run organization serving people with learning disabilities, their families, educators and health professionals, with affiliate offices in more than 40 states and thousands of members nationwide. LDA's "Healthy Children Project" seeks to raise awareness of environmental factors, including toxic chemicals, that are contributing to neurodevelopmental disorders, and to promote changes to policies and practices to reduce those factors. An area of particular concern for LDA is children's unique vulnerability to harm from toxic chemical exposures, beginning at conception.

Established in 1994, the National Hispanic Medical Association is a non-profit association representing the interests of 50,000 licensed Hispanic physicians in the United States. NHMA's vision is to be the national leader to improve the health of Hispanic populations. Our mission is to empower Hispanic physicians to lead efforts to improve the health of Hispanic and other underserved populations in collaboration with the state Hispanic medical societies, resident and medical student organizations, and other public and private sector partners.

Fire Fighters and Other Worker Petitioners

International Association of Fire Fighters ("IAFF") is the driving force behind nearly every advance in the fire and emergency services in the 21st century. With headquarters in Washington, DC, and Ottawa, Ontario, the IAFF represents more than 300,000 full-time professional fire fighters and paramedics in more than 3,100 affiliates. IAFF members protect more than 85 percent of the population in communities throughout the United States and Canada. In 2014, IAFF adopted a Resolution which committed the organization to "work to ensure that the use of carcinogenic flame retardants and other toxic chemicals are eliminated and safer alternatives or methods are pursued."[12]

Worksafe, Inc. is a California-based non-profit organization dedicated to promoting occupational safety and health through education, training, and advocacy. Worksafe pursues public policy initiatives related to the improvement of worker health and safety, including the elimination of toxic hazards that disproportionately impact the workers exposed and other vulnerable populations. Consumer product policies have significant implications for the people who are exposed to organohalogen flame retardants through their work, including during the manufacturing process when these

[12] IAFF (2013). Resolution No. 34 – Flame retardants, toxic chemicals and their relationship to the increase of cancer in fire fighters. Retrieved March 3, 2015 from http://iaffconvention2014.org/resolution-no-34/.

chemicals are added to products, and during fires when products containing these chemicals burn and create toxic fumes that harm emergency responders.

Vulnerable Population Petitioner

With approximately 132,000 members throughout the United States and Puerto Rico, the League of United Latin American Citizens (LULAC) is the largest and oldest Hispanic Organization in the United States. Headquartered in Washington, DC, with 1,000 councils nationwide, LULAC advances the economic condition, educational attainment, political influence, housing, health and civil rights of Hispanic Americans. LULAC's programs, services and advocacy address the most important issues for Latinos, meeting critical needs of today and the future.

Consumer Advocate Petitioners

The Consumer Federation of America is an association of more than 250 non-profit consumer groups that, since 1968, has sought to advance the consumer interest through research, education, and advocacy.

Consumers Union, the public policy and advocacy division of Consumer Reports, is an expert, independent, nonprofit organization with more than one million online activists whose mission is to work for a fair, just, and safe marketplace for all consumers and to empower consumers to protect themselves. Consumer Reports is the world's largest independent product-testing organization, which uses its more than 50 labs, auto test center, and survey research center to rate thousands of products and services annually.

Kids In Danger is a nonprofit organization dedicated to protecting children by improving children's product safety. Banning children's products and other categories of goods that contain dangerous chemicals, organohalogens, is the only way to limit children's exposure.

Science Petitioner

Scientists from the Green Science Policy Institute have been at the forefront of research and communication around the hazards posed by organohalogen flame retardants in consumer products for decades. Their research in the 1970s documented exposure to and toxicity of brominated and chlorinated flame retardants in children's pajamas, and their product testing in the 2000s found that halogenated flame retardant chemicals were being used in a majority of furniture and children's products tested.

III. The Cycle of "Regrettable Substitution" of Organohalogen Flame Retardants Must End

Past attempts to protect consumers from organohalogen flame retardants in household products have been unsuccessful because when one toxic flame retardant is banned or phased out due to its toxicity, it is replaced with another chemical in the same class – a phenomenon that has been termed "regrettable substitution." As Deborah Rice, a former EPA toxicologist who works for the Maine Center for Disease Control and Prevention, told The Chicago Tribune with respect to regrettable substitution of flame retardants: "By the time the scientific community catches up to one chemical, industry moves on to another and they go back to their playbook of delay and denial."[13]

The experience with the polybrominated diphenyl ether ("PBDE") family of flame retardants illustrates the problem. Until 2005, pentabromodiphenyl ether commercial mixture ("pentaBDE") was widely used as a flame retardant in residential seating furniture and in baby products, and octabromodiphenyl ether commercial mixture ("octaBDE") was used in plastics for personal computers and small appliances. Until 2013, decabromodiphenyl ether ("decaBDE") was widely used as a flame retardant in plastic electronic enclosures and fabrics. These organohalogen PBDEs, however, have now been shown to present a range of very serious human health risks, including immune and endocrine disruption, and adverse reproductive and neurodevelopmental effects.[14,15,16,17,18,19,20] As a result, pentaBDE and octaBDE commercial mixtures have

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[13] Michael Hawthorne, *Toxic Roulette*, Chicago Tribune, May 10, 2012, http://www.chicagotribune.com/news/watchdog/flames/ct-met-flames-regulators-20120510,0,4262292.story.

[14] Stapleton, H.M.; Eagle, S.; Anthopolos, R.; Wolkin, A.; & Miranda, M.L. (2011). Associations between polybrominated diphenyl ether (PBDE) flame retardants, phenolic metabolites, and thyroid hormones during pregnancy. *Environmental Health Perspectives*, 119(10), 1454-59. doi: 10.1289/ehp.1003235.

[15] Betts, K.S. (2010). Endocrine damper? Flame retardants linked to male hormone, sperm count changes. *Environmental Health Perspectives*, 118(3), A130. doi: 10.1289/ehp.118-a130b.

[16] Chevrier, J.; Harley, K.G.; Bradman, A.; Gharbi, M.; Sjödin, A.; & Eskenazi, B. (2010). Polybrominated diphenyl ether (PBDE) flame retardants and thyroid hormone during pregnancy. *Environmental Health Perspectives*, 118(10), 1444-49. doi: 10.1289/ehp.1001905.

[17] Gascon, M.; Vrijheid, M.; Martínez, D.; Forns, J.; Grimalt, J.O.; Torrent, M.; & Sunyer, J. (2011). Effects of pre and postnatal exposure to low levels of polybromodiphenyl ethers on neurodevelopment and thyroid hormone levels at 4 years of age. *Environment International*, 37(3), 605-11. doi: 10.1016/j.envint.2010.12.005.

been banned in a dozen U.S. states[21] and phased out by the U.S. chemical industry. DecaBDE has been voluntarily phased out for most uses, including all consumer uses, by the three U.S. producers of flame-retardants, as a result of negotiations with the U.S. Environmental Protection Agency (EPA).[22] Due to their previous use, however, PBDEs remain in products found in millions of homes, are present in the bodies of almost all people living in this country, and will persist in the environment for decades.[23] Moreover, although the U.S.-based PBDE manufacturers agreed to phase out these products, no law or regulation prohibits products containing PBDEs from being imported into this country.

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[18] Herbstman, J.B.; Sjödin, A.; Kurzon, M.; Lederman, S.A.; Jones, R.S.; Raugh, V.; Needham, L.L.; Tang, D.; Niedzwiecki, M.; Wang, R.Y.; & Perera, F. (2010). Prenatal exposure to PBDEs and neurodevelopment. *Environmental Health Perspectives*, 118(5), 712-19. doi: 10.1289/ehp.0901340.

[19] Eskenazi, B.; Chevrier, J.; Rauch, S.A.; Kogut, K.; Harley, K.G.; Johnson, C.; Trujillo, C.; Sjödin, A.; & Bradman, A. (2013). In utero and childhood polybrominated diphenyl ether (PBDE) exposures and neurodevelopment in the CHAMACOS study. *Environmental Health Perspectives*, 121(2), 257-62. doi: 10.1289/ehp.1205597.

[20] Costa, L.G., & Giordano, G. (2007). Developmental neurotoxicity of polybrominated diphenyl ether (PBDE) flame retardants. *Neurotoxicology*, 28(6), 1047-67. doi: 10.1016/j.neuro.2007.08.007.

[21] *See* Cal. Health & Safety Code §§ 108920 to 108923; D.C. Code § 8-108.02; Haw. Rev. Stat. §§ 332D-1 to 332D-3; 410 Ill. Comp. Stat. 48/1 to 48/99; Me. Rev. Stat. tit. 38, § 1609; Md. Code Ann., Envir. §§ 6-1201 to 1205; Mich. Comp. Laws §§ 324.14721 to .14725; Minn. Stat. §§ 325E.385 and .386; N.Y. Envtl. Conserv. Law § 37-0111; R.I. Gen. Laws § 23-13.4-1; Vt. Stat. Ann. tit. 9, § 2973; Wash. Rev. Code §§ 70.76.005 to .110.

[22] U.S. EPA. *Polybrominated Diphenyl Ethers (PBDEs) Action Plan Summary*. Retrieved March 2, 2015, from http://www.epa.gov/oppt/existingchemicals/pubs/actionplans/pbde.html.

[23] Centers for Disease Control and Prevention (2009). *Fourth National Report on Human Exposure to Environmental Chemicals*, at 311-13. Retrieved March 3, 2015, from http://www.cdc.gov/exposurereport/.

Of critical importance to this petition, the organohalogen flame retardants used since the PBDE phaseouts have many of the same properties as PBDEs: they are semi-volatile and migrate out of products into the environment, causing human exposures during normal use, and they have been shown to be toxic. For example:

- After pentaBDE was phased out in 2006 due to its toxicity, tris (1,3-dichloro-2-propyl) phosphate (TDCPP), also known as chlorinated tris, became one of the major pentaBDE replacements in polyurethane foam used in furniture and products for children and babies.[24] TDCPP was recently found by the state of California to be a "known carcinogen," and added to the list of chemicals requiring warning labels under California Proposition 65 law.[25] Research shows that TDCPP exposure is associated with altered hormone levels in men and lower semen quality.[26]
- One of the replacements for TDCPP in polyurethane foam is Firemaster® 550, a mixture of two organophosphate and two organohalogen chemicals, which are also now known to be toxic. Firemaster® 550 is an endocrine disruptor that has been associated with weight gain, early onset of puberty and cardiovascular health effects.[27] A senior EPA

[24] TDCPP has a dark history. After brominated tris (2,3-dibromopropyl) phosphate (TDBPP) was banned as a flame retardant in children's pajamas in the late 1970s as a mutagen and suspected carcinogen, it was replaced with chlorinated tris (TDCPP). Blum, A., & Ames, B.N. (1977). Flame-retardant additives as possible cancer hazards. *Science*, 195(4273), 17-23. doi: 10.1126/science.831254. After studies in the 1970s showed that TDCPP is also mutagenic, this chemical too was phased out from children's pajamas. *See* Gold, M. D.; Blum, A.; & Ames, B.N. (1978). Another flame retardant, tris-(1,3-dichloro-2-propyl)-phosphate, and its expected metabolites are mutagens. *Science*, 200(4343), 785-87. doi: 10.1126/science.347576. However, because TDCPP was not banned, it emerged as a replacement flame retardant for pentaBDE in furniture and children's products until its toxicity was "rediscovered."

[25] California EPA, Office of Environmental Health Hazard Assessment ("OEHHA"), Reproductive and Cancer Hazard Assessment Branch (2011). *Evidence on the Carcinogenicity of Tris(1,3-Dichloro-2-Propyl) Phosphate*. Retrieved March 3, 2015, from http://oehha.ca.gov/prop65/hazard_ident/pdf_zip/TDCPP070811.pdf. OEHHA, Chemicals Known to the State to Cause Cancer or Reproductive Toxicity (2014). Retrieved March 3, 2015, from http://oehha.ca.gov/prop65/prop65_list/files/P65single060614.pdf.

[26] Meeker, J.D., & Stapleton, H.M. (2010). House dust concentrations of organophosphate flame retardants in relation to hormone levels and semen quality parameters. *Environmental Health Perspectives*, 118(3), 318-23. doi: 10.1289/ehp.0901332.

[27] Patisaul, H.B.; Roberts, S.C.; Mabrey, N.; McCaffrey, K.A.; Gear, R.B.; Braun, J.; Belcher, S.M.; & Stapleton, H.M. (2013). Accumulation and endocrine disrupting effects of the flame retardant

administrator expressed serious concerns with this mixture and has doubts about its expedited approval as a replacement for pentaBDE.[28] Nonetheless, Firemaster® 550 continues to be used in large quantities in polyurethane foam in consumer products.

- One of the major replacements for decabromodiphenyl ***ether*** (decaBDE) in televisions and other electronics is decabromodiphenyl ***ethane*** (DBDPE). As sales and usage for the decaBDE have declined, sales and usage for the DBDPE have increased. These two chemicals are very similar in structure and properties. After a comparatively short period of usage, DBDPE has been measured in biota around the world at levels greater than those of the decaBDE, suggesting that it may be even more persistent and bioaccumulative than the very similar chemical it replaced.[29]

We must end this cycle of "regrettable substitutions" in which new organohalogen flame retardants are added to consumer products, only to find that—like the organohalogens they are replacing—they migrate from products, resulting in toxic exposures. To protect the public, we ask the CPSC to regulate all products at issue in this petition if additive organohalogen flame retardants as a class are present in them

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mixture Firemaster® 550 in rats: an exploratory assessment. *Journal of Biochemical and Molecular Toxicology*, 27(2), 124-36. doi: 10.1002/jbt.21439.

[28] Hawthorne, *Toxic Roulette*, *supra* note 13; Testimony of Jim Jones, Acting Assistant Administrator, Office of Chemical Safety and Pollution Prevention U.S. EPA, before the U.S. Senate Committee on Environment and Public Works (Jul. 24, 2012). Retrieved March 3, 2015 from http://www.epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=bef3d3ec-ff01-4d25-b0bd-ce38fb37edb3 ("EPA may have made a different determination in 1995 if TSCA required the submission of more robust hazard, exposure, and use data needed to adequately assess risk. . . ").

[29] Betts, K. (2009). Glut of data on "new" flame retardant documents its presence all over the world. *Environmental Science & Technology*, 43(2), 236-37. doi: 10.1021/es8032154.

above levels set by the CPSC.[30] As explained below, the CPSC has the authority to take this action, and we urge it to do so.

IV. The CPSC Has Authority to Regulate These Products

The CPSC has clear authority to take the actions requested in this petition. Under the FHSA, the CPSC "may by regulation declare to be a hazardous substance . . . any substance or mixture of substances,"[31] which is "toxic,"[32] if such substance "may cause substantial personal injury or substantial illness during or as a proximate result of any customary or reasonably foreseeable handling or use."[33] The FHSA defines "toxic" to mean any substance that has "the capacity to produce personal injury or illness to man through ingestion, inhalation, or absorption through any body surface."[34] CPSC's regulation explains that "[s]ubstantial personal injury or illness means any injury or illness of a significant nature. It need not be severe or serious. What is excluded by the word 'substantial' is a wholly insignificant or negligible injury or illness."[35] A household product classified as a "hazardous substance" cannot be sold without a warning label.

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[30] Regulating consumer products containing organohalogen flame retardants under the FHSA is not a complete solution to the hazards presented when toxic flame retardants migrate out of consumer products. As discussed below, newer flame retardants that are organophosphates rather than organohalogens are also semi-volatile and migrate out of products, and growing evidence suggests they may pose unacceptable human health risks.

[31] 15 U.S.C. § 1262(a)(1).

[32] 15 U.S.C. § 1261(f)(1)(A)(i).

[33] 15 U.S.C. § 1261(f)(1)(A).

[34] 15 U.S.C. § 1261(g).

[35] 16 C.F.R. § 1500.3(c)(7)(ii).

Any "article intended for use by children, which is a hazardous substance, or which bears or contains a hazardous substance in such manner as to be susceptible of access by a child," is automatically deemed a "banned hazardous substance."[36] In the case of a household article classified as a "hazardous substance," but not intended for use by children, the CPSC may classify it as a "banned hazardous substance" despite its labeling, if the CPSC determines that

> notwithstanding [any] cautionary labeling . . . , the degree or nature of the hazard involved in the presence or use of such substance in households is such that the objective of the protection of the public health and safety can be adequately served only by keeping such substance, when ... intended or packaged [for use in the household], out of the channels of interstate commerce.[37]

The CPSC has recognized that the FHSA "defines the term 'toxic' very broadly," and "[t]his broad statutory definition covers both acute and chronic toxicity."[38] While the CPSC regulations and guidelines discuss the particular chronic hazards of cancer, neurotoxicity, and developmental or reproductive toxicity, "*the definition is not limited to these hazards, but includes other chronic hazards*."[39] The determination of what is "toxic" under the FHSA "is a complex matter requiring the assessment of many

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[36] 15 U.S.C. § 1261(q)(1)(A). Special rules apply to articles like chemical sets that are inherently hazardous if they are appropriately labeled and are intended for use by mature children. *Id.*

[37] 15 U.S.C. § 1261(q)(1)(B).

[38] *Labeling Requirements for Art Materials Presenting Chronic Hazards; Guidelines for Determining Chronic Toxicity of Products Subject to the FHSA; Supplementary Definition of "Toxic" under the Federal Hazardous Substances Act*, 57 Fed. Reg. 46,626, 46,656 (Oct. 9, 1992).

[39] *Id.* at 46657 (emphasis added).

factors."[40] There is no formula for what is "toxic," and no requirement that risks meet any particular threshold before regulation is warranted. As the Court of Appeals for the D.C. Circuit has explained: "There is no indication in the language of the [FHSA] or its legislative history that the Commission was bound to develop a precise 'body count' of actual injuries that will be reduced by each regulatory provision."[41]

Courts have not questioned the conclusion that a variety of household products containing chemicals, such as Drano (a drain declogger) and Liquid Wrench (a spray lubricant) are "hazardous substances" within the meaning of the FHSA.[42] In addition, under the Consumer Product Safety Improvement Act of 2008, Congress declared that

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[40] 57 Fed. Reg. 46,626, 46,657. In 2008, the FHSA was amended to make it easier for the CPSC to issue regulations finding that a substance is a "hazardous" or "banned hazardous" substance. Prior to the 2008 amendments, proceedings for the issuance of regulations under the FHSA were governed by section 701 of the Federal Food, Drug and Cosmetic Act ("FFDCA"). 21 U.S.C. § 371. Some case law suggested that the FFDCA set a high bar for regulation. *Cf. Consumer Fed'n of Am., v. CPSC*, 883 F.2d 1073 (D.C. Cir. 1989) (upholding the CPSC's denial of a petition to ban the use of methylene chloride in household products because it did not meet the FFDCA standard). Since that case was decided, Congress dropped the requirement that FHSA regulations meet the FFDCA's "reasonable grounds" standard. *See* Pub. Law 110-314 § 204(b)(2) (Aug. 14, 2008). Instead, proceedings to ban a "hazardous substance" are governed solely by provisions of the FHSA. 15 U.S.C. § 1261(q)(2) ("Proceedings for the issuance . . . of regulations [related to banning a "hazardous substance"] shall be governed by the provisions of subsections (f) through (i) of section 1262 of this title," except in the event of imminent hazard when more streamlined procedures may apply). The 2008 amendment signifies Congressional intent to make it easier for the CPSC to regulate under the FHSA.

[41] *Forester v. CPSC*, 559 F.2d 774, 788 (D.C. Cir. 1977).

[42] *See Miles v. S.C. Johnson & Son, Inc.*, No. 00 C 3278, 2002 Westlaw 31655188, at *1 (N.D. Ill. Nov. 25, 2002) ("CPSC has determined that sodium hydroxide, the primary ingredient in Drano, is a hazardous substance."); *Wagoner v. Exxon Mobil Corp.*, 832 F. Supp. 2d 664, 668 (E.D. La. 2011) ("Defendant does not argue that its Liquid Wrench product contains a banned hazardous substance"); *cf. Leibstein v. LaFarge N. Am., Inc.*, 689 F. Supp. 2d 373, 381 (E.D.N.Y. 2010) (it is undisputed that cement product is a "hazardous substance" because it is corrosive).

any children's product containing lead over a certain level is a "banned hazardous substance" within the meaning of the FHSA.[43]

Courts have also given significant deference to the CPSC's determinations that a product is a "hazardous substance." For example, the Second Circuit Court of Appeals agreed with the CPSC that foam spray paint (essentially food-colored shaving cream) intended for use by children is a "hazardous substance" under the FHSA.[44] The court "defer[red] to the agency's interpretation of the substantial injury requirement" because it was not arbitrary, capricious or manifestly contrary to law.[45] The court emphasized that the statute only required that the product "may cause" substantial injury, and did not require that the product would "likely" cause injury.[46]

There is solid precedent for regulating classes of products under the FHSA. In *Toy Manufacturers of America, Inc. v. CPSC*, 630 F.2d 70 (2d Cir. 1980), a trade association of toy manufacturers challenged a rule issued under the FHSA, which banned toys intended for use by young children that present hazards because of small parts. The toy industry argued that the FHSA was intended to deal only with specific, individual articles, and "not with a broad range of products at the same time."[47] The court soundly rejected this argument, saying: "Certainly, nothing in the FHSA explicitly

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[43] 15 U.S.C. § 1278a(a)(1).

[44] *United States v. Articles of Banned Hazardous Substances Consisting of an Undetermined Number of Cans of Rainbow Foam Paint*, 34 F.3d 91 (2d Cir. 1994).

[45] 34 F.3d at 97.

[46] *Id.* at 97-98.

[47] 630 F.2d at 74.

limits the employment of its banning procedures to situations involving only individual products . . . ."[48] The court went on to note that "[t]he legislative history appears clear in favoring general prescriptive regulations of *the broadest, most comprehensive type* and would favor case-by-case proceedings only where such general prescriptive regulations prove impossible."[49] The court relied on language from the FHSA legislative history in which the Senate Report states:

> It is intended that most determinations made by the (CPSC) will be in the form of general prescriptive rules, further amplifying the definition of . . . hazardous substances where necessary.[50]

More recently, in the context of a petition under the FHSA to ban sulfuric acid drain openers, a request the CPSC had received and rejected several times before, Commissioner Thomas H. Moore wrote separately to explain why the CPSC was again denying the request. Commissioner Moore stated:

> Each time the Commission has dealt with this issue it has expressed unease and concern about the severity of the injuries that can be caused by drain openers. What has stymied the Commission each time, I think, is that *the remedy proposed by the petitioners—the banning of one particular type of chemical drain opener, those made with sulfuric acid—is not expected to solve the problem because of the likelihood that consumers will simply switch to other chemical drain openers, either acid or alkaline, which can be just as dangerous as the sulfuric acid drain openers they would be replacing*. The Commission is not limited to taking the narrow action proposed by the petitioners. Instead of continuing to express concern, but dismissing the issue because of the limitations of

[48] *Id.*

[49] *Id.* (citation omitted) (emphasis added).

[50] S. Rep. No. 91-237, 91st Cong., 1st Sess. 5 (1969).

> the proposed remedy, *perhaps we should be examining the entire class of chemical drain openers to see what can be done to make them **all** safer*.[51]

The class of organohalogen flame retardants in the product categories at issue here is like small parts in toys: these chemicals are intrinsically dangerous by virtue of their inherent characteristics. Consumer products in the four categories at issue pose hazards when they contain any organohalogen flame retardant because of the intrinsic tendency of these semi-volatile chemicals to migrate out of products and attach to other media, such as house dust. Thus, for purposes of being a "hazardous substance" under the FHSA, each foreseeable way that these four categories of products are used, including, handling, mouthing, lying on and within, sleeping on, sitting in, playing with, or watching (as in a television) can pose a risk of harm to consumers if organohalogen flame retardants are added to these product categories during manufacturing. Indeed, the products may cause substantial personal injury or substantial personal illness as a result of their mere presence in the household, which is plainly a foreseeable handling or use. *See* Section VII, below.

And like the chemical drain openers discussed by Commissioner Moore, it makes no sense for CPSC to regulate a product containing one organohalogen flame retardant only to see the same product manufactured with another flame retardant with the same physico-chemical properties.[52] Based on the understanding that the FHSA "favor[s]

[51] U.S. Consumer Product Safety Commission (2006). *Statement of the Honorable Thomas H. Moore on petition HP 04-2 request to ban sulfuric acid drain openers for consumer use.* Retrieved March 3, 2015, from http://www.cpsc.gov/pr/sado_moore.pdf.

[52] The fact that sulfuric acid is a single chemical, not a chemical class, and that drain openers is a single product category are irrelevant distinctions for purposes of this Petition. The CPSC's

general prescriptive regulations of the broadest, most comprehensive type and would favor case-by-case proceedings only where such general prescriptive regulations prove impossible,"[53] and the strong evidence described below that all chemicals in this class – due to their physico-chemical properties – are toxic and may cause substantial injury or illness, consumer products containing organohalogen flame retardants as a class must be understood as "hazardous substances" within the meaning of the FHSA.[54] Indeed, former CPSC Chair Tenenbaum recently said as much. In declaring that there is no need for crib mattresses to be manufactured with *any* chemical flame retardants, Chair Tenenbaum stated: "The law strictly prohibits children's products from having hazardous chemicals [meaning any flame retardant] that children could be exposed to and could foreseeably cause substantial illness or injury."[55]

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expressed preference for remedying consumer risk without inviting a similarly risky product as its replacement is just as applicable here as with the drain openers.

[53] 630 F.2d at 74.

[54] Under the authority of the FHSA, products containing several chemical substances have been found to be "hazardous substances," requiring labeling. These include: diethylene glycol; ethylene glycol; products containing 5% or more benzene; methyl alcohol; turpentine; toluene, and xylene. When the FDA (which administered the FHSA at the time these regulations were adopted) first proposed to regulate products containing these chemicals as "hazardous substances," it said it was doing so based on "human experience" and "together with opinions of informed medical experts." 28 Fed. Reg. 2686, 2686 (Mar. 19, 1963).

[55] Patricia Callahan & Michael Hawthorne, *Chemicals in the Crib*, Chicago Tribune, Dec. 8, 2012, http://articles.chicagotribune.com/2012-12-28/news/ct-met-flames-test-mattress-20121228_1_tdcpp-heather-stapleton-chlorinated-tris.

V. Regulating Products Containing Flame Retardants Should Be a Commission Priority

Household products to which organohalogen flame retardants have been added fall squarely within the priorities for CPSC regulation. The CPSC has long been aware of and concerned about the use of toxic flame retardants in consumer products. In recent years, Commissioners have explicitly recognized that the use of organohalogen flame retardants in consumer products is unnecessary and dangerous.[56] The Chicago Tribune reported that at a congressional hearing in July 2012, then-Chair Tenenbaum "urged lawmakers to grant special authority that could speed the removal of hazardous flame retardants from new upholstered furniture, including sofas that can contain up to two pounds of the chemicals in their foam cushions."[57] The only measure that would ensure

[56] For example, six years ago, when the CSPC proposed a national residential furniture flammability standard, it said that it "developed the proposed standard *mindful of the continuing uncertainty about potential health and environmental effects of FR [flame retardant] chemical usage*, with an objective of achieving significant reductions in fire deaths and injuries from upholstered furniture fires caused by smoking materials while minimizing reliance on FR additives in fabrics and filling materials to meet that objective." *Standard for the Flammability of Residential Upholstered Furniture*, 73 Fed. Reg. 11,702, 11,709 (proposed Mar. 4, 2008) (emphasis added).

[57] Subsequently, Chair Tenenbaum stated:

> I was pleased to read that the Governor of California recently directed that state's Bureau of Home Furnishings to revisit state rules that effectively require the use of flame retardant in many household upholstered furniture items, and I know Commission staff is monitoring this work closely. I am hopeful that Commission staff will generate a rule that will bring safer, more fire resistant upholstered furniture into homes across the nation.

US Consumer Product Safety Commission (Aug. 2, 2012). *Statement of Inez M. Tenenbaum, Chairman, U.S. Consumer Product Safety Commission, Before the U.S. House Committee on Energy and Commerce Subcommittee on Commerce, Manufacturing, and Trade; "Oversight of the Consumer Product Safety Commission."* Retrieved March 3, 2015, from http://www.cpsc.gov//PageFiles/121027/tenenbaum08022012.pdf.

hazardous organohalogen flame retardants are absent from furniture is for the CPSC to ban furniture containing those chemicals under the FHSA, as we seek here.

It is fully consistent with the CPSC's "Policy on establishing priorities for commission action"[58] to prioritize the regulation of products containing any organohalogen flame retardant in order to prevent future injuries, especially to children, given the pervasiveness of consumer products containing these chemicals and the inability of consumers to avoid contact with them. Under the CPSC's "Policy on establishing priorities for commission action," the agency must prioritize action on:

- products where the probability of exposure to the hazard is high due to "the number of units of the product that are being used by consumers, the frequency with which such use occurs, and the likelihood that in the course of typical use the consumer would be exposed to the identified risk of injury";[59]
- preventing product-related injury to children, the handicapped, and senior citizens;[60] and
- "products, although not presently associated with large numbers of frequent or severe injuries, [where] ... there is reason to believe that the products will in the future be associated with many such injuries.[61]

All of these considerations are present here: 1) the affected products are ones that most people use daily, such as chairs, sofas, mattress pads, computers and other electronics; 2) children are at particular risk for several reasons: they tend to spend more time on or near the floor (crawling, playing, and so on) where they are exposed to hazardous dust; they have hand-to-mouth behaviors that result in their ingestion of this

[58] 16 C.F.R. § 1009.8.

[59] 16 C.F.R. § 1009.8 (c)(7).

[60] 16 C.F.R. § 1009.8 (c)(6).

[61] 16 C.F.R. § 1009.8 (c)(3).

material; they may be exposed during critical developmental windows of rapid growth and brain development during which they are particularly vulnerable to these toxins; and children's products in particular are likely to contain flame retardants; and 3) there is strong reason to believe that continued use of additive organohalogen flame retardants in the four product categories will result in future illness and injury, just like the now-banned or discontinued PBDEs.

The CPSC has additional cause to act swiftly to protect consumers and children from the products at issue in this petition when they contain organohalogen flame retardants. As described below in Section VII-B, for reasons that are not fully understood, the highest human levels of harmful flame retardants in the general population have been found in young children from communities of low socio-economic status, and communities of color.[62] This presents an environmental injustice. Pursuant to Executive Order 12898, the CPSC must act to "achiev[e] environmental justice . . . by . . . addressing . . . [the] disproportionately high and adverse human health or environmental effects of its programs [and] policies . . . on minority populations and low-income populations."[63] The CPSC's failure to regulate household products containing hazardous substances in the form of organohalogen flame retardants, despite the abundant evidence that these chemicals are pervasive in the homes and

[62] Quirós-Alcalá, L.; Bradman, A; Nishioka, M.; Harnly, M.E.; Hubbard, A.; McKone, T.E.; & Eskenazi, B. (2011). Concentrations and loadings of polybrominated diphenyl ethers in dust from low-income households in California. *Environment International*, 37(3):592-96. doi: 10.1016/j.envint.2010.12.003.

[63] Exec. Order No. 12,898 (Feb. 11, 1994), at 1.

bodies of people across the country, and especially in people of color and of lower incomes, must be corrected as soon as possible.

For all these reasons, regulating the product categories at issue here when they contain additive organohalogen flame retardants should be a priority for the CSPC.

VI. Organohalogen Flame Retardants Are Pervasive in the Product Categories Covered by This Petition, But Are Not Required by Any Flammability Standard

In Section VI-A below, we present evidence that organohalogen flame retardants are often present in the four product categories at issue here. In Section VI-B below, we explain that these flame retardants are not used to meet any flammability standard.

A. Additive Organohalogen Flame Retardants Are Used Extensively in the Consumer Product Categories Covered by This Petition

A large percentage of the products in the categories at issue in this petition contain organohalogen flame retardants as a result of the flame retardants being intentionally added to the products, as detailed below.

1. Infant and Children's Products

Testing has identified organohalogen flame retardants in the foam in nursing pillows, crib mattresses, strollers, baby carriers, sleep mats, and changing table pads. For example:

A. A 2011 study of baby products sold throughout the United States found flame retardant chemicals in a range of foam-containing products, such as nursing pillows, crib mattresses, strollers, baby carriers, sleep mats, and changing table pads.[64] Out of foam samples collected from 101 commonly used baby products, 80 samples were found to have an identifiable flame retardant additive, and 79 of these contained organohalogens.

B. In 2012, the Chicago Tribune analyzed foam used in crib mattresses, and found that three then-popular brands of baby mattresses tested positive for organohalogen flame retardants.[65]

C. A 2012 survey of flame retardants in sleep products found evidence for the presence of organohalogen flame retardants in all foam samples from 29 sleeping mats from nursery schools and day care centers in the California Bay Area.[66]

D. A study published in 2012 documents extensive use of organohalogen flame retardants in infants' and children's products. The report provides the results of tests carried out on 20 foam-containing products purchased across the United States at major retailers, including baby changing mats and nursing pillows. Seventeen (85%) of the 20 products tested contained organohalogen flame retardants.[67]

The fact that a significant proportion of tested juvenile products has been found to contain organohalogen flame retardants suggests that a high percentage of *all* infant and children's products contain these chemicals. While consumers use these products in different ways (as toys, as carriers, as seating, and so on), the unifying feature is that infants and children come in contact with all of them, and if the product contains any organohalogen flame retardant in additive form, the use of the product — indeed, the

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[64] Stapleton, H.M.; Klosterhaus, S.; Keller, A.; Ferguson, P.L.; van Bergen, S.; Cooper, E.; Webster, T.F.; & Blum, A. (2011). Identification of flame retardants in polyurethane foam collected from baby products. *Environmental Science & Technology*, 45(12), 5323-31. doi: 10.1021/es2007462.

[65] Patricia Callahan, *Chemicals in the Crib*, *supra* note 55.

[66] Gaw, C. (2012). *Sleeping on Toxins? A Study of Flame Retardants in Sleep Products*. Retrieved March 3, 2015, from http://nature.berkeley.edu/classes/es196/projects/2012final/GawC_2012.pdf.

[67] Organohalogen flame retardants identified included tris (1,3-dichloro-2-propyl) phosphate (TDCPP), tris (2-chloroethyl) phosphate (TCEP), and tris (1-chloro-2-propyl) phosphate (TCPP), with chlorinated Tris (TDCPP) found in 80% of the products tested. Washington Toxics Coalition and Safer States (2012). *Hidden Hazards in the Nursery*. Retrieved March 3, 2015, from http://watoxics.org/publications/hidden-hazards.

mere presence of the product in the home — will result in exposure to the flame retardant chemical because of the semi-volatile property of these chemicals, as discussed below in Section VII.

2. Residential Furniture

Most residential seating furniture in use in this country contains additive organohalogen flame retardants. One 2012 study tested 102 samples of polyurethane foam from residential sofas purchased across the United States between 1985 and 2010 and found that 85% contained flame retardants.[68] One of the objectives of this study was to determine which chemicals were being used after the phase-out of pentaBDE in 2005. In furniture purchased before 2005, organohalogen flame retardants were detected in 63% of the samples tested (pentaBDE in 39% of the samples, followed by TDCPP in 24%). In furniture purchased in 2005 or later, organohalogen flame retardants were detected in over 90% of the samples (most common being TDCPP in 52% and components associated with the Firemaster® 550 mixture in 18% of the samples). In other words, the 2005 phase-out of pentaBDE led to the use of other organohalogen flame retardants in polyurethane foam used in upholstered furniture.

3. Mattresses and Mattress Pads

An informal 2012 survey of 28 foam mattresses and 55 mattress pads used by adults found organohalogen flame retardants in 29% and 50% of the samples

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[68] Stapleton, H.M.; Sharma, S.; Getzinger, G.; Ferguson, P.L.; Gabriel, M.; Webster, T.F.; & Blum, A (2012). Novel and high volume use flame retardants in US couches reflective of the 2005 PentaBDE phase out. *Environmental Science & Technology*, 46(24), 13,432-39. doi: 10.1021/es303471d.

analyzed.[69] This was confirmed by the website of the American Chemistry Council / North American Flame Retardant Alliance, which lists foam mattresses as one of the product areas where flame retardants are used.[70]

4. Electronics Enclosures

Flame retardants in additive form are commonly used in plastic casings for televisions and other electronic devices.[71] (To be clear, this petition does not address the flame retardants in reactive form in electronic circuit boards where the flame retardants are chemically bound to the product. This petition focuses exclusively on organohalogen flame retardants in additive form used in the plastic casings for electronic devices.) DecaBDE was commonly used in plastic casings for televisions and electronics before it was phased out by the EPA due to its toxicity. Although decaBDE is no longer used in plastic electronic casings, other similar organohalogen flame retardants such as DBDPE have replaced it.[72]

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[69] Gaw, C., Singla, V.; Peaslee, G.; & Busener, S. (2013). Flame retardants in foam from various consumer products. On file with Green Science Policy Institute.

[70] North American Flame Retardant Alliance lists foam mattresses as one of the products in which flame retardants are commonly used. North American Flame Retardant Alliance, American Chemistry Council. *Flame Retardant Basics*. Retrieved March 03, 2015, from http://flameretardants.americanchemistry.com/FR-Basics.

[71] North American Flame Retardant Alliance lists Electronics and Electrical Devices as one of the four product areas where flame retardants are commonly used including in casings for televisions and other electronic devices. *Id*.

[72] Betts, Glut of data, *supra* note 29.

B. Flame Retardants Are Not Required by Any Federal or State Flammability Standard

The widespread use of organohalogen flame retardants in consumer products described immediately above is not required in order to comply with any government-adopted flammability standard. The extensive use of organohalogen flame retardants in juvenile products and residential furniture began with a 1975 California flammability standard called Technical Bulletin 117 (TB 117).[73] However, after an extensive regulatory review process, the California Bureau of Electronics and Appliance Repair, Home Furnishings and Thermal Insulation ("BEARHFTI") recently revised TB 117, replacing the old flammability standard with a new one that can be met without flame retardants,[74] and exempting 17 juvenile products from flammability requirements.

In addition, no federal furniture flammability standard has been adopted, and the flammability standard proposed by the CPSC in 2008 was specifically designed so it

[73] State of California, Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation (2000). Technical Bulletin 117: Requirements, Test Procedure and Apparatus for Testing the Flame Retardance of Resilient Filling Materials Used in Upholstered Furniture. Retrieved March 3, 2015, from http://www.bhfti.ca.gov/industry/117.pdf. The TB 117 requirements included a 12-second open flame test for furniture and juvenile products filling materials. This requirement was often met by adding flame retardant chemicals to polyurethane foam filling. In part because of the size of the California market, TB 117 became a *de facto* national standard, resulting in nationwide sale of furniture and juvenile products containing flame retardant chemicals.

[74] State of California, Department of Consumer Affairs, Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (2013). Initial Statement of Reasons. Retrieved March 3, 2015, from http://www.bhfti.ca.gov/about/laws/isr.pdf. TB 117-2013 categorically exempts 17 categories of juvenile products made with foam (including strollers, infant carriers, nursing pillows, booster seats, bassinets, and highchairs) from regulation. Cal. Code Regs tit. 4, § 1374.2(c).

could be met without use of flame retardants.[75] Thus, no flammability standard currently in effect requires chemical flame retardants to be added to residential furniture or juvenile products, with the exception of car seats,[76] which are not covered by this petition.

As of 2006, the CPSC has two flammability standards that apply to adult mattresses – a smolder standard in 16 C.F.R. section 1632, and an open flame standard in 16 C.F.R. section 1633. Flame retardants are not needed to meet either of these standards. Like the TB 117-2013 furniture smolder standard discussed above, the mattress smolder standard can be met by selecting smolder-resistant fabrics. In addition, the open flame standard was designed so manufacturers have the option of not using flame retardant chemicals, as confirmed by a "Question and Answer" document prepared by CPSC Staff:

> The regulation does not specify the use of FR chemicals to meet the 12 requirements. Manufacturers are free to choose the means of complying with the regulation and this may include the use of inherently flame resistant materials and FR barriers, in addition to FR chemicals. If the manufacturer

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[75] In the preamble to the 2008 Notice of Proposed Rulemaking for a federal furniture flammability standard, the CPSC states:

> In October 2004, the staff held a public meeting to present the direction of what would become the staff's 2005 draft standard. The staff analyzed comments received at that meeting as well. The proposed standard takes account of that analysis. Staff received comments on its 2005 draft standard, continued its research and analysis *and developed a revised, 2007 draft proposal that focused primarily on preventing smoldering ignitions and reducing the need for flame retardant chemicals. This notice presents the 2007 draft as the Commission's proposed standard.*

Standard for the Flammability of Residential Upholstered Furniture, *supra* note 56.

[76] Children's car seats are regulated by the National Highway Traffic Safety Administration

chooses to use FR chemicals, the regulation does not require tests for durability after exposure to moisture.[77]

Indeed, former CPSC Chair Tenenbaum acknowledged that barrier technologies could be used to meet the CPSC's mattress standards. She stated that the CPSC "strongly encourage[s] all mattress manufacturers to comply with our performance standard through the use of barrier technologies and *to avoid using any potentially harmful chemicals to which children can be exposed*."[78]

Finally, there are no federal or state regulations requiring the use of flame retardant chemicals in plastic electronic enclosures.

VII. Use of Additive Organohalogen Flame Retardants in Household Products Leads to Human Exposure

When consumer products in these four categories contain organohalogen flame retardants in additive form, the actual and foreseeable use of the products will result in human exposures to the chemicals, as described below. This exposure causes a risk of human harm.

A. Organohalogen Flame Retardants Are Semi-Volatile, Meaning They Are Released into the Air, Persist and Lead to Human Exposures

Two considerations greatly influence the likelihood that a chemical substance will migrate out of a consumer product: (1) whether the substance is additive or

[77] U.S. Consumer Product Safety Commission, Office of Compliance, Standard for the Flammability (Open Flame) of Mattress Sets, 16 C.F.R. Part 1633, Questions and Answers. Retrieved March 3, 2015, from https://www.cpsc.gov//PageFiles/117413/mattqa.pdf.

[78] Patricia Callahan, *Chemicals in the Crib, supra* note 55.

reactive, and (2) whether or not it is semi-volatile. Unlike reactive flame retardants, additive flame retardants are not chemically bound to the material of the consumer product and are thus more likely to be released into the home environment, leading to human exposure. Additionally, as explained in Dr. Miriam Diamond's accompanying statement, organohalogen flame retardants as a class are semi-volatile organic compounds ("SVOCs"). When used in additive form in consumer products, SVOCs are released slowly from products and, once released, tend to adsorb onto other solid phases such as dust particles, human and animal skin, clothes, and so on. In addition, exposures occur as a result of direct transfer when touching a product containing additive flame retardants is followed by hand-to-mouth contact. This is true of all additive organohalogen flame retardants. In addition, all organohalogen flame retardants are, by their nature, persistent in the indoor environment.[79,80] In sum, based on the physico-chemical properties of additive organohalogen flame retardants as a class, these chemical substances will migrate out of consumer products and persist in the indoor environment, leading to human exposures. These exposures occur regardless of how the product is used.

Extensive empirical evidence supports this conclusion. Many studies show that organohalogen flame retardants are present in indoor air and house dust. Most

[79] Weschler, C.J. & Nazaroff, W.W. (2008). Semivolatile organic compounds in indoor environments. *Atmospheric Environment*, 42(40), 9018-40. doi: 10.1016/j.atmosenv.2008.09.052.

[80] Shin, H.; McKone, T.E.; Tulve, N.S.; Clifton, M.S.; & Bennett, D.H. (2013). Indoor residence times of semivolatile organic compounds: model estimation and field evaluation. *Environmental Science & Technology*, 47(2), 859-67. doi: 10.1021/es303316d.

research is on the PBDE flame retardants because they have been in use the longest. For instance, a 2004 Canadian study measured concentrations of PBDEs in indoor air from 74 homes and in outdoor air at seven sites.[81] The researchers detected PBDEs in all indoor air samples, but not in all of the outdoor air samples, with levels indoors approximately 50 times higher on average than outdoors. A 2006 UK study also found that PBDE concentrations were one order of magnitude higher indoors compared to outdoors.[82] These higher incidences and levels of PBDEs in indoor air are consistent with the migration of flame retardants from indoors consumer products.

A recent study of 139 California households found PBDEs in the majority of dust samples and many floor wipe samples.[83] Another study found measurable levels of PBDEs, as well as three other additive organohalogen flame retardants – hexabromobenzene, tris (1-chloro-2-propyl) phosphate (TCPP), and tetrabromobisphenol A (TBBPA) – emitted from office equipment to indoor air.[84]

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[81] Wilford, B.H.; Harner, T.; Zhu, J.; Shoeib, M.; & Jones, K.C. (2004). Passive sampling survey of polybrominated diphenyl ether flame retardants in indoor and outdoor air in Ottawa, Canada: implications for sources and exposure. *Environmental Science & Technology*, 38(20), 5312-18. doi: 10.1021/es049260x.

[82] Harrad, S.; Hazrati S.; & Ibarra, C. (2006). Concentrations of polychlorinated biphenyls in indoor air and polybrominated diphenyl ethers in indoor air and dust in Birmingham, United Kingdom: implications for human exposure. *Environmental Science & Technology*, 40(15), 4633-38. doi: 10.1021/es0609147.

[83] Bennett, D.H.; Moran, R.E.; Wu, X.M.; Tulve, N.S.; Clifton, M.S.; Colon, M.; Weathers, W.; Sjödin, A.; Jones, R.; & Hertz-Picciotto, I. (2014). Polybrominated diphenyl ether (PBDE) concentrations and resulting exposure in homes in California: relationships among passive air, surface wipe and dust concentrations, and temporal variability. *Indoor Air*. doi: 10.1111/ina.12130.

[84] Destaillats, H.; Maddalena, R.L.; Singer, B.C.; Hodgson, A.T.; & McKone, T.E. (2008). Indoor pollutants emitted by office equipment: A review of reported data and information needs. *Atmospheric Environment*, 42(7), 1371-88. doi: 10.1016/j.atmosenv.2007.10.080.

Newer studies on the organohalogen flame retardants used as PBDE replacements show that these too migrate from products into the air and end up in dust. For example, a 2006 study in Boston, Massachusetts, analyzed dust samples from 19 homes and found several alternate and new brominated flame retardants: hexabromocyclododecane (HBCD), 1,2-bis (2,4,6,-tribromphenoxy) ethane (BTBPE), DBDPE, and the brominated components found in Firemaster® 550: 2-ethylhexyl 2,3,4,5-tetrabromobenzoate (TBB) and bis (2-ethylhexyl) 3,4,5,6-tetrabromophthalate (TBPH).[85] As described in the accompanying statement from Ruthann Rudel, the Silent Spring Institute tested dust in California homes for the presence of flame retardants between 2006 and 2011, and found that over 50% of those homes contained 41 different organohalogens, and at least one contained as many as 55 flame retardant chemicals.[86] Most commonly found were: PBDE mixtures; components of Firemaster® 550; HBCD; TBBPA; tetrabromobisphenol A-bis(2,3-dibromopropylether) (TBBPA-BDBPE); DBDPE; TDBPP; TDCPP; TCPP; and TCEP. The study also found that concentrations of Firemaster® 550 components TBB, TBPH and triphenyl phosphate (TPhP) increased from 2006 to 2011, as the use of Firemaster® 550 increased to replace the pentaBDE commercial mixture. On the other hand, levels of pentaBDE (which was phased-out in

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85 Stapleton, H.M.; Allen, J.G.; Kelly, S.M.; Konstantinov, A.; Klosterhaus, S.; Watkins, D.; McClean, M.D.; & Webster, T.F. (2008). Alternate and new brominated flame retardants detected in U.S. house dust. *Environmental Science & Technology*, 42(18), 6910-16. doi: 10.1021/es801070p.

86 Dodson, R.E.; Perovich, L.J.; Covaci, A.; Van den Eede, N.; Ionas, A.C.; Dirtu, A.C.; Brody, J.G.; & Rudel, R.A. (2012). After the PBDE phase-out: a broad suite of flame retardants in repeat house dust samples from California. *Environmental Science & Technology*, 46(24), 13,056-66. doi: 10.1021/es303879n.

2005) decreased significantly in dust samples from those households that had purchased new consumer products between 2006 and 2011.[87,88] Similarly, a study of 26 foam-containing consumer products purchased between 2003 and 2009 in the U.S. found TDCPP and TCPP in 15 and 4 of the samples respectively, and detected them in house dust at levels comparable, or even greater, than the levels of PBDEs.[89,90] In one study, a significant positive correlation ($p<0.05$) was found between concentrations of the organohalogen flame retardants BTBPE, DBDPE and TBPH in mattresses and the corresponding concentrations in floor dust ($n=16$).[91]

Of particular concern is that organohalogen flame retardants – both PBDEs and their replacements – are ubiquitous in dust found in child care centers and preschools: PBDEs, brominated components of Firemaster® 550, tris (2-chloroethyl) phosphate (TCEP) and TDCPP (all organohalogen flame retardants) were detected in 100% of the

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[87] *Id.*

[88] This is evidence that once flame retardants are removed from consumer products, their presence in household dust eventually decreases, thus leading to decreased exposure.

[89] Stapleton, H.M.; Klosterhaus, S.; Eagle, S.; Fuh, J.; Meeker, J.D.; Blum, A.; & Webster, T.F. (2009). Detection of organophosphate flame retardants in furniture foam and U.S. house dust. *Environmental Science and Technology*, 43(19), 7490-95. doi: 10.1021/es9014019.

[90] Measurable amounts of four non-PBDE organohalogen flame retardants were also found in house dust in Belgium: BTBPE and DBDPE were identified in 85% and 100% of Belgium house dust samples respectively; TBB and TBPH were found in 31% and 97% of house dust samples respectively. Ali, N.; Harrad, S.; Goosey, E.; Neels, H.; & Covaci, A. (2011). "Novel" brominated flame retardants in Belgian and UK indoor dust: implications for human exposure. *Chemosphere*, 83(10), 1360-65. doi: 10.1016/j.chemosphere.2011.02.078.

[91] Ali, N.; Dirtu, A.C.; Van den Eede, N.; Goosey, E.; Harrad, S.; Neels, H.; 't Mannetje, A.; Coakley, J.; Douwes, J.; & Covaci, A. (2012). Occurrence of alternative flame retardants in indoor dust from New Zealand: indoor sources and human exposure assessment. *Chemosphere*, 88(11), 1276-82. doi: 10.1016/j.chemosphere.2012.03.100.

dust sampled in 40 California early childhood educational facilities between May 2010 and May 2011.[92]

B. The Migration of Organohalogen Flame Retardants Out of Products Leads to Human Exposure

Humans are exposed to organohalogen flame retardants that migrate from consumer products into the air and settle in house dust as a result of the actual and foreseeable use of the products at issue in this petition. The inadvertent ingestion and absorption of contaminated house dust is a major pathway of exposure to organohalogen flame retardants for the general population.[93] An EPA review published in 2008 found that ingestion of organohalogen flame retardants in household dust accounted for over 80% of the overall exposure of study participants to these chemicals, with the remaining exposure primarily due to ingestion of contaminated food products.[94] A 2007 Massachusetts study found that inhalation of PBDEs from indoor air due to their presence in consumer products may also account for a significant

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[92] Bradman, A.; Castorina, R.; Gaspar, F.; Nishioka, M.; Colón, M.; Weathers, W.; Egeghy, P.P.; Maddalena, R.; Williams, J.; Jenkins, P.L.; & McKone, T.E. (2014). Flame retardant exposures in California early childhood education environments. *Chemosphere*, 116, 61-66. doi: 10.1016/j.chemosphere.2014.02.072.

[93] Jones-Otazo, H.A.; Clarke, J.P.; Diamond, M.L.; Archbold, J.A.; Ferguson, G.; Harner, T.; Richardson, G.M.; Ryan, J.J.; & Wilford, B. (2005). Is house dust the missing exposure pathway for PBDEs? An analysis of the urban fate and human exposure to PBDEs. *Environmental Science & Technology*, 39(14), 5121-30. doi: 10.1021/es048267b.

[94] Lorber, M. (2008). Exposure of Americans to polybrominated diphenyl ethers. *Journal of Exposure Science & Environmental Epidemiology*, 18(1), 2-19. doi: 10.1038/sj.jes.7500572

proportion of human exposures to these chemicals.[95] More recent research suggests that product-to-hand transfer followed by hand-to-mouth transfer is the main path of exposure to organohalogen flame retardants.[96,97]

Biomonitoring studies confirm that flame retardants are present in people. The 2003-2004 National Health and Nutrition Examination Survey ("NHANES") conducted by the Centers for Disease Control and Prevention ("CDC"), found at least one PBDE congener in 97% of the study participants, reported to be representative of the U.S. population.[98] The latest CDC report[99] found several PBDEs and 2,2',4,4',5,5'-hexabromobiphenyl (BB 153, known commercially as Firemaster® BP-6) at levels ranging from 1.2 to 28.2 ng/g lipid in human serum. Teenagers (ages 12 to 19) had higher body burdens than adults for all flame retardants measured. Mexican Americans and non-Hispanic blacks had higher levels than the non-Hispanic white population. The fact that

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[95] Allen, J.G.; McClean, M.D.; Stapleton, H.M.; Nelson, J.W.; & Webster, T.F. (2007). Personal exposure to polybrominated diphenyl ethers (PBDEs) in residential indoor air. *Environmental Science & Technology*, 41(13), 4574-79. doi: 10.1021/es0703170.

[96] Watkins, D.J.; McClean, M.D.; Fraser, A.J.; Weinberg, J.; Stapleton, H.M.; Sjödin, A.; & Webster T.F. (2011). Exposure to PBDEs in the office environment: evaluating the relationships between dust, handwipes, and serum. *Environmental Health Perspectives*, 119(9), 1247-52. doi: 10.1289/ehp.1003271.

[97] Stapleton, H.M.; Eagle, S.; Sjödin, A.; & Webster, T.F. (2012). Serum PBDEs in a North Carolina toddler cohort: associations with handwipes, house dust, and socioeconomic variables. *Environmental Health Perspectives*, 120(7), 1049-54. doi: 10.1289/ehp.1104802.

[98] Sjödin, A.; Wong, L.; Jones, R.S.; Park, A.; Zhang, Y.; Hodge, C.; Dipietro, E.; McClure, C.; Turner, W.; Needham, L.L.; & Patterson Jr., D.G. (2008). Serum concentrations of polybrominated diphenyl ethers (PBDEs) and polybrominated biphenyl (PBB) in the United States population: 2003-2004. *Environmental Science & Technology*, 42(4), 1377-84. doi: 10.1021/es702451p.

[99] Centers for Disease Control and Prevention (2015). *Fourth National Report on Human Exposure to Environmental Chemicals, Updated Tables, February 2015*. Retrieved March 4, 2015, from http://www.cdc.gov/exposurereport/.

communities of color bear disproportionately high levels of flame retardant chemicals, coupled with the disproportionate exposure and toxicity borne by children (and developing fetuses) presents environmental justice concerns. Another recent study detected 2,3,4,5-tetrabromobenzoic acid (TBBA), a urinary metabolite of the Firemaster® 550 component TBB, in 72.4% of the 64 study participants, indicating widespread exposure to Firemaster® 550 in the home environment.[100]

Studies have also documented exposure of pregnant women to organohalogen flame retardants, which is of particular concern because there are strong links between prenatal exposures to these chemicals and reduced IQ and greater hyperactivity in children.[101] All pregnant participants in the 2003-2004 NHANES study had measurable levels of at least one PBDE in their bodies.[102] A study of 416 predominantly immigrant pregnant women living in Monterey County, California, detected pentaBDE congeners in 97% of serum samples.[103] In addition, flame retardant chemicals are transferred from

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[100] Hoffman, K.; Fang, M.; Horman, B.; Patisaul, H.B.; Garantziotis, S.; Birnbaum, L.S.; & Stapleton, H.M. (2014). Urinary tetrabromobenzoic acid (TBBA) as a biomarker of exposure to the flame retardant mixture Firemaster® 550. *Environmental Health Perspectives*, 122(9), 963-69. doi: 10.1289/ehp.1308028.

[101] Chen, A.; Yolton, K.; Rauch, S.A.; Webster, G.M.; Hornung, R.; Sjodin, A.; Dietrich, K.N.; & Lanphear, B.P. (2014). Prenatal polybrominated diphenyl ether exposures and neurodevelopment in U.S. children through 5 years of age: The HOME study. *Environmental Health Perspectives*, 122(8), 856-62. doi: 10.1289/ehp.1307562.

[102] Woodruff, T.J.; Zota, A.R.; & Schwartz, J.M. (2011). Environmental chemicals in pregnant women in the United States: NHANES 2003-2004. *Environmental Health Perspectives*, 119(6), 878-85. doi: 10.1289/ehp.1002727.

[103] Castorina, R.; Bradman, A.; Sjödin, A.; Fenster, L.; Jones, R.S.; Harley, K.G.; Eisen, E.A.; & Eskenazi, B. (2011). Determinants of serum polybrominated diphenyl ether (PBDE) levels among pregnant women in the CHAMACOS cohort. *Environmental Science Technology*, 45(15), 6553-60. doi: 10.1021/es104295m.

the mother to the baby during breastfeeding,[104] a potentially major route of exposure for infants. Fetuses and newborn infants are especially at risk when exposed to toxics such as organohalogen flame retardants because their brains and organ systems are in a critical developmental window.

In general, exposure to flame retardants in house dust is highest for toddlers and young children.[105] A study of 20 mothers and their children aged 1.5 to 4 found that the children had typically 2.8 times higher total PBDE levels than their mothers.[106] The authors suggest that this occurs due to the young children's frequent hand-to-mouth activity, dietary preferences, and breastfeeding. In a North Carolina study, levels of PBDEs on toddlers' hands correlated with serum PBDE levels, suggesting that the frequent hand-to-mouth contact exhibited by young children is a major exposure pathway.[107] In a separate study, toddlers in homes with contaminated house dust had up to 100-fold greater estimated exposure levels compared to toddlers who were not exposed to contaminated dust.[108] CPSC exposure estimates suggest that infants could be exposed to higher levels of the organohalogen flame retardant TDCPP from juvenile

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[104] Schecter, A.; Pavuk, M.; Päpke, O.; Ryan, J.J.; Birnbaum, L.; & Rosen, R. (2003). Polybrominated diphenyl ethers (PBDEs) in U.S. mothers' milk. *Environmental Health Perspectives*, 111(14), 1723-29. doi: 10.1289/ehp.6466.

[105] Stapleton, H.M.; Dodder, N.G.; Offenberg, J.H.; Schantz, M.M.; & Wise, S.A. (2005). Polybrominated diphenyl ethers in house dust and clothes dryer lint. *Environmental Science & Technology*, 39(4), 925-31. doi: 10.1021/es0486824.

[106] Lunder, S.; Hovander, L.; Athanassiadis, I.; & Bergman, A. (2010). Significantly higher polybrominated diphenyl ether levels in young U.S. children than in their mothers. *Environmental Science and Technology*, 44(13), 5256-62. doi: 10.1021/es1009357.

[107] Stapleton, H.M., Serum PBDEs, *supra* note 97.

[108] Jones-Otazo, H. A., Is house dust the missing exposure pathway, *supra* note 93.

products compared to the average child's or adult's exposure from upholstered furniture.[109,110,111] A recent study of 21 US mother-toddler pairs confirmed that toddlers have significantly higher concentrations of TDCPP metabolites in their urine compared to their mothers, consistent with increased hand to mouth behavior and elevated dust exposure.[112]

The highest levels of harmful flame retardants in the general population are found in young children from communities of low socioeconomic status and communities of color. For instance, a North Carolina study of 80 toddlers found PBDEs in 100% of the blood samples, and the sum of BDE-47, -99 and -100 (three of the pentaBDE congeners) was negatively associated with the father's level of education.[113] Similarly, Zota et al. (2008), using data from the NHANES, found that individuals in lower income households (<$20,000/year) had significantly higher PBDE exposures.[114] Rose et al. (2010) also found higher body burdens of nearly all measured congeners (including BDE-47, -153, and -209) in 2-5 year-old Californian children in born to mothers with

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[109] *Id.*

[110] Stapleton, H. M., Identification of flame retardants, *supra* note 64.

[111] Babich, M. A., U.S. Consumer Product Safety Commission (2006). CPSC Staff Preliminary Risk Assessment of Flame Retardant (FR) Chemicals in Upholstered Furniture Foam. Retrieved March 4, 2015, from http://www.cpsc.gov//PageFiles/106736/ufurn2.pdf.

[112] Butt, C.M.; Congleton, J.; Hoffman, K.; Fang, M.; & Stapleton, H.M. (2014). Metabolites of organophosphate flame retardants and 2-ethylhexyl tetrabromobenzoate in urine from paired mothers and toddlers. *Environmental Science & Technology*, 48(17), 10432-38. doi: 10.1021/es5025299.

[113] Stapleton, H.M., Serum PBDEs, *supra* note 97.

[114] Zota, A.R.; Rudel, R.A.; Morello-Frosch, R.A.; & Brody, J.G. (2008). Elevated house dust and serum concentrations of PBDEs in California: unintended consequences of furniture flammability standards? *Environmental Science & Technology*, 42(21), 8158-64. doi: 10.1021/es801792z.

lower education.[115] In another study of ethnically diverse 6-8 year-old girls in California, measured pentaBDE levels were higher in children with less educated care-givers.[116] This study also found that black preadolescent girls had significantly higher levels than white girls.[117] Similarly, using NHANES data, Sjödin et al. (2008) showed that, after adjusting for age, levels of BDE-47 and BDE-99 (but not BDE-100 and BDE-153) were significantly lower in white children as compared to Mexican American and black children.[118]

* * *

In sum, additive organohalogen flame retardants are present in the four categories of consumer products addressed by this petition (although no mandatory flammability standard requires this), and body burden testing demonstrates that humans are exposed to and absorb these chemicals when they migrate from household products as a result of reasonable and foreseeable use of these products. As shown below, these exposures present serious health risks due to the physical-chemical properties of organohalogen flame retardants as a class, which renders them toxic to humans.

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[115] Rose, M.; Bennett, D.H.; Bergman, Å.; Fängström, B.; Pessah, I.N.; & Hertz-Picciotto, I. (2010). PBDEs in 2-5 year-old children from California and associations with diet and indoor environment. *Environmental Science & Technology*, 44(7), 2648-53. doi: 10.1021/es903240g.

[116] Windham, G.C.; Pinney, S.M.; Sjödin, A.; Lum, R.; Jones, R.S.; Needham, L.L.; Biro, F.M.; Hiatt, R.A.; & Kushi, L.H. (2010). Body burdens of brominated flame retardants and other persistent organo-halogenated compounds and their descriptors in US girls. *Environmental Research*, 110(3), 251-57. doi: 10.1016/j.envres.2010.01.004.

[117] *Id.*

[118] Sjödin, A., Serum concentrations of polybrominated diphenyl ethers (PBDEs), *supra* note 98.

VIII. Consumer Products in the Four Petition Categories Containing *Any* Organohalogen Flame Retardant in Additive Form Are "Hazardous Substances" Within the Meaning of the FHSA

Not only do organohalogen flame retardants in additive form migrate from consumer products leading to human exposures as a result of actual and foreseeable use, but exposure to any chemical in this class also poses human health risks, as described in detail below. Accordingly, these products are "hazardous substances" within the meaning of the FHSA.

We know that the consumer products in the four categories at issue here pose human health risks if they contain any additive organohalogen flame retardant because:

a. Human exposure to all *studied* organohalogen flame retardants is associated with long-term chronic health effects, as described in the accompanying expert statements from Dr. Kim Harley, Dr. Julie Herbstman, Dr. Susan Kasper, Ruthann Rudel, and Dr. Ted Schettler.

b. Inherent physical, chemical, and biological characteristics of organohalogen chemicals and the historical evidence of regrettable substitution within this chemical class suggest that the entire class of organohalogen flame retardants have (or are vey likely to have) adverse health effects and therefore should be regulated as a class, as explained in the accompanying expert statements from Dr. David Eastmond, Dr. Terry Collins, Dr. Rolf Halden, and Dr. David Epel.

c. When all organohalogen flame retardants burn, they release toxic byproducts, such as acutely toxic soot and smoke, and dioxins and furans, which are associated with long-term chronic health effects, as explained in the accompanying expert statements from Dr. Roland Weber, and Dr. Donald Lucas.

In sum, a consumer product containing *any* organohalogen flame retardant chemical in additive form has "the capacity to produce personal injury or illness" in humans when inhaled, swallowed, or absorbed through the skin – whether the injury or illness is acute or chronic.[119] This "may cause substantial personal injury or substantial illness during or as a proximate result of any customary or reasonably foreseeable handling or use."[120] Because of these risks, any product in the four categories at issue here containing an organohalogen flame retardant chemical in additive form should be declared a "hazardous substance" and "banned hazardous substance" under the FHSA.

A. Exposure to Organohalogen Flame Retardants from Consumer Products Puts Human Health at Risk

All organohalogen flame retardants that have been studied have the capacity to cause long-term adverse health effects in humans who are exposed to them. Because PBDEs were used in consumer products for decades, large segments of the U.S. population were unwitting subjects in an experiment regarding how PBDEs affect human health. Over the last several years, scientists have studied the impacts of ongoing exposure to PBDEs and concluded that there are associations with neurotoxicity, adverse developmental and reproductive effects, and immune and endocrine disruption. The accompanying statements from Dr. Kim Harley, Dr. Susan Kasper and Dr. Julie Herbstman explain their key research findings on the impacts of PBDEs on human health.

The evidence that the newer organohalogen flame retardants are also toxic to humans is compelling, and most are also persistent and/or bioaccumulative. For example:

[119] 15 U.S.C. § 1261(g).

[120] 15 U.S.C. § 1261(f)(1)(A).

- TDCPP was recently added to California's Proposition 65 list of chemicals "known to the State to cause cancer."[121] TDCPP levels in house dust were associated with altered hormone levels in men recruited through an infertility clinic.[122] An *in vitro* study suggests that TDCPP is toxic to the nervous system and affects cell development and DNA synthesis.[123]
- TCEP was added to California's Proposition 65 list of chemicals "known to the State to cause cancer" in 1992. In addition to cancer, TCEP has also been linked to reproductive toxicity[124,125] and neurotoxicity[126,127,128] based on animal studies. The EU classifies TCEP as a "Substance of Very High Concern" based on reproductive toxicity.[129]
- One of the brominated components of Firemaster® 550, TBPH, is a structural analogue of the phthalate di(2-ethylhexyl) phthalate (DEHP), which is listed under Proposition 65 as known to the state of California to

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[121] California EPA, *Evidence on the Carcinogenicity of Tris(1,3-Dichloro-2-Propyl) Phosphate*, *supra* note 25; OEHHA, *Chemicals Known to the State to Cause Cancer or Reproductive Toxicity*, *supra* note 25.

[114] Meeker, J. D., House dust concentrations of organophosphate flame retardants, *supra* note 26.

[123] Dishaw, L.V.; Powers, C.M.; Ryde, I.T.; Roberts, S.C.; Seidler, F.J.; Slotkin, T.A.; & Stapleton, H.M. (2011). Is the PentaBDE replacement, tris (1,3-dichloro-2-propyl) phosphate (TDCPP), a developmental neurotoxicant? Studies in PC 12 cells. *Toxicology and Applied Pharmacology*, 256(3), 281-89. doi: 10.1016/j.taap.2011.01.005.

[124] European Union (2009). *European Union Risk Assessment Report: Tris(2-chloroethyl)phosphate, TCEP. CAS 115-96-8; EINECS 204-118-5. Final Approved Version.* Retrieved March 4, 2015, from http://www.baua.de/en/Chemicals-Act-biocide-procedure/Documents/RAR-068.pdf?__blob=publicationFile&v=1.

[125] Washington State Department of Health (2011). *Children's Safe Products Act Rationale for Chemicals listed under Reporting Requirements.* Retrieved March 4, 2015, from http://www.cj-elec.com/UploadPicFile/20121123141853694.pdf.

[126] European Chemicals Agency (2009). *Support Document for Identification of Tris(2-Chloroethyl)Phosphate as a Substance of Very High Concern Because of its CMR Properties.* Retrieved March 4, 2015, from http://echa.europa.eu/documents/10162/d0f5c171-5086-49c3-a6a3-3a31cb4e08eb.

[127] European Union, *European Union Risk Assessment Report. Tris(2-chloroethyl)phosphate, TCEP, supra* note 124.

[128] Minnesota Department of Health (2013). *Toxicological Summary for Tris(2-chloroethyl)phosphate.* Retrieved March 4, 2015, from http://www.health.state.mn.us/divs/eh/risk/guidance/gw/tcep.pdf.

[129] European Chemicals Agency, *Support Document for Identification of Tris(2-Chloroethyl)Phosphate as a Substance of Very High Concern, supra* note 126.

cause cancer and developmental and reproductive toxicity. DEHP's monoester metabolite is the toxicologically active species. Studies in rats showed that TBPH's monoester metabolite also had toxicological activity, affecting thyroid hormone levels in pregnant dams and potentially affecting fetal testes development.[130] This raises concern that ingested TBPH could lead to toxicological effects in people. One epidemiological study found that the amount of TBPH in house dust was positively correlated with thyroid hormone levels in men seeking treatment for infertility.[131]

Tetrabromobisphenol A (TBBPA), which is commonly used in plastic electronics enclosures, inhibited neurotransmitter uptake in rat brain synaptosomes,[132] showed teratogenic effects for frog embryos,[133] and affected thyroid hormone functioning[134] and the reproductive system in experimental animals.[135] A recent cancer bioassay found clear evidence of carcinogenicity in female rats.[136]

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[130] Springer, C.; Dere, E.; Hall, S.J.; McDonnell, E.V.; Roberts, S.C.; Butt, C.M.; Stapleton, H.M.; Watkins, D.J.; McClean, M.D.; Webster, T.F.; Schlezinger, J.J.; & Boekelheide, K. (2012). Rodent thyroid, liver, and fetal testis toxicity of the monoester metabolite of bis-(2-ethylhexyl) tetrabromophthalate (TBPH), a novel brominated flame retardant present in indoor dust. *Environmental Health Perspectives*, 120(12), 1711-19. doi: 10.1289/ehp.1204932.

[131] Johnson, P.I.; Stapleton, H.M.; Mukherjee, B.; Hauser, R.; & Meeker, J.D. (2013). Associations between brominated flame retardants in house dust and hormone levels in men. *Science of the Total Environment*, 445-446, 177-84. doi: 10.1016/j.scitotenv.2012.12.017.

[132] Mariussen, E., & Fonnum, F. (2003). The effect of brominated flame retardants on neurotransmitter uptake into rat brain synaptosomes and vesicles. *Neurochemistry International*, 43(4-5), 533-42. doi: 10.1016/S0197-0186(03)00044-5.

[133] Shi, H.; Qian, L.; Guo, S.; Zhang, X.; Liu, J.; & Cao, Q. (2010). Teratogenic effects of tetrabromobisphenol A on Xenopus tropicalis embryos. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, 152(1), 62-68. doi: 10.1016/j.cbpc.2010.02.013.

[134] Van der Ven, L.T.; Van de Kuil, T.; Verhoef, A.; Verwer, C.M.; Lilienthal, H.; Leonards, P.E.; Schauer, U.M.; Cantón, R.F.; Litens, S.; De Jong, F.H.; Visser, T.J.; Dekant, W.; Stern, N.; Håkansson, H.; Slob, W.; Van den Berg, M.; Vos, J.G.; & Piersma, A.H. (2008). Endocrine effects of tetrabromobisphenol-A (TBBPA) in Wistar rats as tested in a one-generation reproduction study and a subacute toxicity study. *Toxicology*, 245(1-2), 76-89. doi: 10.1016/j.tox.2007.12.009.

[135] Zatecka, E.; Ded, L.; Elzeinova, F.; Kubatova, A.; Margaryan, H.; Dostalova, P.; & Peknicova, J. (2013). Effect of tetrabrombisphenol A on induction of apoptosis in the testes and changes in expression of selected testicular genes in CD1 mice. *Reproductive Toxicology*, 35, 32-39. doi: 10.1016/j.reprotox.2012.05.095.

[136] Dunnick, J.K., et al., National Toxicology Program ("NTP"), National Institutes of Health, Public Health Service, US Department of Health and Human Services (2013). *NTP Technical Report on*

- Hexabromocyclododecane (HBCD) caused reproductive effects in experimental animals,[137] interfered with thyroid hormone homeostasis,[138] and inhibited neurotransmitter uptake in rat brain synaptosomes.[139] Neonatal exposure to HBCD was found to significantly affect spontaneous behavior, learning and memory in mice.[140,141]
- Tetrabromoethylcyclohexane (TBECH), a flame retardant used in electrical cable coatings and high-impact plastic parts of appliances, is a mutagen[142] and a strong androgen agonist, binding to and activating the human androgen receptor in human liver cells.[143]
- 2,2-bis (bromomethyl) 1,3-propanediol (DBNPG) was found by the NTP to show clear evidence of carcinogenicity in rats and mice of both sexes in two-year cancer bioassays. It is listed as causing cancer under Proposition 65 and classified by the International Agency for Research on Cancer (IARC) as 2B carcinogen (i.e., possibly carcinogenic to humans). A

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the Toxicology Studies of Tetrabromobisphenol A (CAS NO. 79-94-7) in F344/NTac Rats and B6C3F1/N Mice and Toxicology and Carcinogenesis Studies of Tetrabromobisphenol A in Wistar Han [Crl:WI(Han)] Rats and B6C3F1/N Mice (Gavage Studies) - NTP TR 587. Retrieved March 5, 2015, from http://ntp.niehs.nih.gov/ntp/about_ntp/trpanel/2013/october/draft_tr-587.pdf.

137 Ema, M.; Fujii, S.; Hirata-Koizumi, M.; & Matsumoto, M. (2008). Two-generation reproductive toxicity study of the flame retardant hexabromocyclododecane in rats. *Reproductive Toxicology*, 25(3), 335-51. doi: 10.1016/j.reprotox.2007.12.004.

138 Darnerud, P.O. (2003). Toxic effects of brominated flame retardants in man and in wildlife. *Environment International*, 29(6), 841-53. doi: 10.1016/S0160-4120(03)00107-7.

139 Mariussen, E., The effect of brominated flame retardants, *supra* note 132.

140 Eriksson, P.; Viberg, H.; Fischer, C.; Wallin, M.; & Fredriksson, A. (2002). A comparison on the developmental neurotoxic effects of hexabromocyclododecane, 2,2',4,4',5,5'-hexabromodiphenylether (PBDE 153) and 2,2',4,4',5,5',-hexachlorobiphenylether (PCB 153). *Organohalogen Compounds*, 57, 389-90. See http://www.dioxin20xx.org/pdfs/2002/02-346.pdf.

141 Eriksson, P.; Fischer, C.; Wallin, M.; Jakobsson, E.; & Fredriksson, A. (2006). Impaired behaviour, learning and memory, in adult mice neonatally exposed to hexabromocyclododecane (HBCDD). *Environmental Toxicology and Pharmacology*, 21, 317-22. doi: 10.1016/j.etap.2005.10.001.

142 McGregor, D.B.; Brown, A.G.; Howgate, S.; McBride, D.; Riach, C.; Caspary, W.J; & Carver, J.H. (1991). Responses of the L5178Y mouse Lymphoma cell forward mutation assay. V: 27 coded chemicals. *Environmental and Molecular Mutagenesis*, 17(3), 196-219. doi: 10.1002/em.2850170309.

143 Larsson, A.; Eriksson, L.A.; Andersson, P.L.; Ivarson, P.; & Olsson, P.E. (2006). Identification of the brominated flame retardant 1,2-dibromo-4-(1,2-dibromoethyl)cyclohexane as an androgen agonist. *Journal of Medicinal Chemistry*, 49, 7366-72. doi: 10.1021/jm060713d.

recent review identified DBNPG as a chemical likely to lead to premature ovarian failure in descendants following prenatal exposure based on studies in mice.[144]

1,2-bis (2,4,6,-tribromophenoxy) ethane (BTBPE) was found in house dust, with levels positively associated with thyroid hormone levels in men recruited through an infertility clinic.[145] Additionally, one of its identified metabolites, 2,4,6-tribromophenol, is a thyroid disruptor.[146,147]

Tetrabromobisphenol A-bis (2,3-dibromopropylether) (TBBPA-BDBPE) inhibited sulfation of estradiol *in vitro* studies,[148] suggesting that it could also affect normal endocrine activity.

The Statement from Ruthann Rudel and accompanying bibliography and table identify additional studies on health effects of organohalogen flame retardants, including non-PBDE chemicals.

B. Organohalogen Flame Retardants Are Inherently Hazardous Substances and Therefore Should Be Regulated as a Class

Due to their inherent physical, chemical and biological structures and properties, organohalogen flame retardants have the capacity, as a class, to "produce personal injury or illness," and they have the potential, as a class, to cause "substantial personal

[144] Béranger, R.; Hoffmann, P.; Christin-Maitre, S.; & Bonneterre, V. (2012). Occupational exposures to chemicals as a possible etiology in premature ovarian failure: a critical analysis of the literature. *Reproductive Toxicology*, 33(3), 269-79. doi: 10.1016/j.reprotox.2012.01.002.

[145] Johnson, P.I., Associations between brominated flame, *supra* note 131.

[146] Hamers, T.; Kamstra, J.H.; Sonneveld, E.; Murk, A.J.; Kester, M.H.; Andersson, P.L.; Legler, J.; & Brouwer, A. (2006). *In vitro* profiling of the endocrine-disrupting potency of brominated flame retardants. *Toxicological Sciences*, 92(1), 157-73. doi: 10.1093/toxsci/kfj187.

[147] Suzuki, G.; Takigami, H.; Watanabe, M.; Takahashi, S.; Nose, K.; Asari, M.; & Sakai, S. (2008). Identification of brominated and chlorinated phenols as potential thyroid-disrupting compounds in indoor dusts. *Environmental Science & Technology*, 42(5), 1794-800. doi: 10.1021/es7021895.

[148] Hamers, T., In vitro profiling, *supra* note 146.

injury or substantial illness."[149] Thus, as a class, organohalogen flame retardants should be considered and designated as "hazardous substances."

In order to assess the hazards of the class of organohalogen flame retardants, a research group at the University of California, Riverside performed a hazard screen of 83 non-polymeric organohalogen flame retardants, which included all such chemicals that this research group could identify as in use or available for potential use in consumer products in 2012.[150] The hazard screen, which was performed using the Washington State Department of Ecology's Quick Chemical Assessment Tool (QCAT®) methodology,[151] is described in detail in the accompanying statement from Dr. David Eastmond.

The 83 chemicals were screened for nine priority hazard categories (acute mammalian toxicity, carcinogenicity, reproductive toxicity, developmental toxicity, mutagenicity/genetic toxicity, endocrine disruption, acute aquatic toxicity, persistence, and bioaccumulation) and then each chemical was assigned a grade (A, B, C, D, or F). Some hazard data were available for about a third of the organohalogen flame retardants screened; for the others, the researchers employed Structure Activity Relationship (SAR) models. The initial grade results, which were based solely on

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[149] 15 U.S.C. § 1261(f)(1)(A) (defining "hazardous substance"); 15 U.S.C. § 1261(g) (defining "toxic").

[150] It is important to note that this study used all organohalogen flame retardants that could be identified as listed in use or potentially in use; the 83 chemicals were not selected on the basis of suspected toxicity.

[151] Eastmond, D.A.; Bhat, V.S.; & Capsel K. (2012). *A Screening Level Assessment of the Health and Environmental Hazards of Organohalogen Flame Retardants*. Collegium Ramazzini, Capri, Italy.

available data or models and did not include "penalties" for data gaps (missing data), were:

- F for 48 organohalogen flame retardants (58%), meaning that the chemicals are toxic and should not be used;
- D for 26 organohalogen flame retardants (31%), meaning that the chemicals are of high concern and should be avoided; and
- C for 9 organohalogen flame retardants (11%), meaning that the chemicals raise moderate concern and safer alternatives need to be found.

None of the chemicals studied received initial grades higher than C. To get the final grade, under the QCAT Hazard Assessment Methodology, penalties are assessed for excessive data gaps. In the case of the 83 organohalogen flame retardants, 78 chemicals (94%) received a final grade of F (due to toxicity and/or excessive data gaps), and the remaining five chemicals (6%) received a final grade of D (high concern). In other words, when the data gaps were taken into account, all of the organohalogen flame retardants screened were either of high concern or toxic. Based on these results, Dr. Eastmond concluded that all the organohalogen flame retardants with adequate available data "have the potential to pose significant hazards for human or environmental health."

This conclusion is consistent with determinations made by California Environmental Protection Agency ("CalEPA") as part of the California Environmental Contaminant Biomonitoring Program. Under this program, CalEPA designates chemicals for future biomonitoring studies. "Designated chemicals" are "chemicals that are known to, or strongly suspected of, adversely impacting human health or development, based upon scientific, peer-reviewed animal, human, or in vitro studies."[152] Notably, all members of the chemical group "brominated and chlorinated organic compounds used as flame retardants" – in other words, organohalogen flame retardants – are "designated chemicals," meaning they all are known to, or strongly suspected of, adversely impacting human health or development, based upon scientific, peer-reviewed animal, human, or in vitro studies."[153]

This conclusion is further supported by the accompanying statements of Dr. Epel, Dr. Collins, and Dr. Halden. Dr. Epel presents strong empirical evidence that their physical, chemical, and biological properties render the organohalogen flame retardants with low water solubility inherently toxic. They are able to pass into cells easily without being recognized by efflux transporters (the primary line of defense against toxic substances in the cell membranes of all organisms) and, once inside a cell, they are difficult to metabolize, leading to accumulation and potential adverse health effects. Furthermore, preliminary evidence suggests they can inhibit a cell's defense system, and thus exacerbate the harmful effects of other chemicals. Because of their novelty to mammalian cells, even the more water-soluble organohalogen flame retardants may also bypass the cell's defenses. Indeed, there are no naturally occurring chemicals in

[152] Cal. Health & Safety Code § 105440(b)(6).

[153] See Biomonitoring California (2014). Designated Chemicals, October 2014. Retrieved March 3, 2015, from http://biomonitoring.ca.gov/sites/default/files/downloads/DesignatedChemicalList_October2014.pdf.

mammals that contain bromine or chlorine bonded to carbon, which is found in all organohalogen flame retardants.

Dr. Collins' statement explains how organohalogen flame retardants can modify a cell's DNA or disrupt its function, which can lead to cancer and/or epigenetic effects. In addition, some are known to have the potential to disrupt hormone action, which can cause adverse human health effects, even at very low levels of exposure.

Dr. Rolf Halden's statement further describes, the evidence that all organohalogen flame retardants have the potential to cause significant adverse health effects and should be regulated as a class.

C. Organohalogen Flame Retardants Also Warrant Regulation as a Class Because Hazardous Combustion Products from Products Containing these Chemicals Can Result in Significant Short- and Long-Term Health Impacts

The presence of organohalogen flame retardants also poses risks to consumers if the product in which they are used burns. Flame retardants can delay ignition, but do not prevent it. Products containing flame retardants will burn after seconds to minutes when exposed to a heat source. As explained in the accompanying statement from Dr. Don Lucas, when products containing organohalogen flame retardants burn, the combustion produces poisonous gases such as hydrochloric acid, hydrobromic acid, and phosgene, along with increased amounts of carbon monoxide and hydrogen cyanide relative to products that do not contain these chemicals. Inhalation of such toxic gases and carbon monoxide is the main cause for fire deaths and injuries during fires.[154] The presence of these flame retardants in products that burn can also increase the amount of smoke and soot, which hinders escape from fire.[155] Therefore, the addition of halogenated flame retardants to furniture and other products can actually result in an increased likelihood of injury or death during a home fire due to increased levels of carbon monoxide, soot and other toxic combustion products. Not only does this endanger individuals inside the burning home, it increases risks for first responders.

Furthermore, when products containing organohalogen flame retardants burn, brominated and chlorinated dioxins and furans can be formed.[156] Dioxins and furans are known carcinogens,[157] immune suppressors, and endocrine disruptors,[158] and chlorinated dioxins and furans are carcinogenic and listed as unintentional persistent organic pollutants under the Stockholm Convention.[159] This is discussed in more detail in Dr. Roland Weber's accompanying statement.

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[154] Hall Jr., J.R., National Fire Protection Association (2011). *Fatal Effects of Fire*. Retrieved March 3, 2015 from http://www.nfpa.org/research/reports-and-statistics/demographics-and-victim-patterns/fatal-effects-of-fire.

[155] *Id.*

[156] Ebert, J. & Bahadir, M. (2003). Formation of PBDD/F from flame-retarded plastic materials under thermal stress. *Environment International*, 29(6), 711-16. doi: 10.1016/S0160-4120(03)00117-X.

[157] IARC (2015). *Agents Classified by the IARC Monographs, Volumes 1–112*. Retrieved March 4, 2015, from http://monographs.iarc.fr/ENG/Classification/ClassificationsGroupOrder.pdf.

[158] Pohl, H.; Llados, F.; Ingerman, L.; Cunningham, P.; Raymer, J.; Wall, C.; & Gasiewicz, T. (1998). Toxicological profile for chlorinated dibenzo-p-dioxins. Retrieved March 3, 2015, from http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=366&tid=63.

[159] United Nations Environment Programme. The 12 initial POPs under the Stockholm Convention. Retrieved March 5, 2015, from http://chm.pops.int/TheConvention/ThePOPs/The12InitialPOPs/tabid/296/Default.aspx.

Firefighters, who are routinely exposed on the job to the byproducts of burning consumer products, have disproportionately high levels of four cancers associated with dioxin exposure – testicular cancer, melanoma, brain cancer, and esophageal cancer.[160,161] The International Association of Fire Fighters (IAFF) recognizes the likelihood of an association between these high cancer rates and the presence of flame retardant chemicals in household products and resolves to "work to ensure that the use of carcinogenic flame retardants and other toxic chemicals are eliminated and safer alternatives or methods are pursued . . . ."[162] The impact of flame retardants in consumer products on firefighters' health is reviewed in the accompanying statement from Sharyle Patton.

The fact that the smoke from flame-retardant-treated products is more toxic than the smoke from un-treated products is a factor the CPSC must consider when it evaluates the toxicity of products containing organohalogen flame retardants.

Moreover, the concern about formation of furans and dioxins from the breakdown of organohalogen flame retardants may not be limited to firefighters. At least one study has found that the presence of additive brominated flame retardants

[160] LeMasters, G.K.; Genaidy, A.M.; Succop, P.; Deddens, J.; Sobeih, T.; Barriera-Viruet, H.; Dunning, K.; & Lockey, J. (2006). Cancer risk among firefighters: a review and meta-analysis of 32 studies. *Journal of Occupational and Environmental Medicine*, 48(11), 1189-202. doi: 10.1097/01.jom.0000246229.68697.90.

[161] Bates, M.N. (2007). Registry-based case-control study of cancer in California firefighters. *American Journal of Industrial Medicine*, 50(5), 339-44. doi: 10.1002/ajim.20446.

[162] IAFF, Resolution No. 34, *supra* note 12.

such as decaBDE in plastic electronics casings can lead to the formation of brominated furans simply from exposure to sunlight during normal use.[163]

D. Organohalogen Flame Retardants in the Four Product Categories at Issue Here Need Not Be Replaced With Other Chemical Alternatives

The fact that organohalogen flame retardants are the focus of this Petition does not mean that Petitioners endorse their replacement with halogen-free organophosphate flame retardants. Non-halogenated organophosphate flame retardants are also semi-volatile and, when used in additive form, migrate out of consumer products. They have already been detected in house dust, at levels often higher than those of PBDEs,[164,165] as well as in sediment, sewage sludge, and wildlife.[166,167] Several non-halogenated organophosphate flame retardants have also been detected on hand wipes rubbed on children's skin,[168] in human blood,[169] in the

[163] Kajiwara, N.; Noma, Y.; & Takigami, H. (2008). Photolysis studies of technical decabromodiphenyl ether (DecaBDE) and ethane (DeBDethane) in plastics under natural sunlight. *Environmental Science and Technology*, 42 (12), 4404-09. doi: 10.1021/es800060j.

[164] Van der Veen, I., & de Boer, J. (2012). Phosphorus flame retardants: Properties, production, environmental occurrence, toxicity and analysis. *Chemosphere*, 88(10), 1119-53. doi: 10.1016/j.chemosphere.2012.03.067.

[165] Stapleton, H.M., Detection of organophosphate flame retardants, *supra* note 89.

[166] Van der Veen, I., Phosphorus flame retardants, *supra* note 164.

[167] Sundkvist, A.M.; Olofsson, U.; & Haglund, P. (2010). Organophosphorus flame retardants and plasticizers in marine and fresh water biota and in human milk. *Journal of Environmental Monitoring*, 12(4), 943-51. doi: 10.1039/b921910b.

[168] Stapleton, H.M.; Misenheimer, J.; Hoffman, K.; & Webster, T.F. (2014). Flame retardant associations between children's handwipes and house dust. *Chemosphere*, 116, 54-60. doi: 10.1016/j.chemosphere.2013.12.100.

[169] Jonsson, O.B.; Dyremark, E.; & Nilsson, U.L. (2001). Development of a microporous membrane liquid-liquid extractor for organophosphate esters in human blood plasma: identification of triphenyl phosphate and octyl diphenyl phosphate in donor plasma. *Journal of*

urine of pregnant women,[170] and in breast milk.[171] Blood levels in children tend to be higher than in their mothers who would have been in many of the same places as their children.[172]

Growing evidence suggests potential health concerns from exposures to non-halogenated organophosphate flame retardants. For instance, the non-halogenated organophosphate components of Firemaster® 550 affect development and cause heart defects in zebrafish.[173] Higher dust levels of the Firemaster® 550 component triphenyl phosphate (TPhP) were associated with hormone changes and decreased sperm counts in men.[174] A recent study also found evidence that TPhP may act as an obesogen,[175] and another in vitro study found that it has the potential to disrupt metabolism and act as a cytotoxicant.[176] In a recent study on reporter gene assays, TPhP and tricrecyl phosphate

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Chromatography B: Biomedical Sciences and Applications, 755(1-2): 157-64. doi: 10.1016/S0378-4347(01)00055-X.

[170] Hoffman, K.; Daniels, J.L.; & Stapleton, H.M. (2014). Urinary metabolites of organophosphate flame retardants and their variability in pregnant women. *Environment International*, 63, 169-72. doi: 10.1016/j.envint.2013.11.013.

[171] Sundkvist, A.M., Organophosphorus flame retardants and plasticizers, *supra* note 167.

[172] Butt, C.M., Metabolites of organophosphate flame retardants, *supra* note 112.

[173] McGee, S.P.; Konstantinov, A.; Stapleton, H.M.; & Volz, D.C. (2013). Aryl phosphate esters within a major PentaBDE replacement product induce cardiotoxicity in developing zebrafish embryos: potential role of the aryl hydrocarbon receptor. *Toxicological Sciences*, 133(1), 144-56. doi: 10.1093/toxsci/kft020.

[174] Meeker, J.D., House dust concentrations of organophosphate flame retardants, *supra* note 26.

[175] Pillai, H.K.; Fang, M.; Beglov, D.; Kozakov, D.; Vajda, S.; Stapleton, H.M.; Webster, T.F.; & Schlezinger, J.J. (2014). Ligand binding and activation of PPARγ by Firemaster® 550: Effects on Adipogenesis and Osteogenesis *in Vitro*. *Environmental Health Perspectives*, 122(11), 1225-32. doi: 10.1289/ehp.1408111.

[176] Belcher, S.M.; Cookman, C.J.; Patisaul, H.B.; & Stapleton, H.M. (2014). In vitro assessment of human nuclear hormone receptor activity and cytotoxicity of the flame retardant mixture FM

(TCP) showed estrogen receptor agonistic activity; tributyl phosphate (TBP), TPhP and TCP showed androgen receptor antagonistic activity; and TBP, tris (2-ethylhexyl) phosphate (TEHP), tris (2-butoxyethyl) phosphate (TBEP), TPhP and TCP displayed pregnane X receptor agonistic activity.[177] This indicates that some organophosphate flame retardants are potential endocrine disruptors.

Consumer products containing organohalogen flame retardants are the focus of this petition because these chemicals are more pervasive and well-studied. Non-halogenated organophosphate flame retardants have not been as extensively studied yet, however more research is underway. Aromatic phosphate flame retardants were nominated by the CPSC for investigation by the NTP due to their structural similarities to known toxicants and the high risk of exposure to children.[178] Non-halogenated aromatic phosphates are also on the Designated Chemicals list for the California Environmental Contaminant Biomonitoring Program.[179]

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550 and its triarylphosphate and brominated components. *Toxicology Letters*, 228(2), 93-102. doi: 10.1016/j.toxlet.2014.04.017.

[177] Kojima, H.; Takeuchi, S.; Itoh, T.; Iida, M.; Kobayashi, S.; & Yoshida, T. (2013). In vitro endocrine disruption potential of organophosphate flame retardants via human nuclear receptors. *Toxicology*, 314(1), 76-83. doi: 10.1016/j.tox.2013.09.004.

[178] CPSC Staff (2005). Nomination of FR chemicals for NTP testing. Retrieved March 5, 2015 from http://ntp.niehs.nih.gov/ntp/htdocs/chem_background/exsumpdf/cpscfrsnomination_supp_062_508.pdf.

[179] *See* Biomonitoring California (2014). Designated Chemicals, June 2014. Retrieved March 3, 2015 from http://biomonitoring.ca.gov/sites/default/files/downloads/DesignatedChemicalsList_June2014.pdf. California Health and Safety Code section 105440 defines "designated chemicals" as "those chemicals that are known to, or strongly suspected of, adversely impacting human health or development, based upon scientific, peer-reviewed animal, human, or in vitro studies . . . ." Cal. Health & Safety Code § 105440(b)(6).

Accordingly, we ask CPSC not to adopt any regulation that would have the effect of increasing the use of non-halogenated phosphate-based flame retardants in consumer products.

IX. We Urge CPSC to Fill the Regulatory Gap That Puts Consumers at Risk

Despite the widespread and growing recognition that use of organohalogen flame retardants in several categories of consumer products poses genuine – and avoidable – health risks, no federal regulations protect consumers from these toxic products.

Although several states prohibit the manufacture of products containing PBDEs[180] and the manufacture of PBDEs in the U.S. has been "voluntarily" phased out, no federal law or regulation prohibits the *use* of PBDEs in consumer products or prohibits the sale of consumer products containing PBDEs.[181] Moreover, PBDEs are still being produced in other countries such as China, yet no federal law or regulation prohibits the import of consumer products containing PBDEs that are manufactured outside of the United States.[182] Without action by the CPSC, imported chairs, sofas and

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[180] *See* note 21, *supra*.

[181] PentaBDE and octaBDE are listed as Persistent Organic Pollutants (POPs) in Annex A of the Stockholm Convention, requiring elimination of their production and use by parties to the Convention. United Nations Environment Programme. *Convention on Persistent Organic Pollutants (Stockholm Convention), as amended in 2009*. Retrieved March 9, 2015, from http://chm.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx. The U.S. is not a party to the Convention.

[182] EPA proposed a Significant New Use Rule under the Toxic Substances Control Act for certain PBDEs, which would require notice to EPA before articles containing PBDEs could be imported.

juvenile products containing PBDEs can still be sold in this country, despite the clearly documented health risks.

Legislatures and regulatory bodies around the globe have started to restrict the use of PBDE-replacement organohalogen flame retardants in consumer products. For instance, TDCPP and TCEP are banned in children's products and/or furniture in Maryland, New York and Vermont,[183] and regulated under California's Proposition 65 as known carcinogens.[184] TCEP is also included on Maine's and Minnesota's lists of "Chemicals of High Concern,"[185,186] and on Washington's list of "Chemicals of High Concern to Children."[187] Three flame retardant chemicals —TCEP, TCPP, and TDCPP — are banned in the European Union (EU) above trace amounts in toys intended for use by children younger than 3 years old due to the risk of adverse health effects from these

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Certain Polybrominated Diphenylethers; Significant New Use Rule and Test Rule, 77 Fed. Reg. 19,862 (proposed April 2, 2012). It is unclear if the Proposed Rule will be finalized.

[183] *E.g.*, Md. Code Ann., Health-Gen. § 24-306 (banning TCEP and TDCPP in child care products); N.Y. Envtl. Conserv. Law § 37-0701, et seq. (banning TCEP and TDCPP in child care products); Vt. Stat. Ann. tit. 9, § 2974 (banning TCEP and TDCPP in residential upholstered furniture and children's products); *see generally* Safer States Bill Tracker, available at: http://www.saferstates.com/bill-tracker/.

[184] OEHHA, *Chemicals Known to the State to Cause Cancer or Reproductive Toxicity*, *supra* note 25.

[185] Maine Department of Environmental Protection. *Chemicals of High Concern*. Retrieved March 3, 2015, from http://www.maine.gov/dep/safechem/highconcern/.

[186] Minnesota Department of Health (2013). *Toxic Free Kids Act: Chemicals of High Concern*. Retrieved March 4, 2015, from http://www.health.state.mn.us/divs/eh/hazardous/topics/toxfreekids/highconcern.html.

[187] Department of Ecology, State of Washington. *Children's Safe Products Act: The Reporting List of Chemicals of High Concern to Children (CHCC)*. Retrieved March 4, 2015, from http://www.ecy.wa.gov/programs/swfa/cspa/chcc.html.

chemicals.[188] However, no federal law or regulation prevents the sale of consumer products containing any organohalogen flame retardant or prevents the use of any of these chemicals in any consumer products sold nationally, and there is overwhelming evidence that their use is pervasive.[189]

To protect human health from the prenatal stage forward, we urge CPSC to regulate the four product categories described in this petition when they contain *any* organohalogen flame retardant – just as it broadly regulates small parts in toys and, as Commissioner Moore suggested, it should regulate all chemical drain openers.

X. Labeling Will Not Protect Human Health

The FHSA empowers the CPSC to ban "hazardous substances" in products if "notwithstanding [any] cautionary labeling . . . the degree or nature of the hazard involved in the presence or use of such substance in households is such that the objective of the protection of the public health and safety can be adequately served only by keeping such substance, when ... intended or packaged [for use in the household], out of the channels of interstate commerce." In this circumstance, the

[188] European Commission Directive D029354/03, amending Appendix C of Annex II to Directive 2009/48/EC of the European Parliament and of the Council on the safety of toys, as regards TCEP, TCPP and TDCP. Retrieved March 4, 2015, from http://ec.europa.eu/transparency/regcomitology/index.cfm?do=Search.getPDF&zEhJKHDiw8RP6FEoZ1GKtqDbby3gYP7DoFPCzj0pZY65SVAw47eF02NzJJLXFBE77kGvLzo2Pu5uyjPyPE0HGhn1Yyu8a5hceFqN5ixnqYI=.

[189] *See* Section VI, *infra*.

CPSC may declare the substance to be a "banned hazardous substance."[190] Children's products containing "hazardous substances" are automatically "banned hazardous substances," irrespective of labeling.[191]

The consumer products at issue in this Petition meet the definition of "banned hazardous substances" when they contain any chemical in the organohalogen flame retardant class because labeling is not an adequate means of protecting public health. The knowledge that toxic chemicals migrate out of furniture, juvenile products, mattresses, mattress pads, and the casings of electronics and attach to house dust does not enable consumers to take protective action. The CPSC should not assume that consumers can vacuum and wipe up all of the dust contaminated with organohalogen flame retardants that is present in the average U.S. household. The only way to protect consumers from the genuine risks posed by these hazardous substances is to declare all products in the four specified categories to be "banned hazardous substances" if they contain any chemical in the organohalogen flame retardant class.

[190] 15 U.S.C. § 1261(q)(1)(B). The CPSC has promulgated regulations finding a variety of chemical substances to be "banned hazardous substances" under the FHSA, including: mixtures that are intended for application to interior masonry walls as a water repellant treatment and that are "extremely flammable"; carbon tetrachloride and mixtures containing it; liquid drain cleaners containing 10 percent or more by weight of sodium and/or potassium hydroxide; products containing soluble cyanide salts; and paint containing lead over a certain level. 16 C.F.R. § 1500.17.

[191] 15 U.S.C. § 1261(q)(1)(A).

XI. Conclusion

Given the evidence that organohalogen flame retardants migrate from consumer products by virtue of their semi-volatile state and are absorbed by humans, and that these foreseeable exposures – especially during the earliest stages of human life – are associated with serious adverse health impacts, we petition the CPSC to regulate the four consumer product categories discussed above if they contain any chemical in the additive organohalogen flame retardant class.

Dated: June 30, 2015

Respectfully submitted,

Eve C. Gartner, Earthjustice
Rachel Weintraub, Consumer Federation of America

On behalf of

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
Worksafe

FLAME RETARDANTS REFERENCED IN THIS PETITION

Chemical	*Abbreviation*
1,2-bis (2,4,6,-tribromphenoxy) ethane	BTBPE
2,2',4,4',5,5'-hexabromobiphenyl (Firemaster® BP-6)	BB 153
2,2-bis (bromomethyl) 1,3-propanediol	DBNPG
2,3,4,5-tetrabromobenzoic acid	TBBA
2-ethylhexyl 2,3,4,5-tetrabromobenzoate	TBB
Bis (2-ethylhexyl) 3,4,5,6-tetrabromophthalate	TBPH
Decabromodiphenyl ethane	DBDPE
Decabromodiphenyl ether	decaBDE
Di(2-ethylhexyl) phthalate	DEHP
Hexabromocyclododecane	HBCD
Octabromodiphenyl ether	octaBDE
Pentabromodiphenyl ether	pentaBDE
Polybrominated diphenyl ether	PBDE
Tetrabromobisphenol A	TBBPA
Tetrabromobisphenol A-bis (2,3-dibromopropylether)	TBBPA-BDBPE
Tetrabromoethylcyclohexane	TBECH
Tributyl phosphate	TBP
Tricrecyl phosphate	TCP
Triphenyl phosphate	TPhP
Tris (1-chloro-2propyl) phosphate	TCPP
Tris (1,3-dichloro-2-propyl) phosphate ("chlorinated tris")	TDCPP
Tris (2-butoxyethyl) phosphate	TBEP
Tris (2-chloroethyl) phosphate	TCEP
Tris (2-ethylhexyl) phosphate	TEHP
Tris (2,3-dibromopropyl) phosphate	TDBPP

TAB B: Directorate for Health Sciences Response to the Petition

T
A
B

B

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MARYLAND 20814

Memorandum

Date: May 18, 2017

TO : Alice M. Thaler, D.V.M., Associate Executive Director,
Directorate for Health Sciences

THROUGH: Michael A. Babich, Ph.D., Division Director,
Directorate for Health Sciences
Division of Toxicology and Risk Assessment

FROM : Melanie B. Biggs, Ph.D., Toxicologist
Directorate for Health Sciences,
Division of Toxicology and Risk Assessment

SUBJECT : Health Sciences response to Petition HP-15-1, requesting rulemaking on products containing organohalogen flame retardants[21]

1. INTRODUCTION

On July 1, 2015, the American Academy of Pediatrics, American Medical Women's Association, Consumer Federation of America, Consumers Union, Earthjustice, 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 America, National Hispanic Medical Association, and Worksafe (petitioners) petitioned the Commission to initiate rulemaking on four categories of consumer products containing organohalogen flame retardants (OFRs). The petitioners asked the U.S. Consumer Product Safety Commission (CPSC or Commission) to promulgate a rule under the Federal Hazardous Substances Act (FHSA), declaring that children's products, upholstered furniture, mattresses, and casings surrounding electronics are banned hazardous substances if they contain any non-polymeric, additive OFR.

As stated by two of the petitioners, the precise number of chemicals in this OFR class is unknown.[22] However, one commenter referenced a report in the Petition, which identified 83

[21] This report was prepared by the CPSC staff; it has not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.
[22] CPSC-2015-0022-0135.

non-polymeric OFRs to be in use or available for use in consumer products.[23] Another report lists more than 70 OFRs (IPCS, 1997); however, staff notes that new OFRs currently are being developed. Information on the uses of OFRs is largely unknown because manufacturers of consumer products are not required to report the inclusion of these substances to CPSC before manufacturing their products. In addition, toxicity data are not available for all OFRs known to be in use (NTP, 2014; Stapleton et al., 2012b; Van Bergen et al., 2015). The purpose of this memorandum is to review and assess the available information related to the toxicity, human exposure, and health risks of OFRs currently in use. Due to the unknown number of OFRs currently available for use in consumer products, CPSC staff assessed only those OFRs for which information is available, as referenced in the Petition, or known to exist by the CPSC staff or other organizations.

2. BACKGROUND

Flame retardants (FRs) are chemicals added to natural and synthetic materials to improve their resistance to ignition, reduce flame spread, or burning rate after ignition occurs. As such, FRs provide additional time to escape from fires (IPCS, 1997; Van Bergen et al., 2015; WHO, 1998). FRs are used in many consumer products, such as building materials, furniture, plastics, electronics equipment, and textiles. FRs are primarily added to consumer products at levels greater than 10 grams per kilogram (1% or 10,000 ppm). FRs present in consumer products at lesser amounts, (*e.g.*, 0.1% or 1,000 ppm) are likely present due to contamination and not intentional addition (Dishaw et al., 2014b; EPA, 2015; Van Bergen et al., 2015).

There are two general classes of FR chemical applications: additive and reactive. Additive FRs typically are applied to foams, textiles, and polymers before, during, or after production, and before manufacturing the end product. Additive FRs are not chemically bound to the substrate and may be released from the product, thereby leading to potential human and environmental exposures (EPA, 2005; EPA, 2015; IPCS, 1997; Van Bergen et al., 2015). Reactive FRs react chemically with the substrate material, or they may be incorporated directly into a polymer. This increases the durability of the FR treatment and reduces the potential for human exposure (EPA, 2005; IPCS, 1997; Van Bergen et al., 2015).

FR chemicals contain inorganic or organic compounds and may be applied in many different ways to products. Inorganic FRs frequently contain aluminum, antimony, magnesium, boron, or nitrogen, and organic FRs typically contain phosphorus, nitrogen, chlorine, or bromine atoms (IPCS, 1997; Van Bergen et al., 2015). The Petition addresses organic FRs containing halogens (organohalogen), such as bromine or chlorine.

OFRs reduce the fire hazard of materials by interfering with the combustion process. Combustion is propagated by a series of chemical reactions, where oxygen combines with chemicals in the burning product (EPA, 2015). OFRs contain chlorine or bromine that is covalently bound to a carbon backbone. These FRs act in the gas phase by releasing chlorine

[23] See Appendix C of the Petition; Accompanying Statement of David Eastmond, Ph.D., Professor and Chair of the Department of Cell Biology and Neuroscience, and Research Toxicologist at UC Riverside.

and/or bromine radicals and absorbing energy. These released radicals help to interrupt the reactions that propagate fire, thus slowing combustion (Cooper et al., 2016; Dishaw et al., 2014b; EPA, 2015). OFRs may be used in the four product categories covered by the Petition to mitigate combustion of materials to meet flammability standards. However, staff does not know the extent of their use, and toxicity, exposure, and risk of these chemicals to consumers are often unknown

3. ADDRESSING CHEMICAL HAZARDS UNDER THE FEDERAL HAZARDOUS SUBSTANCES ACT (FHSA)

The FHSA requires cautionary labeling for hazardous substances intended or packaged in a form suitable for use in the household or by children. Under the FHSA, to ban a substance, the Commission must determine that the hazard posed by the presence or use of the substance in the product is such that the labeling required by the FHSA would not protect the public health and safety. A toy or other article intended for use by children that is, bears, or contains a hazardous substance that a child can access is a "banned hazardous substance" under the FHSA, regardless of labeling. 15 U.S.C. § 1261(q)(1). To be considered a "hazardous substance" under the FHSA, a substance or product must satisfy a two-part definition. First, it must be "toxic," as defined under the FHSA, or present one of the other hazards enumerated in the statute.[24] Second, it must have the potential to cause substantial personal injury or substantial illness during or as a result of customary and reasonably foreseeable handling or use, including ingestion by children. 15 U.S.C. § 1261(f)(1)(A). In other words, an FHSA determination is risk based. Therefore, when assessing whether a household substance is a "hazardous substance" under the FHSA (and thus would require cautionary labeling), CPSC staff considers the customary and reasonably foreseeable use of the product, the formulation of the product, and any adverse health effects associated with the exposure, including toxicity (CPSC, 1992).

The first step in the risk assessment process is hazard identification, that is, to review the available toxicity data for each chemical under consideration and determine whether the chemical is "toxic" under the FHSA. The FHSA defines the term "toxic" to apply to any substance that has the capacity to produce personal injury or illness through ingestion, inhalation, or absorption through any body surface. 15 U.S.C. § 1261(g). Thus, the FHSA applies to both acute and chronic toxicities. "Acute toxicity" is defined by LD_{50} (median lethal dose) values in the statute, and that definition is supplemented in the implementing regulations at 16 C.F.R. § 1500.232 (b)(i). However, reliable human experience data take precedence over animal data. 16 C.F.R. § 1500.4. Under the FHSA, a substance is considered "toxic" if it presents a chronic hazard, such as carcinogenicity, neurotoxicity, or reproductive or developmental toxicity, and if it is either known to be, or probably, toxic in humans (16 C.F.R. § 1500.3 (c)(2)(ii)). According to the Commission's chronic hazard guidelines (CPSC, 1992), which are summarized in the regulation at 16 C.F.R. §1500.135, a substance or mixture is considered "known to be toxic" in humans only if there is sufficient evidence of the substance's or mixture's toxicity in humans

[24] Other hazards enumerated in the statute include corrosive, an irritant, a strong sensitizer, flammable or combustible, or generates pressure through decomposition, heat or other means.

(Table 1). The substance or mixture is considered "probably toxic" if there is either limited evidence in humans or sufficient evidence in animals.

Table 1. Guidance on Chronic Hazards under the FHSA

	Humans	Animals
Sufficient Evidence	Known*	Probable*
Limited Evidence	Probable*	Possible
Inadequate Evidence	Possible	--

* Considered "toxic" under the Chronic hazard guidelines.

If staff determines a substance to be toxic under the FHSA due to acute or chronic toxicity, then staff performs a quantitative assessment of exposure and risk to determine whether the chemical may be a "hazardous substance" under the FHSA. The quantitative risk assessment includes a consideration of dose response, bioavailability, and exposure.

The use of surrogate exposure data (such as data derived from chemicals of similar structure or reactivity as the chemical of interest) when no exposure data exist for a chemical is discussed in the Commission's chronic hazard guidelines. 16 C.F.R. §1500.135 (CPSC, 1992). These guidelines do not address the use of surrogate data for determining toxicity of a chemical where no toxicity data are available. Surrogate exposure data have not been used extensively by the Commission, and it "should only be used when data concerning a chemical of interest is sparse or unavailable and when there is a reasonable assurance that the surrogate data will accurately represent the chemical of interest." As stated in these guidelines, "surrogate data should only be used as a screening process to determine whether additional studies are necessary and what the parameters for those studies are." (CPSC, 1992). These guidelines state that care should be taken in interpreting surrogate data to minimize potential errors due to the differences between the surrogate substance and the "real" substance of interest, such as physical properties (*i.e.*, vapor pressure and diffusion constants).

4. TOXICITY DATA FOR ORGANOHALOGEN FLAME RETARDANTS

Some of the OFR chemicals found in these four product categories have been associated with endocrine, neurological, or developmental toxicities or cancer in animals (Table 2). However, the toxicity profiles of OFRs are chemical specific and vary within the class as discussed below. Furthermore, toxicity data are not available for all OFRs known to be in use (NTP, 2014; Stapleton et al., 2012b; Van Bergen et al., 2015). Therefore, these insufficient toxicity data and varying toxicity profiles within the OFR class make it difficult to conclude that every OFR is toxic under the FHSA.

Some OFRs are known to bioaccumulate because of their high lipophilicity and resistance to metabolism. Toxicity studies have been performed on a limited number of these OFRs to determine adverse health effects from exposure. CPSC staff has previously evaluated the health risks of certain OFRs, largely in support of flammability standard development for consumer products. However, staff's most recent work on mattresses and upholstered furniture was completed in 2006 (See Section 4 of this memorandum) (Babich, 2006; Thomas and Brundage, 2006). In 2013, a contractor report prepared for CPSC reviewed the toxicity of tris(2-

chloroethyl)phosphate (TCEP) (CPSC, 2013). Thus, CPSC staff does not have any recent comprehensive reviews of OFR toxicity, except for TCEP.

a. PBDEs

One of the main categories of OFRs that have been used in some of these product categories and for which toxicity information is available are the polybrominated diphenyl ethers (PBDEs). CPSC staff has not completed comprehensive reviews of PBDEs toxicities, except for DecaBDE (Babich et al., 2004; Bittner, 1999a). PBDEs were commonly used in electronics, clothes, toys, motor vehicles, plastics, and textiles to reduce flammability. In the mid-2000s, one of the most common classes of FRs used in consumer products, such as upholstered furniture and electronics, were the PBDEs (Birnbaum and Staskal, 2004; Lorber, 2008). PBDEs have a common structure of a brominated diphenyl ether molecule, which may have anywhere from one to 10 bromine atoms attached. Three main commercial formulations of PBDEs were marketed: PentaBDE, OctaBDE, and DecaBDE (Birnbaum and Staskal, 2004; Lorber, 2008; Stapleton et al., 2012a). PentaBDE and OctaBDE are no longer manufactured in the United States or the European Union; and DecaBDE has been phased-out in all products in the United States and in electrical and electronic products in the European Union (Abou-Elwafa Abdallah et al., 2016; Butt et al., 2016; EPA, 2015). PentaBDE was used in upholstered furniture foam and in electronic circuit boards. DecaBDE was used primarily in rigid plastics, but also in upholstered furniture fabrics. These FRs have been shown to be persistent, bioaccumulative, and/or toxic, and have been detected in the environment, wildlife, and human populations across the globe (Birnbaum and Staskal, 2004; Butt et al., 2016; Buttke et al., 2013; Kim et al., 2014; Stapleton et al., 2011a).

PBDEs have been shown to disrupt neurodevelopment and the endocrine system, resulting in effects on thyroid, ovarian, and androgen function. In rodent models, the toxic effects of PBDEs following prenatal or neonatal exposure include effects on liver enzymes, thyroid hormone levels, and reproduction, and immunotoxicity and neurotoxicity. Disruption of thyroid homeostasis during development is of special concern because small changes may cause neurologic impairments, including decreases in the IQ (Birnbaum and Staskal, 2004; Buttke et al., 2013; Dodson et al., 2012; Eriksson et al., 2002; Shaw et al., 2010). Epidemiology studies have found associations between prenatal and childhood PBDE exposures and a greater risk for IQ deficits and impaired learning behaviors later in life (Chen et al., 2014; Herbstman et al., 2010). One study also demonstrated an association between school-age, child-development and transplacental transfer of PBDEs (Roze et al., 2009). Exposure to PentaBDE results in increased lipolysis and reduced insulin-stimulated metabolism in rat adipocytes, which are hallmark features of obesity, insulin resistance, and type 2 diabetes (Shaw et al., 2010). In addition, PBDE concentrations in the serum of U.S. women are associated with a longer time to pregnancy and reduced fecundability[25]; and female animal studies have shown associations with delayed onset to puberty and changes in circulating estradiol (Harley et al., 2010; Stoker et al., 2004; Talsness et al., 2008). The phase-out of PentaBDE, OctaBDE, and DecaBDE has led to the development

[25] The probability of pregnancy during a single menstrual cycle.

of alternative FRs to meet flammability standards; however, little toxicological information exists on these alternative FRs.

Table 2. Chronic Health Effects of Selected Organohalogen Flame Retardant Chemicals

Chemical	Availability of Toxicity Data[a]								
	Acute	Subchronic	Chronic	Repro/Dev	Neurotox	Genetox	Human	Chronic Toxicity[b]	Endpoint[c]
Polybrominated diphenyl ethers (PBDEs)	X	X	X	X	X		X	B	E, N
FM550[d]	X	X	X	X	X	X	—	C	E, N
Tetrabromobenzoate (TBB)	X	?	—	X	?	?	—	I	E
bis(2-ethylhexy1) tetrabromophthalate (TBPH)	?	X	—	X	X	X	—	I	E, R
Triphenyl phosphate (TPP)	X	X	—	X	X	X	—	I	E, O
Isopropylated triphenyl phosphate (IPTPP)	X	?	—	X	X	X	—	I	D, R
Tetrabromobisphenol A (TBBPA)	X	?	X	X	X	X	X	C	C, E
Hexabromocyclododecane (HBCD)	X	X	X	X	X		X	B	N, D, R
1,2-dibromo-4-(1,2 dibromoethyl)cyclohexane (TBECH)	?	X	—	X	—	X	—	I	O, E
Decabromodiphenyl ethane (DBDPE)	—	X	—	—	—	—	—	I	O
1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE)	?	—	—	?	?	—	—	I	E
Tris(1,3-chloropropyl-2) phosphate (TDCPP)	X	X	X	X	X	X	—	B	E, R, C
Tris(2-chloroethyl) phosphate (TCEP)	X	X	X	X	X	X	—	B	C, R, N
Tris(chloropropyl) phosphate (TCPP) (mixture of isomers)	X	X	—	X	X	X	—	C	R, D, O
2,2-bis (chloromethyl)propane-1,3-diyl tetrakis(2-chloroethyl)bis (phosphate) (V6)	X	X	—	X	X	X	—	I	O

[a] X, data available; ?, limited data available; —, No data.
[b] "Chronic toxicity," as defined by the FHSA and the CPSC chronic hazard guidelines: A, known to be toxic in humans; B, probably toxic in humans; C, possibly toxic in humans; I, insufficient data.
[c] Chronic endpoint(s): C, cancer; D, developmental; N, neurotoxic; R, reproductive; E, endocrine; O, other (*e.g.*, liver or other organ toxicity).
[d] Studies evaluating the FM550 mixture.

b. Alternative OFRs to PBDEs

Studies have shown that other OFRs have replaced PBDEs in upholstered furniture and products with foam, such as children's products (Kim et al., 2014; Stapleton et al., 2009; Stapleton et al., 2011b). These studies have shown a shift from PBDEs to organohalogen or phosphate FR chemicals in these products. Some of these alternative FRs are not bound to the substrate material, such as polyurethane foam, and may be released from the product, leading to potential human and environmental exposures. Toxicity and exposure information are limited for most of the alternative OFRs, and it is unknown how many of these OFRs are being used in these four product categories. Toxicity information on select brominated and chlorinated OFRs are presented in the following sections. These selected OFRs include some referenced in the Petition, others that CPSC and other organizations have assessed, and those with information from the scientific literature.

i. Brominated aromatic FRs

<u>FireMaster^{TM}550 (FM550)</u>

One brominated alternative to PentaBDE in polyurethane foam is FM550, which is a mixture of 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (TBB or EH-TBB), bis(2-ethylhexy1) tetrabromophthalate (TBPH or BEH-TBB), triphenyl phosphate (TPP), and isopropylated triphenyl phosphates (IPTPPs) (Stapleton et al., 2008; Van Bergen et al., 2015). FM550 has been identified as a mixture of approximately 50 percent TBB and TBPH at a ratio of 4:1 by mass, while the remainder is comprised of TPP and IPTPP (EPA, 2015). FM550 was the second most commonly detected FR in polyurethane foam from baby products in one U.S. study, suggesting it is a replacement for PentaBDE (Dishaw et al., 2014b; Stapleton et al., 2011b).

CPSC staff has not performed a comprehensive review of the toxicity of TBB or TBPH. CPSC did review the toxicity of the non-brominated components TPP and IPTPPs in the 1990s (Ferrante, 1999a). CPSC staff proposed the aromatic phosphates (including TPP and IPTPPs) for toxicity testing by the National Toxicology Program (NTP) in 2005 (Babich, 2005), and that study is currently underway.

Developmental, reproductive, neurological, genotoxic, and repeated dose studies have been performed on individual FM550 components and mixtures of these components. It is unclear in some studies what component/components are driving the effects noted in these studies; however, some studies point to one component as the driver for a certain endpoint (EPA, 2015). Dermal and eye irritation from individual components of and the FM550 mixture itself range from very low to mild. Developmental effects (reduced fetal body weight and altered fetal ossification) were noted when a commercial mixture of TBB and TBPH (FireMaster BZ54; CN-

2065) was given orally to rats in a 2-generation reproductive study and a prenatal study (EPA, 2015). Growth and neurodevelopmental endpoints were impacted in rats orally given FM550 throughout gestation and lactation. Dams showed increased thyroxine levels, and the offspring showed elevated body weight in adolescence and into adulthood, early puberty, and glucose intolerance in females and thickened left ventricle walls in males. TBPH and the primary metabolite of TBB (tetrabromobenzoic acid (TBBA)) were also detected in the livers of dams, indicating absorption of some FM550 components in rats following oral exposure (Patisaul et al., 2013). A combined repeated dose and reproductive/developmental toxicity screening study in rats orally given IPTPP from premating to postpartum indicated decreased fertility, litter size, and pup survival and organ weight changes. No neurotoxicity effects were noted in a 28-day oral subchronic toxicity study in rats given FM550. Brain acetylcholinesterase and neuropathy target esterase activities were significantly inhibited in rats following oral and dermal exposures to commercial mixtures containing TPP and IPTPP; however, studies in hens, mice, and rats exposed to TPP do not show neurotoxicity, and TPP did not induce organophosphate-induced delayed neurotoxicity in numerous hen studies (Babich, 2006; EPA, 2015).

The components of FM550 also show endocrine effects. The structure of TBPH is similar to the phthalate di(2-ethylhexyl)phthalate (DEHP), which is a reproductive and developmental toxicant (CalEPA, 2003; Springer et al., 2012). Similar to DEHP and the DEHP metabolite mono(2-ethylhexyl) phthalate (MEHP), which cause anti-androgenic effects in the rat fetal testis (Furr et al., 2014), some anti-androgenic effects were reported with *in vivo* exposure to the TBPH metabolite mono-(2-ethyhexyl) tetrabromophthalate (TBMEHP) (Springer et al., 2012). Oral TBMEHP exposure to pregnant rats produced increased multinucleated germ cells in fetal testes, similar to effects produced by exposure to MEHP. Maternal hypothyroidism with decreased serum triiodothyronine and maternal hepatotoxicity were also noted (Springer et al., 2012). One *in vitro* study using yeast demonstrated anti-androgenic effects for TBPH, as well as weak estrogen antagonism and increased estrogen production, suggesting potential estrogen-specific mechanisms of endocrine disruption for this *in vitro* system (Dodson et al., 2012; EPA, 2005; Saunders et al., 2013; Springer et al., 2012). *In vitro* studies on TPP, TBB and TBPH show potential for endocrine disruption through altering the androgen and thyroid receptors. *In vitro* studies suggest that TBMEHP and FM550, likely through TPP, induce adipocyte differentiation (Dishaw et al., 2014b; Liu et al., 2012; Pillai et al., 2014; Saunders et al., 2013; Springer et al., 2012). One researcher is studying the effects of FM550 on prostate cancer stem cells and has initially observed that TBB, TBPH, and IPTPP stimulate the rapid expansion of these cells (Kasper, 2014). Additionally, systemic exposure to TBB or its metabolites occurs based on urinary elimination in animals with oral administration. However, TBB shows a low likelihood of bioaccumulation with chronic exposure (Knudsen et al., 2016a).

FM550 is considered toxic under the FHSA;[26] however, it is not considered highly toxic.[27] On a preliminary basis, CPSC staff concludes that FM550 may be considered "possibly toxic in humans," based upon limited evidence of developmental toxicity in animal studies for the FM550 mixture. A finding of "possibly toxic" does not meet the definition of "toxic" under the

[26] 16 C.F.R. § 1500.3 (b) (5). LD_{50} range 50-5000 mg/kg.
[27] 16 C.F.R. § 1500.3 (b) (6) (i).

FHSA. This does not mean that this chemical is "safe," only that there are not sufficient data to satisfy the regulatory definition of "toxic."

Tetrabromobisphenol A (TBBPA)

CPSC staff has not completed a comprehensive toxicity review of TBBPA. TBBPA is the most widely produced and used brominated FR. It is primarily used (80%-90%) in printed circuit boards as a reactive FR. The reactive use of TBBPA on circuit boards and its relative inaccessibility presumably reduces exposure potential. TBBPA is used as an additive FR (10%-20%) in textiles and in the plastic housing for electrical and electronic equipment (Carignan et al., 2012; Colnot et al., 2014; Dodson et al., 2012; Hamers et al., 2006; Kim et al., 2014; NTP, 2014; Van Bergen et al., 2015; Wikoff et al., 2015). TBBPA is generated by the bromination of bisphenol A (BPA); however, TBBPA has different toxicity and chemical and physical properties than BPA. Additionally, BPA was not measured as a metabolite of TBBPA in rats (Knudsen et al., 2014; Wikoff et al., 2015). A derivative of TBBPA, TBBPA- bis(2,3-dibromopropyl ether) (DBPE), is poorly absorbed in the gut of rats, but the small amounts that are taken up accumulate in the liver. TBBPA-DBPE is metabolized slowly and eliminated in the feces (Covaci et al., 2011).

TBBPA is biotransformed by conjugation reactions after oral administration in humans and rodents, and it is rapidly excreted. Therefore, TBBPA shows a low potential for bioaccumulation in these species. Limited data are available for TBBPA bioavailability after inhalation or dermal exposures; however, this data shows limited bioavailability through these exposure routes (Colnot et al., 2014; EFSA, 2011). TBBPA shows low acute toxicity. Human and animal data conclude that TBBPA is non-irritating and non-sensitizing, and laboratory studies have concluded that TBBPA does not show genotoxicity or mutagenicity (Colnot et al., 2014; Ma et al., 2014; NTP, 2002; NTP, 2014; Wikoff et al., 2015). TBBPA has been reported as toxic to primary hepatocytes, neurons and immune cells *in vitro*. *In vivo*, associations between TBBPA exposure and neurotoxicity, developmental toxicity, and body weight changes have been reported in rodents. Some *in vitro* and *in vivo* studies report effects on the endocrine system, such as binding of TBBPA to hormone receptors, altering circulating thyroid hormone levels, or estrogenic and androgenic effects in rats (Dodson et al., 2012; Van der Ven et al., 2008; Wikoff et al., 2015; Zatecka et al., 2013). However, a recent review on the toxicity of TBBPA and on exposure and risk assessments performed on TBBPA found no evidence that it affects the endocrine system *in vivo* or that it meets the definition of an endocrine disruptor. The Committee on Toxicology (COT) in the United Kingdom and the European Chemicals Bureau also reviewed TBBPA studies and concluded that TBBPA is not an endocrine disruptor (Colnot et al., 2014; COT, 2004; ECB, 2006). These conclusions that TBBPA does not meet the definition of an endocrine disruptor were based on analyzing many *in vivo* and *in vitro* studies. The author stated that animal studies of TBBPA toxicity did not indicate adverse effects through endocrine pathways. However, some *in vivo* studies did indicate small changes in circulating thyroid hormones, but the author did not consider these changes adverse. This was in part because these changes were noted at concentrations in animals that were above those suggesting thyroid-related effects *in vitro* (Colnot et al., 2014).

In 2014, the NTP conducted a 2-year animal bioassay for TBBPA, which included both cancer and non-cancer data in rats and mice. NTP concluded that chronic TBBPA administration at very high doses (up to 1000 mg/kg-day) resulted in uterine tumors in female rats (classified as equivocal evidence) and liver tumors in male mice (classified as some evidence), as well as a number of non-neoplastic effects, such as forestomach lesions, ovarian cysts, uterine hyperplasia, and renal tubule cytoplasmic alterations (NTP, 2014; Wikoff et al., 2015). EPA's Cancer Assessment Review Committee (CARC) classified TBBPA as "likely to be carcinogenic to humans," based on the presence of uterine epithelial tumors in female rats and hemangiomas/hemangiosarcomas in male mice found in this NTP study. CARC disagreed with NTP's conclusion of equivocal and some evidence of carcinogenic activity based on findings of testicular adenomas in rats and hepatoblastoma in mice, respectively, deeming these were not treatment-related. While NTP determined that the hemangiosarcomas in mice may have been related to treatment, CARC determined that they were treatment-related (EPA, 2014a; NTP, 2014). Wikoff et al. (2016) used an adverse outcome pathway framework to evaluate the mechanism of action (MOA) associated with the uterine tumors in rats and to evaluate human plausibility. The authors concluded that these TBBPA-induced uterine tumors occurred via a non-genotoxic MOA, which is not feasible in humans given differences in the kinetic and dynamic factors associated with the high-dose exposures in rats (1,000 mg/kg-day) in the NTP study relative to human TBBPA exposure levels (Wikoff et al., 2016). Also, the COT concluded that TBBPA was unlikely to be carcinogenic based on absence of genotoxicity and proliferative lesions in available studies (COT, 2004; EPA, 2014a).

CPSC staff has not performed an in-depth review of TBBPA toxicity. Preliminarily, CPSC staff concludes that TBBPA may be considered "possibly toxic to humans," based on limited evidence of carcinogenicity in animals. A finding of "possibly toxic" does not meet the definition of "toxic" under the FHSA. However, these conclusions are based on limited data. This does not mean that this chemical is "safe," only that there are not sufficient data to satisfy the regulatory definition of "toxic."

Hexabromocyclododecane (HBCD)

CPSC last reviewed the toxicity of HBCD in 2004 (Babich et al., 2004; Hatlelid, 1999). HBCD is used primarily as an additive flame retardant in thermoplastic polymers and styrene resins. It is also used in upholstery textile coatings, cable, building insulation, and in electronic housings (Carignan et al., 2012; Dodson et al., 2012; NRC, 2000). The commercial HBCD product is composed of three diastereomers: α-, β-, and γ-HBCD, with γ-HBCD dominating (Birnbaum and Staskal, 2004; Carignan et al., 2012). HBCD is highly lipophilic, bioaccumulative, and persistent. After oral absorption, HBCD is rapidly absorbed in the gastrointestinal tract, distributed to the adipose tissue, and rapidly eliminated primarily in the feces (Hatlelid, 1999; NRC, 2000; van der Ven et al., 2006).

HBCD shows a range of systemic, reproductive, developmental, endocrine, and neurological effects in animals. *In vitro* tests show that HBCD interacts with the endocrine system via the thyroid receptor, with less interaction with progesterone, thyroid, estrogen, and androgen receptors (Hamers et al., 2006; van der Ven et al., 2006). Following pre- and neonatal oral exposure in rodents, hyperactivity, reduced habituation, and learning and memory impairment were noted, along with thyroid homeostasis disruption. Increased liver weight and fatty liver were noted in rats in 28- and 90-day oral studies, respectively (Carignan et al., 2012; Eriksson et al., 2006; Shaw et al., 2010; van der Ven et al., 2006). A two-generation reproductive toxicity study assessing HBCD in rats showed treatment-related reproductive (a significant decrease in the number of primordial follicles in the F1 females) and developmental effects (delayed F2 generation eye opening) (Carignan et al., 2012; Dodson et al., 2012; Ema et al., 2008; NRC, 2000; Shaw et al., 2010; van der Ven et al., 2006). HBCD shows no evidence of genotoxicity. One *in vivo* mouse carcinogenicity study showed an increase in hepatic tumor incidence compared to controls; however, the author concluded no correlation between dose and tumor incidence (EPA, 2014b; Hatlelid, 1999; NRC, 2000). HBCD was recommended for addition to the list of persistent organic pollutants under the Stockholm Convention in 2012 (SCCH, 2012).

HBCD is not considered acutely toxic under the FHSA. Preliminarily, CPSC staff concludes that HBCD is "probably toxic to humans," based on sufficient evidence of chronic organ toxicity in animals. A finding of "probably toxic" means that a risk assessment must be completed to determine whether HBCD is a hazardous substance and presents a hazard to consumers during reasonably foreseeable handling and use.

<u>Other Brominated Aromatic FRs</u>

Less toxicity information is available for other brominated aromatic FRs, such as decabromodiphenyl ethane (DBDPE), 1,2-dibromo-4-(1,2 dibromoethyl)cyclohexane (TBECH or DBE-DBCH), and 1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE), which are used in consumer products.

In a 28-day study, DBDPE, at oral doses up to 1,000 mg/kg-day, produced hepatotoxicity and increased blood glucose levels in rats (Sun et al., 2014). TBECH was fed to rats in a 28-day study at doses up to 330 mg/kg-day. Adverse effects on the kidney and hematologic evidence of inflammatory responses were the most sensitive outcomes of TBECH exposure. Limited evidence of endocrine changes, such as elevated serum testosterone levels in males and changes in serum T3 and T4 levels in females, were noted at high doses of TBECH; however, adverse effects on endocrine function in birds and fish and in *in vitro* studies have been reported (Curran et al., 2016). One study showed through experimental analysis and modeling that TBECH binds to and activates the human androgen receptor (AR) in human cancer liver cells (Walstad et al., 2007). TBECH tested positive for mutagenic potential in another study using a mouse lymphoma cell mutation assay (McGregor et al., 1991). BTBPE was measured in house dust and found to be positively associated with T3 levels in men recruited though a fertility clinic (Johnson et al., 2013). A metabolite of BTBPE (2,4,6-tribromophenol) shows thyroid disruption (Hamers et al., 2006). Studies have shown BTBPE to be poorly absorbed from the gastrointestinal tract of rats and 94 percent is excreted in the feces (Covaci et al., 2011).

ii. Chlorinated alkyl phosphate FRs

Chlorinated alkyl phosphate FRs include tris(1,3-dichloro-2-propyl)phosphate (TDCPP), TCEP, and tris(2-chloroisopropyl) phosphate (TCPP). These chlorinated FRs are used as FRs in flexible and rigid polyurethane foams. They are also used as plasticizers in other products (glue and paint) (Abou-Elwafa Abdallah et al., 2016; van der Veen and de Boer, 2012). The use of these FRs have increased, due to the phase-out of PBDEs, and they have been detected in polyurethane foam in children's products, upholstered furniture, and mattresses (Babich, 2006; Stapleton et al., 2011b; Stapleton et al., 2012b). The toxicological effects of these OFRs vary in animal experiments. Some are suspected carcinogens, and others show thyroid hormone disruption and neurotoxicity. Because these OFRs are structurally similar to organophosphate pesticides, which have been shown to adversely affect the nervous system and reproductive development, a potential for neurotoxicity and developmental toxicity exists. In zebrafish, developmental exposure to these chlorinated OFRs was linked to neurotoxicity similar to chlorpyrifos (Behl et al., 2016; Dishaw et al., 2014a; Fromme et al., 2014; Harrad et al., 2016; Meeker and Stapleton, 2010; Van Bergen et al., 2015).

Tris(1,3-dichloro-2-propyl)phosphate (TDCPP)

TDCPP is an additive FR used mainly in polyurethane foam. It is also used as an FR and plasticizer in rigid polyurethane foams, resins, plastics, and textile coatings (CalEPA, 2011; Dishaw et al., 2014b; Schreder et al., 2016; Stapleton et al., 2011b).

CPSC HS staff reviewed the toxicity of TDCPP in 1999 and 2006 (Ferrante 1999b; Babich 2006). TDCPP shows evidence of endocrine disruption, developmental toxicity, reproductive toxicity, neurotoxicity and carcinogenicity; however, it does not possess skin sensitization potential (Dishaw et al., 2014a; EU, 2008c). Several studies have reported TDCPP sex-dependent effects on the hypothalamic-pituitary-gonad axis, perhaps as an estrogen receptor agonist (Liu et al., 2012; Wang et al., 2013). There are also studies suggesting that TDCPP disrupts thyroid regulation in humans and animals and shows effects on embryonic development (Dishaw et al., 2014b; Liu et al., 2012; Meeker and Stapleton, 2010; Tanaka et al., 1981; Wang et al., 2013). One study reported decreased sperm concentrations and altered thyroid levels in men with measured TDCPP in house dust (Meeker and Stapleton, 2010).

Studies have shown the carcinogenic potential of TDCPP. In a 2-year dietary study, significant increases in tumor incidence in the liver, kidney, and testes were observed in TDCPP-treated male and female rats. Other non-neoplastic findings were also noted, such as hemoglobin and hematocrit abnormalities and organ weight increases versus control (Freudenthal and Henrich, 2000). Some TDCPP metabolites are also carcinogenic, such as 1,3-dichloro-2-propanol (1,3-DCP) and 3-monochloropropane-1,2-diol (3-MCPD), and induce tumors at similar sites as TDCPP (liver, kidney, testes) (CalEPA, 2011). The main metabolite of TDCPP, bis(1,3-dichloro-2-propyl) phosphate (BDCPP), has not been tested for carcinogenicity in animals; however, mutagenicity is not reported in *in vitro* testing (CalEPA, 2011). A genotoxic MOA for cancer has been suggested for TDCPP, based on positive tests in a variety of genotoxicity assays, showing mutations, chromosomal aberrations, and cell transformation in multiple types of cells in culture (CalEPA, 2011). In 2006, CPSC concluded that TDCPP is a probable human carcinogen, based on sufficient evidence in animal studies (Babich, 2006), and TDCPP was nominated to NTP's Report on Carcinogens in 2013 (NTP, 2013). In California, TDCPP was listed as a Prop 65 chemical in late 2011, due to concerns about carcinogenicity, and TDCPP is classified in the EU as "suspecting of causing cancer" (Abou-Elwafa Abdallah et al., 2016; CalEPA, 2011; EPA, 2015). TDCPP is also structurally similar to two OFR carcinogens identified under Prop 65, tris(2,3-dibromopropyl) phosphate (TDBPP or Tris) and TCEP (CalEPA, 2011).

TDCPP is acutely toxic, as defined in FHSA regulations, although it is not considered highly toxic. CPSC staff concluded that TDCPP is "probably toxic to humans," based on sufficient evidence of chronic organ toxicity and carcinogenicity in animal studies (Babich, 2006; Ferrante, 1999b). The finding of probably toxic means that a risk assessment must be completed to determine whether TDCPP is a hazardous substance and presents a hazard to consumers during reasonably foreseeable handling and use.

Tris(2-chloroethyl) phosphate (TCEP)

TCEP has been used as an FR in a variety of products, such as flexible and rigid polyurethane foams, textiles, paints, and glue (ATSDR, 2012; Marklund et al., 2003). A contractor report to CPSC on TCEP toxicity was completed in 2013 (CPSC, 2013). Studies in rats and mice show that TCEP is well absorbed (> 90% of the dose) and distributed after oral administration, and higher concentrations were found in the liver and kidney up to 24 hours after administration. Limited data exist on inhalation and dermal absorption of TCEP; however, these data provide evidence of absorption by these routes (EU, 2008c; Herr et al., 1991). TCEP shows reproductive, developmental, and neurological toxicities and carcinogenicity, and the European Chemicals Agency has designated TCEP as a substance of very high concern due to reproductive toxicity (EU, 2008c; Schreder et al., 2016). In an oral continuous mouse breeding study, TCEP significantly reduced fertility, with males being more sensitive. TCEP also significantly decreased the number of live pup births per litter in the F2 generation at the lowest dose tested (ATSDR, 2012; NTP, 1991). Neurodegenerative lesions in the cerebral cortex and hippocampus and ataxia and convulsive movements were observed in rodents orally dosed with TCEP (ATSDR, 2012; EPA, 2015; NTP, 1991). TCEP is not considered to be a skin or eye irritant or corrosive, and it is non-sensitizing to humans upon dermal contact (EPA, 2015; EU, 2008c).

TCEP is carcinogenic in rats and mice of both sexes; however, it is not considered mutagenic by *in vitro* and *in vivo* testing (EU, 2008c; Follmann and Wober, 2006). TCEP induced brain lesions in rats and mice in 16-week and 2-year gavage studies. Additionally noted in these studies were changes in kidney and liver weights (16-week study) and renal tubule epithelial hyperplasia in rats (2-year study). NTP concluded clear evidence of carcinogenic activity for male and female Fischer-344/N rats, due to significantly increased incidence of renal tubule adenoma or carcinomas and equivocal evidence of carcinogenic activity for mice due to an increase in the incidence of a rare renal tubule neoplasm (males) and Harderian gland tumors (females) (ATSDR, 2012; CalEPA, 2014; Follmann and Wober, 2006). A dietary study also found that TCEP increased the incidence of renal and liver tumors in male mice and forestomach tumors and leukemia in female mice (ATSDR, 2012). The International Agency for Research on Cancer (IARC) has classified TCEP as a group 3 carcinogen, not classifiable as to its carcinogenicity in humans (ATSDR, 2012; IARC, 1999), while the EU has classified TCEP as a "potential human carcinogen" (carcinogen category 3) (Abou-Elwafa Abdallah et al., 2016). TCEP is identified as a carcinogen under Prop 65 (CalEPA, 1992).

TCEP is acutely toxic under the FHSA, although it is not considered highly toxic. CPSC staff concludes that TCEP is "probably toxic in humans," based on sufficient evidence of chronic organ toxicity and carcinogenicity in animal studies. The finding of probably toxic means that a risk assessment must be completed to determine whether TCEP presents a hazard to consumers during reasonably foreseeable handling and use.

Tris(chloropropyl) phosphate (TCPP)

TCPP is a mixture of isomers, with the tris(1-chloro-2-propyl) isomer the main component at 50 percent-85 percent (EU, 2008b). A shift in the usage of TCEP to TCPP in polyurethane foams has been noted (Follmann and Wober, 2006). TCPP is readily absorbed in rodents after oral administration. TCPP is detected in the highest amounts in the liver and kidney, and it is quickly metabolized to bis(1-cloro-2-propyl)phosphate (BCPP) and other Phase I metabolites. TCPP is rapidly excreted, primarily in the urine, but also in the bile and feces (EPA, 2015). TCPP does not possess significant skin sensitization potential (EPA, 2015; EU, 2008c).

A two-generation reproductive study assessed TCPP in rats and observed decreased body weight in parental animals, decreased uterine weights in F0 females and in the high-dosed F1 females, and effects on the estrous cycles in both generations. Decreased seminal vesicle weights were also reported for some F0 and F1 males. The number of runts was significantly increased in the F1 and F2 generations (EU, 2008, EPA, 2015). TCPP is not genotoxic *in vivo* (EU, 2008b; Follmann and Wober, 2006). Oral repeated dose studies of TCPP to rats report hepatocellular swelling, alterations in liver, kidney, and body weights, and pathological kidney and thyroid changes. Increased female mortality has also been reported at 1,000 mg/kg/day (EPA, 2015; Freudenthal and Henrich, 1999).

TCPP is "acutely toxic," as defined in FHSA regulations, although it is not considered highly toxic. It is considered "possibly toxic to humans," based on limited evidence of developmental and reproductive toxicity in animal studies. A finding of "possibly toxic" does not meet the definition of "toxic" under the FHSA. However, these conclusions are based on limited data. This does not mean that this chemical is "safe," only that there are not sufficient data to satisfy the regulatory definition of "toxic." In 2005, CPSC staff nominated TCPP for testing by NTP. A 2-year bioassay of chronic toxicity and carcinogenicity with perinatal exposure is currently in the histopathology stage (NTP, 2017).

Other Chlorinated OFRs

V6 (2,2-bis (chloromethyl)propane-1,3-diyl tetrakis(2-chloroethyl)bis (phosphate)) is an FR mixture containing TCEP as a 10 percent impurity by weight. It is used with TCPP and TDCPP in polyurethane foam in furniture and cars; however, it has been detected in the foam of baby products, such as changing table pads and sleep positioners (Stapleton et al., 2011b; van der Veen and de Boer, 2012). V6 is potentially persistent in the environment, but not considered bioaccumulative. It is not considered neurotoxic, a mutagen, or skin irritant. Oral absorption studies in the rat indicate 100 percent absorption of V6. Acute toxicity is low by oral, dermal, and inhalation routes via studies in the rat (EU, 2008a; van der Veen and de Boer, 2012). One study in zebrafish found no significant effects on embryonic development or survival after V6 exposure; however, a reproductive study in rats showed increased thyroid weights and the frequency of cells with chromosomal aberrations. Liver and thyroid weights were affected by V6 exposure in a 28-day oral study in rodents. No carcinogenicity studies have been conducted on V6; however, given the presence of TCEP in this mixture, carcinogenicity may be of concern (EU, 2008a; Fang et al., 2013; McGee et al., 2012; van der Veen and de Boer, 2012).

c. Smoke Toxicity

Household fire deaths occur due to smoke inhalation, not from thermal burns, in the post-flashover stage of a fire. This post-flashover stage produces conditions that provide enough smoke for these deaths to occur (Gann and Hall, 1994). One commenter[28] stated that when flashover occurs, the concentration of combustion byproducts, such as carbon monoxide (CO), increases, thereby increasing the toxicity of the smoke. The commenter states that the main function of FRs is to inhibit or suppress the combustion process to reduce the overall heat release and flame spread, which delays flashover. However, while FR chemicals reduce ignition potential, FR-treated products may extend the smoldering time, and will ignite if exposed to sufficiently high temperatures. Combustion products from products burning with OFRs include hydrogen chloride (HCl), hydrogen bromide (HBr), CO, and particulate matter (Babrauskas et al., 1988). Incomplete combustion products from the smoldering of products with OFRs may also produce halogenated dioxins and furans, with some being considered carcinogens and immunotoxicants (Ebert and Bahadir, 2003).

The National Bureau of Standards (now the National Institute of Standards and Technology (NIST)) performed a fire hazard comparison of FR and non-FR products, such as TV cabinet housings, upholstered chairs, cables, and laminated circuit boards. They found that total toxic gas production, such as CO, was much lower for products with FRs, and that smoke potency and CO concentrations were similar for FR and non-FR products (Babrauskas et al., 1988). However, one statement in the Petition discussed how these fire effluents from materials with OFRs can be more acutely toxic because irritant gases (HCl and HBr) may be produced and cause incapacitation and lung injuries, and the soot may produce limited visibility. The petitioners also discussed how chronic toxicity could be increased by the amount of persistent organic pollutants produced (Lucas, 2015). CPSC staff is aware of the potential impact that FRs may have on the irritant properties of the smoke and has identified a possible approach to quantify the impact that these FRs may have on egress time (Thomas et al., 2003). The petitioners also state that firefighters are routinely exposed to these combustion byproducts on a daily basis, and the International Association of Fire Fighters (IAFF) recognizes the likelihood of an association between high cancer rates of fire fighters and the presence of OFRs in consumer products. CPSC is concerned about the safety of fire fighters and realizes that OFRs in products could affect their health; however, CPSC's jurisdiction does not include occupational exposures.

[28] CPSC-2015-0022-0198.

5. EXPOSURE DATA FOR ORGANOHALOGEN FLAME RETARDANTS

Most OFRs are classified as semi-volatile organic compounds (SVOCs) due to their relatively low volatility. Products containing SVOCs slowly emit OFRs over time, through passive migration, as well as abrasion during normal use. SVOCs tend to adsorb to dust particles, and thus, indoor dust is a sink and a repository for SVOCs, such as FRs and many other indoor environmental contaminants. This persistence in the indoor environment causes SVOCs to redistribute from their original source and separate into air, dust, and onto surfaces. Therefore, contaminants in indoor dust can be considered a marker of indoor exposure (Liu et al., 2016; Ma et al., 2014; Mitro et al., 2016). This redistribution within the indoor environment could result in exposure to these FRs through inhalation, ingestion, and dermal absorption of air and dust (Cooper et al., 2016; Liu et al., 2016; Mitro et al., 2016; Pawar et al., 2016; Van Bergen et al., 2015). However, vapor phase emission factors, migration through the product, and dermal absorption factors are lacking for many/most of these OFRs. Additionally, the redistribution of SVOCs into dust does not relate chemical exposures to specific products in the home, which is necessary to support FHSA regulations and is discussed below.

Dust is an important pathway for human exposure to FRs because people in developed countries spend more than 90 percent of their time in the indoor environment, such as at home and at work (Liagkouridis et al., 2016; Mitro et al., 2016). There are important differences among individuals, such as pre-existing conditions and genetics, which affect their likelihood of developing an adverse health effect from chemical exposure. In addition, the likelihood of exposure to chemicals is also specific per individual and impacts the amount of chemical to which someone may be exposed. For example, children are uniquely susceptible to chemical exposure through indoor dust due to their proximity to the ground, as demonstrated by a higher body burden compared to adults. This higher body burden is likely from dust ingestion (hand-to-mouth and mouthing activities), as well as diet and breastfeeding (Mitro et al., 2016).

Exposure to these FRs through the inhalation route is also of concern. It has been estimated for PBDEs that inhalation accounts for 11 percent to 22 percent of total exposure (Allen et al., 2007). Some studies have suggested that inhalation exposure to chlorinated OFRs is more of an issue than for PBDEs, due to their high water solubility and lower hydrophobicity (Allen et al., 2007; Babich, 2006; Marklund et al., 2005; van der Veen and de Boer, 2012). One study measured TDCPP, TCEP, and TCPP in respirable and inhalable fractions in air to determine the likelihood of deep lung penetration using personal air samplers. Inhalable particulates deposit primarily in the upper parts of the respiratory tract, whereas respirable dust penetrates lower into the lungs. These FRs were detected higher in the inhalable fraction than the respirable fraction, and TCPP concentrations were the highest measured (La Guardia and Hale, 2015). Another study also concluded that the inhalable fraction of airborne particulates was the source of OFRs versus the respirable fraction. These studies indicate that inhalation is an important route of exposure to these compounds (La Guardia and Hale, 2015; Schreder et al., 2016).

OFRs have been measured in these four product categories considered in the Petition and in indoor and outdoor environments, such as indoor and outdoor air, indoor dust, water, and soil. OFRs also tend to accumulate in lipids in the body, such as breast milk and blood, due to their lipophilic properties, and they have also been measured in human breast milk, serum, and urine

(Abou-Elwafa Abdallah et al., 2016; Stapleton et al., 2009; Sundkvist et al., 2010). *In vivo* studies have also measured these FRs in blood and urine, showing that they are bioavailable and absorptive (EPA, 2015). However, although some of these OFRs have been measured in blood, urine, and breast milk, the products they are being released from, their quantity, and how they are being released is unknown.

a. Measurement of PBDEs

Several studies suggest that house dust is a significant source of exposure to PBDEs in the U.S. (Dishaw et al., 2014b; Lorber, 2008). Studies on PBDEs show that ingestion and dermal contact with indoor dust are significant pathways for human exposure. One study measured PBDEs on hand wipe samples, suggesting hand to mouth activity as a source of exposure for these chemicals. Significant associations between PBDE levels in dust and serum have also been shown. Ownership of household electronics was also found to be a potential route for PBDE exposure (Abou-Elwafa Abdallah et al., 2016; Allen et al., 2008; Buttke et al., 2013; Johnson et al., 2010; Stapleton et al., 2012a). Other studies measured PBDE serum levels, and levels were higher in children than in their mothers, likely due to maternal transfer and breastfeeding in infants and hand-to-mouth ingestion in toddlers and children (Eskenazi et al., 2011; Fromme et al., 2016). Although PBDEs are no longer manufactured, products containing PBDEs are still present in homes, and PBDEs persist in the environment. Although human exposure is beginning to decline, it is expected to continue for years, due to the persistent nature of PBDEs.

b. Measurement of Alternative OFRs to PBDEs

TDCPP, TCEP, and TCPP have been detected in both dust and air samples in a variety of indoor environments, such as homes, day care centers, hospitals, and offices. V6 has been detected in house and car dust samples (Bradman et al., 2014; Carignan et al., 2012; Dodson et al., 2012; Fang et al., 2013; Fromme et al., 2014; Marklund et al., 2003; Meeker and Stapleton, 2010; Stapleton et al., 2009; Stapleton et al., 2014). House dust, hand wipe, and urine samples were collected to determine the relationship between the home environment and exposure. TDCPP concentrations in indoor dust were not associated with hand wipe samples; however, the hand wipe samples were associated with its urinary metabolite. This suggests that hand-to-mouth contact or dermal exposure may be important pathways of exposure to OFRs (Hoffman et al., 2015). A significant correlation was found between TCEP levels in dust and indoor air samples from daycares in Germany. A significant correlation was also observed between these TCEP levels in dust and indoor air and its metabolite concentration in urine (Fromme et al., 2014). These chlorinated OFRs have also been measured in adipose tissue, seminal plasma, and breast milk (CalEPA, 2011; Hoffman et al., 2015; Meeker and Stapleton, 2010; Sundkvist et al., 2010). A possible association between TDCPP and TPP house dust levels and decreased sperm concentrations and altered thyroid levels in men have also been noted (Meeker and Stapleton, 2010).

TBBPA has been detected in human serum samples, breast milk, and adipose tissue, and in household dust. It has also been detected in food, water, and air (Carignan et al., 2012; Dodson et al., 2012; NTP, 2014; Van Bergen et al., 2015; Wikoff et al., 2015). HBCD has been detected in house dust, breast milk, and serum, TPP has been detected in breast milk, and BTBPE, DBDPE, TBB, and TBPH have been detected in house dust (Carignan et al., 2012; Covaci et al., 2011; Roosens et al., 2009; Stapleton et al., 2008; Stapleton et al., 2009; Sundkvist et al., 2010). TBBPA is found in human samples at lower levels than other OFRs (Van Bergen et al., 2015), and in general, concentrations of TBBPA in indoor dust are much lower than those reported for BPA. Additionally, one study found no correlation between the levels of TBBPA and BPA in dust samples (Geens et al., 2009; Ma et al., 2014). One retrospective study calculated exposure to children and toddlers using dust data outside the United States and concluded that dust ingestion is an important source of TBBPA exposure for these populations. One recent review also noted that measured concentrations of TBBPA in house dust and human serum samples are low, and exposure assessments have estimated human exposure of TBBPA to not exceed a few ng/mg/day (Colnot et al., 2014; Ma et al., 2014). Concern for recycled plastics containing OFRs has been noted due to TBBPA being detected in Mardi Gras beads (Van Bergen et al., 2015). HBCD content in dust has been reported as a significant predictor of levels in human serum (Carignan et al., 2012; Roosens et al., 2009). HBCD has also been found in umbilical cord blood and breast milk (UNEP, 2010).

OFRs have been detected in children's products. Children's products, such as changing table pads, sleep positioners, nursing pillows, high chairs, and crib mattresses were purchased, and TDCPP, FM550, V6, TCEP, and TCPP were detected in the foam (Stapleton et al., 2011b). The State of Washington's Department of Ecology has tested consumer products to determine the presence of FR chemicals. In 2011, they screened children's products with X-ray fluorescence (XRF) and showed high bromine in children's furniture foam, but PBDE levels were low; therefore, they concluded that alterative brominated FRs were being used. In 2012/2013, they collected more children's products and detected TDCPP TCEP, TCPP, V6, and FM550 in foam from these products. TBBPA and HBCD were also detected in some samples. They also detected TBBPA in four plastic electrical enclosure components (Davies, 2015; Van Bergen et al., 2015).

FRs are mixed into plastic polymers of electronics additively to prevent or minimize flame spread. Some studies have measured OFRs in the environmental media surrounding electronic waste (e-waste) facilities and in the e-waste itself (Van Bergen et al., 2015). In e-waste recycling facilities of old electronics outside the United States, XRF screening showed high bromine, but low PBDEs, suggesting alternative FRs were used in these products. DecaBDE, TBBPA, BTBPE, and DBDPE were measured in e-waste samples in New Zealand, Australia and the Netherlands. One study in the Netherlands measured TBBPA, PBDEs, 2,4,6-tris(2,4,6-tribromophenoxy)-1,3,5-triazine (TTBP-TAZ), BTBPE, and DBDPE in plastic electronic casings, with TBBPA being measured the most. The study concluded that the presence of these compounds was due to their use as FRs or because of cross-contamination from recycled plastic. These authors then took the previously screened plastic cases and their extracts and analyzed the bioactivity of these compounds in a human cell-based assay. None of the OFRs present in the samples showed estrogenic responses (Ballesteros-Gomez et al., 2016; Van Bergen et al., 2015). One recent study tested the casings of select electronics (*i.e.*, TVs, laptops, desktops, and household appliances) in Canada for OFRs using wipe samples and found that a majority of the samples contained an OFR, such as TDCPP, DBDPE, EH-TBB and BEH-TBP. They also collected dust samples and found a correlation between OFR wipe levels and their levels in dust, suggesting that products with the highest OFR concentrations contribute most to concentrations in dust (Abbasi et al., 2016).

c. Measurement of OFR metabolites and biomonitoring

Researchers suggest that the metabolites formed by the metabolic transformation of OFRs may be useful for human biomonitoring (HBM). The dialkyl- and diaryl phosphates that are generated are eliminated in the urine efficiently and represent the main part of the excreted metabolites, and methods have been developed to detect some of these metabolites (Cooper et al., 2011; Fromme et al., 2014). A recent study measured TBBA, a metabolite of EH-TBB, in >70% of urine samples and suggested that it would be a good biomarker of exposure to FM550. These TBBA levels were significantly associated with EH-TBB levels measured in hand wipes (Dishaw et al., 2014b; Hoffman et al., 2014). A metabolite of TDCPP (bis (1,3-dichloropropyl) phosphate (BDCPP)) was detected in urine samples from men in the United States, and TDCPP in the house dust may have been a source of exposure (Meeker et al., 2013). BDCPP was also detected in paired urine samples in U.S. mothers and their toddlers, with higher concentrations in the children, compared to the mothers, suggesting higher child exposure. These studies suggest that these metabolites may be useful urinary biomarkers of exposure; however, the potential toxicity of these metabolites is unknown (Butt et al., 2014; Dishaw et al., 2014b; Hoffman et al., 2014). Breast milk may be another source for OFR biomarkers of exposure, given that its high fat content makes it amendable for chemical analysis (Fromme et al., 2016). However, methods for estimating daily intakes from HBM data are not yet available for the majority of FRs.

6. REGULATORY AGENCIES' ACTIVITIES ON ORGANOHALOGEN FLAME RETARDANTS

a. CPSC

CPSC staff has been concerned with FR chemicals in consumer products since the 1970s, including conducting laboratory research and health risk assessments. These activities have been largely in connection with flammability standard development for consumer products, such as upholstered furniture and mattresses. These standards are generally performance based and do not require the use of FR chemicals to meet them.

i. Sleepwear

Following the completion of an NTP bioassay, staff assessed the cancer risk from Tris. The Commission subsequently determined that children's sleepwear treated with Tris was a hazardous substance, and therefore, banned under the FHSA due to mutagenicity concerns (CPSC, 1977); however, the ban was later overturned in federal court for procedural reasons. Although the Tris ban was overturned, most manufacturers stopped using FR chemicals in consumer apparel, including voluntarily stopping TDCPP use in children's sleepwear (Sanders, 1978). In 1987, the U.S. Environmental Protection Agency (EPA) issued a significant new use rule (SNUR), which effectively banned the manufacture or importation of Tris (52 FR 2703, January 26, 1987). 41 C.F.R. 721.6000.

ii. Upholstered Furniture

CPSC staff has assessed the potential health risks associated with FR use in upholstered furniture cover fabrics and foam. CPSC staff completed toxicity reviews on 16 classes of FR chemicals (more than 50 chemicals) suggested for use in upholstered furniture fabrics by the public. These reviews were part of the risk assessment process for the draft standard (59 FR 30735) (Babich and Saltzman, 1999; Bittner, 1999b; Bittner et al., 2001; Ferrante, 1999a; Ferrante, 1999b). Staff's toxicity reviews contributed to a National Research Council (NRC) report mandated by Congress on these 16 FR chemicals/classes. NRC concluded that eight of the 16 chemicals or classes (including HBCD and DecaBDE) could be used in upholstered furniture fabrics without presenting a risk to consumers. NRC also recommended additional toxicity and exposure studies for the remaining eight FRs. These remaining eight included TDCPP and chlorinated paraffins (NRC, 2000). CPSC staff performed exposure studies on the release of the remaining eight FRs from this NRC study for furniture fabrics and completed a risk assessment of these FR chemicals (Babich and Thomas, 2001). Staff concluded that DecaBDE and HBCD were among the five[29] FR chemicals that would not present a hazard to consumers under this use scenario and that additional toxicity and exposure data were needed on the remaining chemicals,[30] including TDCPP (Babich and Thomas, 2001).

CPSC staff published an updated draft standard in 2005 to reflect input from the public that upholstery cover fabrics would not use FR treatment to comply; rather, flexible polyurethane foam or other filling materials would require FR treatment to meet the draft standard (CPSC, 2006). As discussed above, PBDEs were voluntarily taken off the market in December 2004. Therefore, when staff conducted the risk assessment, a number of alternative FR treatments were available, including TDCPP and several new proprietary formulations, such as FM550 (EPA, 2005). Staff concluded that TDCPP might present a hazard to consumers and suggested that additional exposure data, such as vapor-phase emissions of TDCPP were needed. The staff also concluded that there was insufficient information on the toxicity of FM550 or its components to assess their potential health risks (Babich, 2006).

iii. Mattresses

CPSC staff assessed the risk of FR chemicals (*i.e.*, antimony trioxide, boric acid/zinc borate, DecaBDE, melamine, and vinylidene chloride) used in mattresses to support the development of the CPSC's 2006 flammability standard (16 C.F.R. part 1633; 71 FR 13472) (Thomas and Brundage, 2006). To meet the proposed mattress performance standard, mattress manufacturers would be able to select from a number of available technologies, such as barriers, which might contain FR chemicals. To quantify the amount of FR chemical(s) that may be released from the barriers, the CPSC's Laboratory Sciences Chemistry staff conducted migration/exposure assessment studies on FR-treated mattress barriers. The result of the exposure assessment for DecaBDE showed relatively low levels released from the barrier, even with aggressive

[29] The five FRs were: Cyclic phosponate esters (CPE), Decabromodiphenyl ether (DecaBDE), 2-Ethylhexyl diphenyl phosphate (EHDP), HBCD, and Phosphonic acid, (3-([hydroxymethyl]amino)-3-oxopropyl)-, dimethyl ester (PA)).

[30] Antimony Trioxide (AT), TDCPP, and Tetrakis(hydroxymethyl) phosphonium chloride (THPC).

extraction, suggesting DecaBDE is a durable FR treatment for barrier use in mattresses. All chemicals tested for use in barriers were not expected to pose any appreciable risk of health effects to consumers who sleep on these mattresses with treated barriers (Thomas and Brundage, 2006).

iv. Children's Products

CPSC is currently studying the use of FRs in children's products. These are products commonly found in the home as of 2014, and that represent many product categories (*i.e*., nursing pillows, upholstered chairs, crib mattresses, soft carriers, infant car seats (hard carriers). In phase I of this study, which is ongoing, staff is testing select children's products for the presence of FRs. Thus far, staff has detected OFRs in about 22 percent of the children's products tested that contained polyurethane foam. Although most of the FRs detected are commonly used, some of the FRs were not identified and likely represent novel compounds. Phase II is to conduct exposure studies, and Phase III is to perform risk assessments.

b. U.S. and Other Countries

In 2004, PentaBDE and OctaBDE were voluntarily removed by manufacturers in the United States (EPA, 2015; Meeker and Stapleton, 2010; Watkins et al., 2012). That same year, the European Union banned the same two FRs. PentaBDE and OctaBDE are now listed as "persistent organic pollutants" under Annex A of the Stockholm Convention (Abou-Elwafa Abdallah et al., 2016; Butt et al., 2016; Buttke et al., 2013). In 2008, the European Union banned DecaBDE in electrical and electronic applications. A voluntary phase-out of DecaBDE in all products occurred in the United States in 2013 (Butt et al., 2016; Dodson et al., 2012; Knudsen et al., 2016b; Van Bergen et al., 2015).

Due to concerns of the health effects of OFRs, some states have restricted their use. In 2012, the major United States manufacturer of TDCPP announced its voluntary phase-out of production by 2015 (EPA, 2015; ICL-IP, 2012), and some states, such as Vermont, New York, Oregon, Maryland, and Washington, have banned or placed restrictions or reporting requirements on TDCPP and TCEP use in children's products. Minnesota has also placed use restrictions on these FRs in residential upholstered furniture. In 2008, Washington passed the Children's Safe Products Act, which requires manufacturers of children's products sold in Washington to report if their product contains a Chemical of High Concern to Children. This reporting list contains five organohalogen flame retardants (DecaBDE, TBBPA, TCEP, TDCPP, and HBCD (Davies, 2015; Van Bergen et al., 2015). In 2014, the EU banned TDCPP, TCEP, and TCPP from toys, and Canada prohibited the use of TCEP in polyurethane foam intended for children age 3 and under (Canada, 2014; Schreder et al., 2016; Van Bergen et al., 2015). In California, TDCPP and TCEP are listed as Prop 65 chemicals for concerns about carcinogenicity (CalEPA, 2011). Due to TCEP's carcinogenic potential, its use and production have decreased significantly, and TCEP is no longer produced in the European Union (Follmann and Wober, 2006). In 2015, the Alaska

Federation of Natives passed a resolution (Resolution 15-17) asking the Alaska State Legislature to ban 10 flame retardants from use in children's products and furniture.[31]

Given these studies measuring OFRs in environmental media and health concerns, the EPA prepared a fact sheet on how to decrease indoor exposure through vacuuming, dusting, and hand washing (EPA, 2016b). Additionally, associated with the newly passed Technical Bulletin (TB) 117-2013, is California Senate Bill 1019, which requires upholstered furniture to be labeled to indicate whether it contains FR chemicals. These two measures provide consumers with guidance on these OFRs and potential exposure (BEARHFTI, 2015).

Currently, EPA is currently evaluating FRs, including OFRs, under the Toxics Substances Control Act. CPSC and EPA staff members are sharing information to prevent duplicating efforts.

7. DISCUSSION

Toxicity

The petitioners stated: *"due to their inherent physico-chemical properties, additive OFRs . . . are toxic."* Staff considers OFRs to represent a broad class of chemicals defined largely by their functional use and the presence of a halogen, such as a bromine or chlorine. As discussed, OFRs represent several subclasses of chemicals, such as PBDEs, brominated aromatic FRs, brominated aliphatic FRs, and chlorinated alkyl phosphates. The varying toxicological properties of individual OFR compounds indicate that OFRs, in fact, represent several subclasses of chemicals that should be examined separately. However, even then, members within the same subclass may differ in the effects that they cause, their potency, and bioaccumulation potential. As discussed, many of the chlorinated alkyl phosphates are carcinogenic, but their MOAs appear to vary, and there are no clear structure-activity relationships. The tris alkyl phosphates also show evidence of neurotoxicity, but additional neurotoxicity studies, particularly studies on developmental neurotoxicity in mammals, are needed. Although PBDEs (representing certain brominated OFRs) have a relatively high bioaccumulation potential, other brominated OFRs, such as TBB and TBBPA, show a low potential for bioaccumulation. Despite these differences, there are likely to be similarities within each subclass. For example, most brominated FRs have effects on the thyroid, at least at high doses. Due to the varying toxicological properties among OFR subclasses (and even within those subclasses) and the many data gaps relating to toxicity, available data indicate that one cannot consider OFRs as a class under the FHSA because every OFR cannot be concluded to meet the toxicity prong of the FHSA's definition of "hazardous substance."

Overall, toxicity data are incomplete, limited, or lacking for some individual OFR compounds, as shown in Table 2. Many of the studies cited by the petitioners are suggestive, but are insufficient to conclude that they are all likely to cause similar effects in humans. For example, the petitioners cited *in vitro* studies or studies on invertebrates that identify the need for additional

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studies in mammals. Most of the epidemiological studies cited in the Petition identify associations; however, these studies cannot rule out confounding factors. Under CPSC's chronic hazard guidelines, to conclude that a chemical is "probably toxic to humans" requires either sufficient evidence in animal studies or limited evidence in humans (CPSC, 1992). Sufficient evidence in animals generally means a statistically significant effect in multiple species, multiple sexes, at multiple doses, or by multiple routes of administration. Limited evidence in humans means having a statistically significant effect when causality is plausible, but chance, bias, or confounders cannot be ruled out.

Although FR chemicals reduce ignition potential, FR-treated products may extend the smoldering time, and will ignite if exposed to sufficiently high temperatures. Combustion byproducts, produced when products with and without OFRs burn, have been studied and measured in fire effluents from FR and non-FR treated products. However, it is debatable if the smoke toxicity from the combustion of products with OFRs is more toxic to consumers than without FRs, and likewise, unclear how this toxicity may impact consumers' ability to safely egress from a fire scenario. Therefore, more research is needed on how much of an effect FRs have on the toxicity of smoke to consumers.

<u>Exposure</u>

The petitioners stated: *"due to their inherent physico-chemical properties, additive OFRs migrate out of products regardless of how the product is used; thus, there is a nexus between the mere presence of products containing these chemicals and exposures that put consumers at risk of harm."* As discussed, additive FRs are not chemically bound to their matrix, and they tend to migrate from products. Most OFRs are SVOCs, which tend to adhere to dust particles and surfaces in the home. Exposure data, such as dermal absorption factors, for many OFRs are lacking. HBM data, such as measurements of FRs in urine or blood, demonstrate that exposure and uptake occur. Petitioners state that, according to the Centers for Disease Control and Prevention (CDC), 97 percent of people living in the United States have measurable quantities of OFRs in their blood. However, the mere presence of a chemical, including those that may be considered toxic under the FHSA, in a person's blood or urine is not enough to demonstrate that an item containing that chemical is a "hazardous substance" under the FHSA because levels may indicate exposures that are too low to cause adverse effects in humans. In addition, for most OFRs there is insufficient information to estimate exposure from urine or blood levels. HBM and environmental data do not reveal the source of the exposure. Rather, both types of data represent exposure from all sources (including food and vehicles). Thus, it is not possible to determine that adverse health effects result from exposure to OFRs in the specific products in these categories that the petitioners identify. Accordingly, these data are not an accurate measure of OFR exposure relating to those enumerated categories. For the Commission to issue the regulation that the petitioners request based on exposure to dust, the Commission would need to determine a connection between the four product categories covered in the Petition and OFRs measured in household dust. Petitioners have not submitted data establishing this connection, and staff is not aware of such information. In the absence of exposure data relating to the specified product categories in the Petition, it would be difficult for the Commission to determine that those categories of products that contain OFRs are "hazardous substances."

There are important differences among individuals, such as pre-existing conditions and genetics, which affect their likelihood of developing an adverse health effect from chemical exposure. Additionally, the likelihood of exposure to chemicals is also specific per individual and impacts the amount of chemical to which someone may be exposed. The relative contribution of ingestion, dermal contact, and inhalation to the overall human exposure to these OFRs is unknown, although some studies have estimated exposure to some OFRs (Hoffman et al., 2015; La Guardia and Hale, 2015). In different parts of the world, different exposure pathways have been determined as most important for exposure and body burden of PBDEs; in Europe, ingestion through diet and dust are stated as the most important for exposure; whereas dust ingestion and dermal absorption are reported in the United States (Abou-Elwafa Abdallah et al., 2016; Lorber, 2008). One exposure route with little data is dermal contact. One study did perform experiments using *ex vivo* human skin and a human equivalence model to assess dermal absorption of chlorinated OFRs and to determine implications of hand washing to exposure. The model was more permeable to these compounds than the *ex vivo* skin, with the *ex vivo* values similar to another study. Hand washing reduced the overall dermal absorption of these FRs, with varying results, depending on the properties of the OFR (Abou-Elwafa Abdallah et al., 2016). Therefore, the extent of exposure and relative importance of different exposure routes are likely to depend on the specific FR chemical and specific product.

Use of Surrogate Data

Although many data gaps exist concerning the toxicity and exposure data for OFRs, the petitioners are asking the Commission to conclude that OFRs, where limited or no data are available, possess the same toxicity and exposure potential as OFRs where data exist. The petitioners ask the Commission to use these conclusions to determine that products in these four product categories are "banned hazardous substances" if they contain any OFRs. This constitutes a "surrogate data" approach. The Commission's chronic hazard guidelines (16 C.F.R. §1500.135), discuss the use of surrogate data in the context of exposure assessment. The guidelines indicate that surrogate exposure data may be used in limited circumstances, including identifying whether more data are needed, and whether additional studies are necessary. The preamble to the guidelines (CPSC. 1992) provides additional discussion of the limitations on the use of surrogate data. Surrogate exposure data cannot be used to determine the exposure potential of an unstudied OFR for regulatory decision making because chemical specific data would be needed for a robust assessment to support a regulation. Staff notes that the guidelines do not address the use of surrogate data for determining toxicity of a chemical where no toxicity data are available. Currently, staff considers the tools available to assess the toxicity of a chemical, without data specific to that chemical, are too limited to allow surrogate data to be used for toxicological assessments for regulatory decisions. Therefore, OFRs could not be assessed at the class level by staff under the FHSA.

Scope of the Petition

The abundance of products in these four categories, the unknown number of OFRs in use, and the lack of data on their associated health effects limit assessing their risk to consumers under the FHSA. Most of the environmental data on OFRs are from dust or air in the indoor environment. However, many studies have small sample sizes and different collection methodologies, leaving it difficult to compare and assess these studies (Mitro et al., 2016). Additionally, it is unknown what products these chemicals are coming from when they are measured in dust or indoor air for potential exposure. One study tried to elucidate the relationships between FR sources and FR concentrations in dust and air by using detailed questionnaires and FR measurements. The study reported specific brominated FR sources for some microenvironments, such as foam in furniture and mattresses and total number of electronic/electrical devices (de Wit et al., 2012). However, some of the study's correlation coefficients were low, indicating other sources may have not been accounted for in the questionnaire. The authors noted the importance of including a variety of microenvironments with varying room contents and a large sample size to prove correlation (de Wit et al., 2012). As this study shows, to have a high correlation from OFR content in a product to its measurement in a medium, such as dust, a large sample size and many different indoor environments would need to be included. In addition, the exposure potential of that medium and toxicity information on the specific OFR would need to be understood for any risk assessment under the FHSA.

Regulatory Activities

Regulatory activities on OFRs, such as regulations by states within the United States, EPA, and the European Union, as well as public awareness, may change or has changed the landscape of FR usage in the four product categories specified in the Petition. In fact, levels of some bioaccumulative compounds are steadily decreasing in the U.S. population following regulatory bans and voluntary phase-outs. For example, bans and phase-outs of certain PBDEs have led to declines in concentrations measured in pregnant women (Morello-Frosch et al., 2016).

CPSC staff does not know the extent to which OFRs are being used in the four product categories in the Petition. Staff would need to analyze products in these categories to determine OFR usage, and therefore, exposure potential. The petitioners cited numerous studies showing the presence of OFRs in products. However, regulatory actions, such as the revision of TB 117, appear to be affecting changes in OFR usage. Thus, many of the studies cited by the petitioners are outdated and may not reflect the current usage of OFRs in these product categories. For example, CPSC staff is currently studying FR chemicals in children's products. From the first phase of this project, CPSC staff found that 7 percent of the overall products contain an OFR (22% of the products with polyurethane foam contain an OFR). This is a lower frequency of detection than in many reports in the literature. Staff has also determined that another 5 percent of the products contain a phosphate FR; however, staff is unable to identify some of these phosphate FRs due to lack of analytical standards, which have not previously been reported in the literature. Some OFRs are added intentionally for purposes that are not FR related, such as flexibility, which the petitioners' state is not included in this Petition. Therefore, if an OFR is measured, determining whether it was added for its FR properties would be difficult.

Finally, EPA is currently investigating the toxicity and exposure potential of some of these OFRs as part of their first chemicals to review under the Frank R. Lautenberg Chemical Safety for the 21st Century Act, which amends the TSCA. These chemicals are broken out into similarly structured clusters within the OFR category, such as cyclic aliphatic bromides (EPA, 2016a). After this work is completed, EPA may consider a regulatory path forward on these chemicals. CPSC staff is working closely with EPA to coordinate on FR activities.

8. CONCLUSIONS

The varying toxicological properties of individual OFR compounds indicate that OFRs, in fact, represent several subclasses of chemicals that should be examined separately. In addition, toxicity data are incomplete, limited, or lacking for some individual OFR compounds. Under CPSC's chronic hazard guidelines, to conclude that a chemical is "probably toxic to humans" requires either sufficient evidence in animal studies or limited evidence in humans. Most of the epidemiological studies cited by the petitioners are limited by their study design and have not been replicated. Therefore, due to the varying toxicological endpoints among OFR subclasses (and even within those subclasses) and the many data gaps relating to toxicity and exposure data, staff believes that insufficient data exist to assess OFRs as a class under the FHSA. Additionally, due to this limited data, petitioners are asking the Commission to conclude that OFRs, where limited or no data are available, possess the same toxicity and exposure potential as OFRs where data exist. The guidelines indicate that surrogate exposure data may be used in limited circumstances, including identifying whether more data are needed and whether additional studies are necessary; however, these data cannot be used to determine the exposure potential of an unstudied OFR for regulatory decision making because chemical specific data would be needed for a robust assessment to support a regulation. Staff notes that the guidelines do not address the use of surrogate data for determining toxicity of a chemical, where no toxicity data are available. Therefore, since the limited toxicity and exposure data on OFRs show variation in toxicity under the FHSA and in exposure potential, OFRs could not be assessed at the class level by staff to conclude that all products defined by the petitioners with OFRs were hazardous substances under the FHSA.

The petitioners cite a number of studies showing the presence of OFRs in products. However, regulations by states, the EPA, and the European Union appear to affect how, and in what products, OFRs are being used. In addition, new FRs are being introduced, and analytical standards are not available to identify these FRs. Therefore, staff would need to conduct additional studies to identify which FRs are being used in which products. This would be a difficult and resource-intensive task, due to the large number of products, the introduction of new FRs, and their constantly changing use patterns.

Although there are studies demonstrating human exposure to OFRs, most of the studies cited by the petitioners cannot be linked to specific products. HBM and environmental data do not reveal the source of the exposure. Rather, both types of data represent exposure from all sources (including food and vehicles). Thus, it is not possible to determine that adverse health effects result from exposure to OFRs in the specific products in these categories that the petitioners identify. Accordingly, these data are not an accurate measure of exposure relating to those enumerated categories. In addition, for most OFRs, there is insufficient information to estimate exposure from urine or blood levels. The abundance of products in these four categories, the unknown number of OFRs in use, and the limited and varied toxicity and exposure data on OFRs make regulating the entire class of OFRs infeasible under the FHSA.

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TAB C: Division of Laboratory Sciences Engineering Response to the Petition

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UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MARYLAND 20814

Memorandum

May 18, 2017

TO: Melanie Biggs, Ph.D., Project Manager
Directorate for Health Sciences, Division of Toxicology and Risk Assessment

THROUGH: Andrew G. Stadnik, P.E., Associate Executive Director
Directorate for Laboratory Sciences

Allyson Tenney, Division Director
Directorate for Laboratory Sciences, Division of Engineering

FROM: Paige Witzen, Textile Technologist
Directorate for Laboratory Sciences, Division of Engineering

SUBJECT: Applicable Flammability Standards and Activities for Children's Products, Upholstered Furniture, Mattresses, and Mattress Pads for Proposed Petition HP 15-1

1. Introduction

Petition HP 15-1 asks the U.S. Consumer Product Safety Commission (CPSC, or Commission) to initiate rulemaking for products in the categories of upholstered furniture, mattresses and mattress pads, children's products, and plastic enclosures in electronics containing any non-polymeric, additive, organohalogen flame retardants (OFRs) to be banned under the Federal Hazardous Substances Act (FHSA) due to the possibility of adverse health effects of the chemicals. This memorandum reviews the applicable mandatory flammability standards, voluntary standards, and other activities pertaining to the products specified by the petitioners.

2. Applicable Mandatory Standards for Clothing Textiles, Children's Sleepwear and Mattresses

There are many regulated products under the Flammable Fabrics Act (FFA). The applicable standards under the FFA for the products mentioned in the Petition include clothing textiles, children's sleepwear, and mattresses and mattress pads.

a. Clothing Textiles

The Standard for the Flammability of Clothing Textiles, codified at 16 C.F.R. part 1610, was developed to address the risk of burn injury from dangerously flammable textiles. Flammable brushed rayon cowboy chaps, brushed rayon sweaters, and other dangerously flammable fabrics in interstate commerce resulted in the enactment of the FFA in 1953. Since the enactment of the FFA, the number of burn injuries and fatalities from dangerously flammable apparel fires (for adults and children) has been reduced. Although a specific study of the number of apparel injuries has not been conducted by the CPSC in many years, CPSC collects and maintains data on incidents involving apparel.

All textiles used to make clothing for adults and children's daywear are within the scope of this Standard. The Standard specifies testing procedures and determines the relative flammability of textiles used in apparel using three classes of flammability performance. Part 1610 is a performance standard that does not prescribe or prohibit any specific components, such as flame retardants (FRs), to be used to meet the Standard. Most fabrics are able to meet the Standard, based on their fabric weight and/or fiber content, without being treated with FRs. Based on years of test data, part 1610 contains exemptions that allow for specific fiber types and fabric weights with specific construction to be exempt from testing. Certain durable infant and toddler products that include textiles and that are worn are required to meet this Standard, e.g. soft infant carriers and slings.

b. Children's Sleepwear

There are two standards under the FFA that address the flammability of children's sleepwear, 16 C.F.R. parts 1615 and 1616. These Standards were developed to prevent children's sleepwear from igniting due to exposure to certain ignition sources, such as matches, lighters, candles, and space heaters. All "children's sleepwear," as defined in the Standards, its fabric, seams and trim, must meet these Standards before entering commerce. Children's sleepwear must meet more stringent flammability requirements, compared to the requirements for children's daywear, which is subject to part 1610. The children's sleepwear fabrics, seams and trim must be flame-resistant and self-extinguish when removed from the small ignition source. In general, some fabrics, such as polyester, are able to meet the requirements without additional treatments, like FRs. Other fabrics, such as cotton and cotton-blends, typically must be treated with a chemical finish, like FRs, to meet the flammability requirements. To maintain flammability performance, the test procedures are conducted on finished items and after 50 washing and drying cycles. The Children's Sleepwear Standards are performance-based and do not require or prohibit any specific fibers or components. The Standards do not require the use of FRs to meet the flammability requirements. In 1977, the Commission determined that tris(2,3 dibromoprophyl) phosphate (Tris) was a hazardous substance, and therefore, it was banned under the FHSA for use in children's sleepwear due to mutagenicity concerns.[32] However, the ban was later overturned in federal court for procedural reasons. Although the Tris ban was overturned, most manufacturers stopped using FR chemicals in consumer apparel, including voluntarily stopping Tris (1,3-dichloro-2-propyl)phosphate (TDCPP) use in children's sleepwear.[33]

[32] CPSC. 1977. Children's wearing apparel containing TRIS; interpretation as a banned hazardous substance. Federal Register. 42:18850-18854. [Later withdrawn following judicial proceedings.].
[33] Sanders, H.J. 1978. Flame retardants. Chemical and Engineering News. 56:22-36

Parts 1615 and 1616 define "tight-fitting" sleepwear garments and exempt those garments from testing. Many tight-fitting garments are made from other fibers, *e.g.*, cotton and cotton blends, with no chemical treatments. Tight-fitting sleepwear must meet specific dimensions and is still subject to 16 C.F.R. part 1610.

c. Mattresses

The CPSC administers two Standards for mattresses under the FFA to address the flammability of mattresses and mattress pads that include 16 C.F.R. part 1632 and 16 C.F.R. part 1633. Products that are subject to these Standards must meet both of these Standards in order to be sold in the United States.

The regulation at part 1632 tests the flammability of mattresses and mattress pads when exposed to a standardized, smoldering cigarette. The prototype is tested in the bare and sheeted configurations. All sleep surfaces are tested. The pass/fail criterion for this test method is that the char length cannot exceed 2 inches in any direction for each location where the cigarettes are placed on the sample. The test may be stopped before the char length reaches 2 inches if there is obvious ignition of the sample. This Standard is a performance standard and does not require or prohibit specified components, including the use of FRs.

Part 1633 prescribes a full-scale test method that establishes flammability requirements for mattresses and mattress sets. The test method uses two gas burners as the ignition sources, which are applied to the top and side of the mattress for 70 seconds (s) and 50 s, respectively. Within the 30-minute period, the total heat release cannot exceed 15 megajoules (MJ) in the first 10 minutes of the test, and the peak rate of heat release cannot exceed 200 kilowatts (kW) during the 30-minute test. This is a performance standard that does not prescribe or prohibit the use of any specific components, such as FRs. Manufacturers choose how they design their product to meet the requirements.

Mattress manufacturers have numerous technologically feasible and viable solutions, including fiber and fabric barriers, for meeting the requirements set forth in the Standards. In the development of part 1633, the CPSC carefully considered the various fibers and treatments used in these barriers. CPSC staff conducted a quantitative risk assessment to provide an estimate of the potential risk to consumers associated with exposures to select FRs in commercially available treated barriers that may be used by mattress manufacturers to meet the proposed flammability standard. CPSC staff concluded that these commercially available FR-treated barriers could be used to meet part 1633, and they are not expected to pose any appreciable adverse health effects to consumers who sleep on mattresses using them.[34] The mattress industry has consistently stated to the CPSC that they do not use FR chemicals in their manufacturing and rely on various technologies to create compliant products.[35] According to the International Sleep Product

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[34] Thomas and Brundage. Quantitative assessment of potential health effects from the use of flame retardant (FR) chemicals in mattresses. Briefing Package. Final Rule for the Flammability (Open Flame) of Mattress Sets. Tab D. 2006. http://www.cpsc.gov/PageFiles/88208/matttabd.pdf

[35] Notice of Proposed Rulemaking for 16 C.F.R. part 1633: Standard for the Flammability of Mattresses and Mattress Sets. July 1, 2007.

Association (ISPA), the trade association for the mattress industry, the United States mattress industry does not spray finish mattresses with any FR chemicals to meet federal standards for residential mattresses, and they oppose any standards that require using FRs.

3. Additional Discussion of Carriers, Slings, and Toys

a. Relevant CPSC Standards and Staff Work on Children's Products

In addition to clothing, children's sleepwear and mattresses, certain children's products are subject to one of the Standards under the FFA, 16 C.F.R. part 1610. One of the product categories subject to part 1610 is "infant and toddler carriers." These products are in scope because they are comprised of textiles and are worn by the user. For example, the Commission approved a federal safety standard for sling carriers in January 2017, which incorporates by reference ASTM F2907-14: Standard Consumer Safety Specifications for Sling Carriers and references 16 C.F.R. part 1610 for the flammability performance of sling carriers. The same rationale for including a flammability requirement for this product exists. Fabrics that meet one of the specific exemptions in §1610.1(d) do not require flammability testing to show compliance with the Standard. A majority of fabrics used for slings are plain-surface textiles and have a fabric weight above 2.6 ounces per square yard and would be exempt from testing.

b. FRs in Children's Products

CPSC is currently studying the use of FRs in children's products. These are products commonly found in the home as of 2014, and represent many product categories (*i.e.*, high chairs, upholstered chairs, crib mattresses, soft infant carriers, and hard infant carriers). In Phase I of this study, which is not yet complete, staff is testing select children's products containing polyurethane foam for the presence of FRs. Thus far, staff has detected OFRs in about 22 percent of the products tested containing polyurethane foam. Although most of the FRs are commonly used, some of the FRs were not identified and likely represent novel compounds. Phase II is to conduct exposure studies, and Phase III is to perform risk assessments.

c. Applicable Standards for Toys

The mandatory standard for toys is ASTM F963, 2011: *Standard Consumer Safety Specification for Toy Safety*. In this standard, 16 C.F.R. part 1610 is referenced for toys containing textile materials, and 16 C.F.R. § 1500.44, *Method for Determining Extremely Flammable and Flammable Solids*, is referenced for non-textile materials found in toys. As stated, 16 C.F.R. part 1610 is a performance-based standard with classification criteria, for which the use of FRs is not required. The regulation at 16 C.F.R. §1500.44 is a test method and does not have pass/fail criteria, and therefore, does not require the use of FRs.

Under the International Organization for Standardization (ISO), the applicable standard is ISO 8124-2, 2007: Safety of Toys—Part 2: Flammability. It is similar to 16 C.F.R. part 1610, except for language stating that the burner impinges on the bottom edge of the fabric, rather than the surface of the fabric, and the flame is applied for 10 s rather than 1s for part 1610. This Standard has specifications for materials that cannot be used in these products, such as cellulosic material, highly flammable materials and volatile gases. This Standard is otherwise performance-based and requires products to meet specified rates of flame spread, depending on the type of toy.

5. Upholstered Furniture

a. *Applicable CPSC Standards and Staff Work on Upholstered Furniture*

The Commission is in rulemaking to develop a mandatory standard to address the flammability of upholstered furniture under the FFA. Currently, there are no federal mandatory flammability standards for upholstered furniture.

To support the rulemaking to develop a mandatory flammability standard for upholstered furniture, CPSC staff began assessing possible solutions or treatments that manufacturers might use to meet a standard and eliminate or reduce possible adverse health effects to consumers. Staff completed a quantitative risk assessment to evaluate the potential health risks associated with FR use in upholstery fabric treatments. Staff concluded that two of the five FRs would not present a hazard to consumers under this use scenario, and decided that additional toxicity and exposure data were needed on the remaining chemicals.[36]

On March 4, 2008, the Commission issued a notice of proposed rulemaking (NPR) for a flammability standard for residential upholstered furniture under the FFA. The NPR was for a performance-based standard that would not require the use of FR chemicals. CPSC is involved in active rulemaking, and additional actions on upholstered furniture have not been determined; at this time, the Commission has not directed further action.

In support of the NPR, CPSC staff conducted an exploratory study of upholstered furniture constructed using components with enhanced flammability properties (barrier fabrics). The barrier fabrics are commercially available because they are used by the mattress industry to meet part 1633. The different barriers contained fibers composed of cellulosic fibers, a combination of fibrous glass modacrylic and polyester fibers, modacrylic fibers and silica, and two types composed of rayon and polyester. Of the barriers used during testing, none contained OFRs.[37]

b. *History of TB 117 and TB 117-2013*

Technical bulletin (TB) 117 and TB 117-2013 are Standards developed by the State of California. TB 117 was developed in 1975, and amended in 2013. Currently, California is the only state to have a mandatory flammability standard for residential upholstered furniture. The Standard is mandatory for furniture sold in California; however, manufacturers often sell furniture across the United States and Canada that complies with California state requirements.

[36] Babich, M.A., and T.A. Thomas. 2001. CPSC staff exposure and risk assessment of flame retardant chemicals in residential upholstered furniture. B. U.S. Consumer Product Safety Commission, MD 20814.
[37] Fansler, L. 2016. Summary Report of Open Flame and Smoldering Tests on Chairs. U.S. Consumer Product Safety Commission. Rockville, MD.

The Standard started when the Bureau of Home Furnishings and Thermal Insulation (BHFTI) now called the Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (BEARHFTI) created and enforced the mandatory Standard TB 117 Requirements, Test Procedure and Apparatus for Testing the Flame Retardance of Resilient Filling Material used in Upholstered Furniture in October 1975. This Standard required the testing of all cover fabrics, fillings, and stuffing materials used in upholstered furniture to be both open-flame and smolder-resistant for upholstered furniture sold in California, with a larger focus on open flames. The TB 117 testing requirements consisted of a component test rather than a combined test of the materials used in the finished product. To meet the testing requirements for TB 117, manufacturers typically used foam treated with FRs. Studies performed by BEARHFTI, National Bureau of Standards (now the National Institute of Standard and Technology (NIST)), and CPSC concluded that cover fabrics have a bigger impact on the fire performance than filling materials, and FR foam can increase smolder propensity compared to untreated foam.[38,39,40,41,42]

BEARHFTI revised and reissued TB 117 in 2013 (TB 117-2013). The revised Standard was expanded to cover fabrics, decking materials, barrier materials, and filling materials and their interactions. The revision also exempted the foam used in many children's products from testing in the Standard. The revised TB 117-2013 is based on the ASTM E-1353-08a standard. Manufacturers were able to update to TB 117-2013 testing requirements on January 1, 2014, and all manufacturers were required to follow TB 117-2013 requirements by January 1, 2015. The open-flame test was discontinued, and the smolder test was revised in this version of the Standard. Although TB 117-2013 does not ban the use of FRs, the new performance measures defined in TB 117-2013 make it possible for manufacturers to meet the Standard without the use of these chemicals. In response to the Petition, CPSC received comments from the American Home Furnishings Alliance (AFHA), which represents the upholstered furniture industry, stating that they do not use FRs in manufacturing upholstered furniture.[43]

c. *Relevant Voluntary and International Standards for Upholstered Furniture*

There are several voluntary standards that apply to upholstered furniture. The Upholstered Furniture Action Council (UFAC), founded in 1978, introduced a voluntary test standard in 1979, to measure the cigarette ignition resistance of furniture components, including cover fabric and filling materials. This is a voluntary program, but it is widely adopted by furniture manufacturers.

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[38] Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation Laboratory Data, "Development of a Flammability Standard for Testing the Smolder Resistance of Upholstered Furniture," October 2012.
[39] Babrauskas, V.; Krasny, J.F. "Fire Behavior of Upholstered Furniture," National Bureau of Standards, November 1985.
[40] "Upholstered Furniture Flammability: Regulatory Options for Small Open Flame & Smoking Material Ignited Fires," U. S. Consumer Product Safety Commission, October 1997.
[41] Fansler, L.; Scott, L. Memorandum to D. Ray, "Performance Criteria, and Standard Materials for the CPSC Staff Draft Upholstered Furniture Standard," U. S. Consumer Product Safety Commission, May 2005.
[42] Mehta, S. Memorandum to D. Ray, "Upholstered Furniture Full Scale Chair Tests – Open Flame Ignition Results and Analysis," U. S. Consumer Product Safety Commission, May 2012.
[43] Comment Docketed as: CPSC-2015-0022-0077.

There are two voluntary standards developed by different standards development bodies that are based on UFAC. The National Fire Protection Association (NFPA) issued NFPA 260 – *Standard Methods of Tests and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture*. ASTM International also has a standard, ASTM E1353 – *Standard Test Methods for Cigarette Ignition Resistance of Components of Upholstered Furniture*. The NFPA and ASTM standards are very similar in that they measure the cigarette ignition resistance of the upholstered furniture components (cover fabric, interior fabric, welt cord, filling/padding, barrier material, and decking material) using small mock-up assemblies that have the same dimensions. These methods also classify the furniture components into two categories, depending on performance. Components are not evaluated together, as found in furniture; rather, components are evaluated individually. These standards are performance-based and do not require that specific chemicals be used to meet them. These two standards are also currently being updated, and it is not known what changes may be made.

There are two ISO standards that apply to upholstered furniture. The first standard is ISO 8191-1, 1987: *Furniture—Assessment of the Ignitability of Upholstered Furniture—Part 1: Ignition Source: Smoldering Cigarette*. The standard tests a combination of cover and filling materials that represent real assemblies that can be used in full-scale furniture when exposed to a cigarette ignition source. There are specifications given for the size and burn rate of the cigarette ignition source. The second standard is ISO 8191-2, 1988: *Furniture—Assessment of the Ignitability of Upholstered Furniture—Part 2: Ignition Source: Match-Flame Equivalent*. This standard assesses the ignitability of material combinations, such as covers and fillings, used in upholstered furniture when subjected to a small flame as an ignition source. Both of the ISO standards are performance-based standards and only use components that will be used in the final upholstered furniture product.

In the United Kingdom, furniture components and composites must meet specific ignition-resistance levels as measured by British Standard (BS) 5852, Methods of test for assessment of the ignitability of upholstered seating by smoldering and flaming ignition sources. BS5852 tests for assessment of the ignitability of upholstered seating by shouldering and flaming ignition sources. To meet these flammability requirements, most upholstery fabrics and foam are treated with FR chemicals. There is an effort in the United Kingdom to update the Furniture and Furnishings (Fire) (Safety) Regulations. The proposed update focuses on "making changes to the testing methods in the regulations so that they better reflect the way current furniture is made and also to allow manufacturers to reduce flame retardant use."[44]

6. Other State Regulations

In addition to TB 117, CPSC staff is aware of various states that have chemical regulations or bans on OFRs; however, these are not federally mandated regulations and are not discussed here. These state regulations are discussed in the Health Sciences memorandum (Tab B).

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[44] Consultation on Updating the Furniture and Furnishings (Fire) (Safety) Regulations, Department for Business, Energy and Industrial Strategy, UK, September 2016

7. Discussion/Conclusions

The petitioners are requesting that CPSC initiate rulemaking to declare children's products, mattresses and mattress pads, upholstered furniture, and casings surrounding electronics with OFRs to be banned hazardous substances under the FHSA. This memorandum reviewed the applicable standards and activities associated with children's products, mattresses and mattress pads, and upholstered furniture. The mandatory standards that apply to these products and are enforced by the CPSC are performance standards and not design standards. These standards do not require the use of any specific design features, methods of assembly or specific components, including the use of any FRs or treatments.

The mattress open-flame standard does not require any specific components to meet the flammability requirements. The industry has consistently stated that OFRs are not used in mattresses and has opposed any standards that would require the use of these chemicals. CPSC staff is aware that the mattress industry uses a variety of fiber technologies that do not include the use of OFRs to pass 16 C.F.R. part 1633. These technologies include fiber and fabric barriers. Manufacturers have the responsibility of conducting appropriate analysis to ensure that their products are not hazardous substances, or if they are, that they are labeled in accordance with the FHSA.

The mandatory and voluntary standards for children's products do not require the use of FRs for these products to meet the standards. The CPSC is looking at the presence of FRs in children's products and assessing the potential risk associated with exposures to the FR chemicals in these products.

Although there are no mandatory federal standards for upholstered furniture, there are voluntary standards and mandatory standards for furniture sold in California. The applicable voluntary standards and the 2013 revised California requirements discussed here for upholstered furniture are performance based and do not require the use of FRs. The industry affected by TB117 is changing in a way that would negate the need for the requested regulation. The Petition received comments from the upholstered furniture industry stating that they no longer use FRs in manufacturing upholstered furniture. At this time CPSC staff does not have the data to confirm or negate this statement on the reduction of FR use in upholstered furniture.

There is insufficient data on which to base the requested regulation and extensive resources would be needed to carry out the data collection if the Petition is granted. CPSC staff would need to conduct extensive research to determine whether any OFR treatments are used in these product categories and discern how any ban would affect performance and safety. OFRs are not specifically required for any of the mandatory or voluntary standards currently reviewed in this memorandum.

TAB D: Division of Electrical Engineering Response to the Petition

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UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MARYLAND 20814

Memorandum

Date: May 18, 2017

TO:	Melanie Biggs, Ph.D. Project Manager, Organohalogen Flame Retardants Directorate for Health Sciences
THROUGH:	Joel R. Recht, Ph.D. Associate Executive Director Directorate for Engineering Sciences
	Andrew Trotta Director, Division of Electrical Engineering and Fire Sciences Directorate for Engineering Sciences
FROM:	Mark F. Gill Electrical Engineer Directorate for Engineering Sciences
SUBJECT:	Petition Requesting Rulemaking on Products Containing Organohalogen Flame Retardants: Electronic Casings.

1. Introduction

A Petition has been presented to the Commission requesting a ban on certain products containing a class of flame retardants (FRs) because of alleged adverse health effects. The Petition seeks to ban the use of additive non-polymeric organohalogen flame retardants (OFRs) in (1) any durable infant or toddler product, children's toy, child care article or other children's products (other than children's car seats); (2) any article of upholstered furniture sold for use in residences; (3) any mattress or mattress pad; and (4) any electronic device with additive, non-polymeric OFRs in its plastic casings.

Regarding item (4), this memorandum discusses the use of additive OFRs in electronic device casings and possible manufacturing alternatives. Given the various flame ratings for plastics in voluntary standards (HB, V2, V1, V0, 5V), staff cannot tell where within these five categories OFRs are used. In accordance with the specific request in the Petition, staff clearly distinguishes "electronic" device casings from "electrical" device casings, with consumer electronic devices being a subset of electrical devices. This memorandum does not address the economic feasibility of such alternatives, which would require a separate economic analysis in the event of rulemaking.

2. Consumer Electronics Included in Petition

For the purposes of this memorandum, "consumer electronics" broadly includes products classified as information technology, audio, and video equipment. Examples of such equipment are personal computers and computer displays, cell phones, televisions, audio equipment, power adapters, cameras and similar electronic products. The applicable voluntary standards for these types of products are UL 60950-1, *Information Technology Equipment - Safety - Part 1*, and UL 60065, *Standard for Audio, Video and Similar Electronic Apparatus - Safety Requirements*. There are no federal requirements promulgated for products under CPSC's jurisdiction addressing plastic electronic casings, although there are locally adopted electrical codes that provide flammability requirements for some plastic electrical casings.

Regarding electronic device casings, in accordance with the two applicable voluntary standards, the casings are designed to provide a level of protection against possible hazards, such as electric shock, excessive temperatures, radiation, implosion, mechanical hazards, and fire. As for fire, these standards note that certain circuits may present a risk due to causes such as overloads, component failure, insulation breakdown, poor connections, and wire breakage. Where such circuits are identified, the standards require the use of a "fire enclosure (casing)" to reduce the likelihood of fire spreading from a product. Additionally, some international safety standards, *e.g.*, CENELEC EN 60065, *Standard for Audio, Video and Similar Electronic Apparatus - Safety Requirements*, require flame-resistant casings for electronic devices to provide resistance against ignition due to external flame sources, such as candles. Where non-metallic casings are used and are formed from plastic, the voluntary standards assign required flame ratings for the plastics. It is in this area that OFRs are sometimes used to increase the flame rating of the casing's plastic to achieve the required rating.

Although these standards require fire casings in certain instances, they do not require the use of a plastic casing for protection against fire. Fire casings may be formed entirely from metals, such as steel or aluminum, or they may be constructed with a two-part approach from a metal/plastic design. In the two-part approach, an inner, thin, metal fire casing encloses circuits presenting a risk of fire and, in turn, is surrounded on the outside by a decorative casing that is formed from plastic with a low-flammability rating. These approaches, metal or two-part, involve costlier materials and manufacturing approaches, and may limit flexibility in other areas, such as electromagnetic compatibility, ergonomics, and aesthetics.

3. Conclusions

In summary, there are no mandatory federal requirements for the use of OFRs in the construction of electronic device casings. The applicable voluntary standards for consumer electronic products do not require the construction of electronic casings with plastics, and the use of plastics is an optional approach. However, when manufacturers choose to use plastics, OFRs appear to be the preferred FRs used in product casings to meet current flammability requirements. If the Petition is granted, an economic analysis is required to understand the financial impact of moving from plastic fire casings that might use OFRs, to fire casings formed from other materials, such as metal, or a casing consisting of a two-part construction, before proceeding with FHSA rulemaking.

TAB E: Division of Laboratory Sciences Chemistry Response to the Petition

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UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MARYLAND 20814

Memorandum

Date: May 23, 2017

TO	:	Melanie Biggs, Ph.D., Project Manager Directorate for Health Sciences, Division of Toxicology and Risk Assessment
THROUGH	:	Andrew Stadnik, P.E., Associate Executive Director Directorate for Laboratory Sciences Aaron Orland, Ph.D., Division Director Directorate for Laboratory Sciences, Division of Chemistry
FROM	:	Matthew Dreyfus, Ph.D., Chemist Directorate for Laboratory Sciences, Division of Chemistry
SUBJECT	:	Feasibility of Testing Flame-Retardant Chemicals Under Proposed Petition HP 15-1

1. Introduction

Petition HP 15-1 requests that the U.S. Consumer Product Safety Commission (CPSC) develop regulations under the Federal Hazardous Substances Act (FHSA) to declare that any children's products, upholstered furniture, mattresses or mattress pads, and plastic casings surrounding electronics are banned, hazardous substances if they contain any non-polymeric, additive, organohalogen flame retardant (OFR) in excess of a CPSC-defined detection level. The scope of this Petition is vast, covering a plethora of chemicals and consumer products. This memorandum discusses the rule that the petitioners request with respect to:

- Developing and issuing test procedures to qualitatively and quantitatively analyze products for the chemicals to be prohibited; and
- Performing compliance testing of the affected product categories by the Division of Chemistry (LSC).

2. Developing Test Methods

The Petition requests that all non-polymeric, additive, organohalogen chemicals added as flame retardants (FRs) be prohibited; therefore, dozens of test methods may need to be developed and certified to cover all of the organohalogen compounds that may be used as an FR. This task is further complicated by the varying behavior of the many different OFRs. For example, compounds that contain chlorine may have different properties than compounds that contain bromine. Other differences, such as molecular weight and polarity, may require not only different extraction procedures, but also different analytical instrumentation for analysis.

Currently, staff is not aware of any specific test method that targets OFRs used from any standardization body. There are many academic manuscripts that describe functional test methods, and the EPA has published methods covering a broad range of analytes. Many of these methods have been successfully adopted by CPSC staff for internal use, and they can be used as a starting point in developing a certified test protocol. However, a significant effort would remain to ensure that these methods are efficient and reliable for all pertinent analytes. Essentially, it could take years and consume significant staff resources to prepare the test methods needed to perform third party certification and CPSC compliance testing.

A secondary hurdle to creating test protocols is the availability of standard reference materials (SRMs). These SRMs are used to ensure proper chemical identification and to calibrate an instrument's response for quantitation. It is not certain that each chemical has an SRM available for purchase. Additionally, the costs to purchase all applicable SRMs could be burdensome.

The Petition did not explicitly state a concentration limit for OFRs, instead deferring to the Commission. Defining such a limit should consider the technical feasibility of the various OFR detection limits and ensure that the limit chosen produces reliable and repeatable results.

Another uncertainty is how "additive OFRs" would be defined. Laboratories cannot test to distinguish additive usage. With more than 20,000 organohalogens listed in the CAS database,[45] it cannot be assumed that a compound from this chemical class will never be intentionally added to the specified consumer products to fulfill roles other than FR. For example, although it is not an organohalogen, the compound triphenyl phosphate has been used as both an FR and a plasticizer.[46] In a scenario where a manufacturer intentionally adds an organohalogen in a role other than FR, it is unclear how that product will be regulated.

3. Feasibility of Marketplace and Compliance Testing

Market Survey

Once test methods are established, a market survey would be conducted to determine the presence of OFRs in the marketplace. The results of this market survey would be used to support potential rulemaking if a health hazard needs to be addressed. Due to the breadth of the four product categories covered by the Petition, it would take multiple years and significant staff resources to collect, analyze, and interpret the resultant data.

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[45] CAS numbers are unique numeric identifiers each of which identifies a single chemical material. This database of over 70 million materials is used internationally to identify materials in an unambiguous manner, and is administered by Chemical Abstracts Service, a division of the American Chemical Society. (http://www.cas.org/content/chemical-substances).

[46] Stapleton, H. M., et al. (2009). "Detection of organophosphate flame retardants in furniture foam and US house dust." Environmental Science & Technology **43**(19): 7490-7495.

Compliance Testing

The scope of Petition HP 15-1as submitted would demand a massive expansion of CPSC's chemical testing laboratory capabilities to ensure that CPSC is able to develop test methods, as explained above, and enforce added regulations for organohalogen content in products. Considering the broad product categories and thousands of potential chemicals previously referenced to analyze, additional technical staff and a laboratory expansion (in terms of size and capabilities) would be necessary to support, even minimally, the compliance testing requirements if the Petition were approved and the Commission issued the rule the petitioners seek.

Additional analytical instrumentation would be needed to perform the often difficult analysis required for OFRs. A typical analysis would require a step to extract the FR out of the substrate, then an analysis using an instrument capable of separating analytes, identifying unknowns, and quantifying. Instrumentation, such as liquid chromatography-mass spectrometers, can cost in excess of $500,000 per unit. The volume of samples, combined with the presumptive analysis time (estimated 30-60 minutes per component part tested) would require numerous instruments to ensure timely analysis. The costs to operate and maintain the instruments and purchase testing consumables (*e.g.*, solvents, filters, and sample vials) and SRMs would necessitate yearly budget increases to support day-to-day operations.

The current CPSC laboratory at 5 Research Place in Rockville, MD, does not have the space to house the required instrumentation, the additional staff required to perform the work, or the general lab space to process and prepare incoming samples. The agency would either need to acquire an additional laboratory space of sufficient size that is capable of such chemical testing, or, depending on theoretical workload, create satellite laboratories at multiple locations.

Along with facility and capability upgrades, several additional full-time employees (FTEs) with expertise in chemical analysis would be required to support the efforts and even more to staff additional laboratories. It would follow suit that additional FTEs would be needed in the Office of Import Surveillance and the Office of Compliance and Field Operations to screen for and collect samples. Furthermore, the Office of Compliance and Field Operations would also need additional staff to evaluate data and take any necessary enforcement actions.

4. Conclusions

Currently, staff is not aware of any specific test method that targets OFRs from standardization bodies, academia, or government. The rule that the petitioners request would require dozens of test methods to be developed and certified to cover all of the organohalogen compounds that may be used as an FR. CPSC's facilities are not sufficient to undertake the testing that would be required if the Petition were approved and the Commission issued the rule that the petitioners' request. CPSC's instrumental capabilities, facility space, or personnel are also not sufficient to create applicable test methods and/or perform compliance testing.

Another challenge to CPSC would be to determine appropriate regulatory limit for OFRs. To develop this limit, staff would need to consider the technical feasibility of any OFR detection limit and ensure that the limit chosen produces reliable and repeatable results.

Not to be understated is the uncertainty of how test labs will determine the purpose of any organohalogen found while testing applicable products. Due to the vast number of organohalogens, and the potential for the development and use of novel compounds, trying to sort out which organohalogens are and are not OFRs may lead to unintended confusion and burden to the regulation.

TAB F: Directorate for Economic Analysis Response to the Petition

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UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MARYLAND 20814

Memorandum

Date: May 18, 2017

TO : Melanie B. Biggs, Ph.D., Project Manager
Organohalogen Flame Retardants Petition
Directorate for Health Sciences
Division of Toxicology and Risk Assessment

THROUGH: Gregory B. Rodgers, Ph.D.
Associate Executive Director
Directorate for Economic Analysis

Robert Franklin
Senior Staff Coordinator
Directorate for Economic Analysis

FROM : Samantha Li
Economist
Directorate for Economic Analysis

SUBJECT : Market and Economic Considerations Related to the Organohalogen Flame Retardants Petition

1. Introduction

In July, 2015, the Commission received a Petition (HP 15-1) from Earth Justice, the Consumer Federation of America, and several other organizations requesting that the Commission initiate rulemaking to ban mattresses and mattress pads, upholstered furniture, the plastic casings of electronic devices, and most children's products that contain non-polymeric, additive, organohalogen flame retardants (OFRs) . The Petition asserts that (1) Warning labels provided pursuant to the Federal Hazard Substance Act (FHSA) would not adequately protect the public health or safety because warning labels cannot prevent or control exposure to FRs that migrate from these products into homes and (2) banning these four categories of products containing the entire class of FRs is necessary because focusing on only individual chemicals within the class would allow other inherently toxic chemicals within the class to be used. The Petition was docketed, and a request for comments was published in the *Federal Register* on August 19, 2015 (80 FR 50238).

This memorandum provides information on OFR chemicals, the market for products containing flame-retardant (FR) chemicals, state and federal regulations, and economic considerations. The discussion is based on information that was readily available, including information provided by the petitioners and public comments.

2. Flame Retardants

FR chemicals are intended to increase the resistance of materials to ignition and reduce flame spread with minimal degradation of the materials' properties. Organohalogen refers to compounds with covalent carbon-halogen bonds. There are thousands of organohalogen compounds.[47]

The Petition requests that CPSC initiate rulemaking to prohibit the use of non-polymeric, additive, OFRs in several classes of products, including most children's products (*e.g.*, durable infant or toddler products, toys and child care articles), upholstered furniture, mattresses and mattress pads, and the casings of electronic devices. The Petition asserts that OFRs in additive form may be released from the product leading to human and environmental exposures.

The petitioners state the scope of the Petition applies to the entire class of non-polymeric OFRs and that they do not know the precise number of OFRs in this class that are or could be used in consumer products.[48] However, the petitioners state that OFRs are "inherently toxic" and should be regulated as a class to prevent industry from reacting to restrictions on one OFR by simply substituting another OFR.

3. The Market for Flame Retardants and Use of Flame Retardants in Furniture, Mattresses, Children's Products, and Electronic Devices

The petition asserts that additive OFRs are frequently added to flexible polyurethane foam (FPF). FPF is widely used because it is light weight, resilient, low odor and resistant to mildew and other triggers of common allergies. FPF may also be molded and cut.[49] FPF can be used in a variety of consumer applications, including carpet padding, mattresses and mattress pads, and upholstered furniture.[50] FPF can also be used as padding in many durable infant and toddler products and stuffed toys.

Based on 2013 census data, there are approximately 444 firms categorized as foam manufacturers (*326150 Urethane and Other Foam Product (except Polystyrene) Manufacturing*),

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[47] Memorandum from Matthew Dreyfus, Directorate for Laboratory Sciences, Subject: Feasibility of Testing Flame Retardant Chemicals under Proposed Petition HP 15-1. Tab E

[48] The public comment from Earth Justice and Consumer Federation of America notes the actual number of FRs is unknown. The entire comment is available at: https://www.regulations.gov/document?D=CPSC-2015-0022-0135.

[49] Flexible Polyurethane Foam: Industry at a Glance Furniture, Bedding, Carpet Cushion, Automotive, Packaging. 2010. PolyurethaneFoam Association. http://www.pfa.org/Library/IAG_no_logo.pdf.

[50] "Flexible Polyurethane Foam: a Primer." In Touch magazine. Vol 1. Issue 1. 1991 (Revised 2013). http://www.pfa.org/intouch/new_pdf/lr_IntouchV1.1.pdf .

358 firms categorized as mattress manufacturers (*337910 Mattress Manufacturing*), and 1,032 firms categorized as upholstered furniture manufacturers (*337121 Upholstered Household Furniture Manufacturing).*

Although additive OFRs can be used in polyurethane foam, not all polyurethane foam contains FR chemicals. For example, the Alliance for Flexible Polyurethane Foam, Inc., administers the CertiPUR-US® voluntary testing and performance certification program, a program through which an independent laboratory tests and certifies that FPF used in mattresses or upholstered furniture is manufactured without FR chemicals, including two mentioned in the Petition (TCEP and TDCPP).[51] Companies that have verified they use CertiPUR-US®-certified flexible polyurethane foam in their products may use the seal.[52] Approximately 300 manufacturers and retailers list products containing FPF that have been certified through the CertiPUR-US program. This includes approximately 30 producers of foam.[53] Information on dollar sales, market share, and number of units sold is not available.

Several industry sources have stated that the use of OFRs in FPF to manufacture upholstered furniture and mattresses is unlikely today. According to the American Home Furnishing Alliance (AHFA), FRs were used in upholstered furniture to meet the open-flame requirements of the California flammability standard Technical Bulletin (TB 117). However, TB 117 was amended in 2013, and FRs are no longer used to meet the standard. Consequently, the AHFA claims that there has already been a significant reduction in the use of FRs in upholstered furniture, and the use of FRs in upholstered furniture "will soon be very low or non-existent."[54] The International Sleep Products Association (ISPA), a trade association that represents mattress manufacturers, states that they are unaware of any U.S. manufacturers of new mattresses that contain OFRs.[55] The largest U.S. bedding and mattress manufacturer participates in the CertiPUR program, and its mattresses are certified not to contain certain FR chemicals.[56] While it is certainly plausible that manufacturers have decreased their use of OFRs since the amendments to TB 117, CPSC staff has not verified the extent to which the use of OFRs has decreased in FPF.

Like upholstered furniture, juvenile products containing FPF were also treated with FR chemicals to meet TB 117 flammability requirements. However, the 2013 amendments to TB 117 exempted most children's products from the TB 117 requirements, including bassinets,

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[51] PFA Links. 2016. Accessed May 12, 2016. http://www.pfa.org/links.html and "About Our Seal" Certi-PUR. 2016. Accessed May 12, 2016. http://certipur.us/about-our-seal/.
[52] "Certi-Pur: Frequently Asked Questions." 2016. Accessed May 12, 2016. http://certipur.us/faq/.
[53] "CertiPUR-US® Registered Foam Producers." 2016. Accessed Jun 29, 2016. http://certipur.us/for-manufacturers-retailers/find-a-foam-producer/.
[54] Public comment from American Home Furnishing Alliance (AHFA). The entire comment is available at: https://www.regulations.gov/#!documentDetail;D=CPSC-2015-0022-0077.
[55] Public comment from International Sleep Products Association (ISPA). The entire comment is available at: https://www.regulations.gov/#!documentDetail;D=CPSC-2015-0022-0179.
[56] "Serta Mattresses Now Made With CertiPUR-US Certified Foams." July 31, 2015. http://bedroomretailers.com/materials/serta-mattresses-now-made-with-certipur-us-certified-foams/ and http://www.serta.com/news/serta-to-use-only-certipurus-certified-polyurethane-foam. The Certi-Pur program asserts that foam producers do not use the chemicals PBDE, TDCPP, or TCEP in their products.

booster seats, changing pads, floor play mats, highchairs and pads, infant bouncers, infant seats, infant swings, infant walkers, nursing pads, playpen side pads, play yards, and portable hook-on chairs. As a result of these amendments, the use of FR chemicals in these products is expected to be significantly reduced.[57]

The extent to which FR chemicals are used in children's toys and electronic devices is unknown. According to the Toy Industry Association, toy manufacturers typically do not add FRs to toys. However, some of these substances may be present in certain components of toys, such as electronic circuit boards and assemblies. Moreover, commercially available plastic can be used in a variety of applications, including toys. Because it is not easily identifiable to tell if a plastic has been treated with FRs, many toy companies may not even be aware of this when selecting materials. In addition, the use of recycled plastics, which some may consider to be an environmentally preferable practice, can lead to inclusion of FRs in toys.[58]

According to the National Electrical Manufacturers Association (NEMA), OFRs are used in plastic casing of electronic devices. FRs are used in these devices because these devices "are in constant contact with an electrical current. As a result, there is a potential fire hazard with these devices from issues including electrical arcing." NEMA asserts that the use of FRs is needed in these devices to mitigate these hazards. Additionally, NEMA notes that the performance, use, and installation of electronic devices are subject to many different standards that have requirements for flammability resistance, citing specifically, the National Electric Code, which incorporates by reference the requirements of other standards developed by various organizations, including NEMA, Underwriters Laboratories, and ANSI.[59]

NEMA states that it is not aware of evidence that any non-OFR would be suitable for use with electronic devices or that the risk associated with human exposure to these other FRs would be any less. NEMA also asserts that there are inherently flame- or heat-resistant materials that could theoretically be used to encase electronic devices, but these were generally unacceptable due to other characteristics, such as weight, instability, and "drastically increased cost."[60]

4. Economic Implications of a Rule Banning Certain Products Containing Organohalogen Flame Retardants

To evaluate the benefits and costs of a rule banning certain products containing some or all additive OFRs, staff would need more information on the health effects of the specific chemicals and the extent to which consumers could be exposed to these chemicals from their use in consumer products. This information would be needed to evaluate the societal cost of injuries or

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[57] Green Science Policy Institute. 2016. Accessed on June 13, 2016. http://greensciencepolicy.org/topics/childrens-products/.

[58] Toy producers make up a very small share of the customer base for plastic materials and purchase the same materials available to and used by others making a variety of non-toy products. The entire comment from the Toy Industry Association is available at: https://www.regulations.gov/#!documentDetail;D=CPSC-2015-0022-0176.

[59] Public comment from National Electronic Manufacturers Association. The entire comment is available at: https://www.regulations.gov/#!documentDetail;D=CPSC-2015-0022-0060.

[60] Public comment from National Electronics Manufacturers Association. The entire comment is available at: https://www.regulations.gov/document?D=CPSC-2015-0022-0060.

illnesses associated with the use of OFRs in these products and the potential benefits of a ban. Additionally, more information would be needed about the reasons that these chemicals are used in the consumer products and the costs and risks of alternatives to these chemicals that are available to manufacturers. For example, flame-resistant enclosures for electronic devices can be made using metals or using a two-part metal and plastic design without the need for FR chemicals.[61] However, as noted earlier, an industry group suggests that such an alternative would be costly.

If manufacturers have largely eliminated the use of additive OFRs in polyurethane foam for consumer products because of the amendments to CA TB 117, as suggested by several industry groups, then the benefits and costs of a ban on the use of OFRs in mattresses, upholstered furniture, and many children's or nursery products would be low. Staff would need to conduct product testing to determine whether the FR chemicals have actually been eliminated in these products. To evaluate the benefits and costs of a ban on the use of OFRs in electronic enclosures, more research, as outlined above, would be required.

If the Commission bans children's products containing these OFRs , then manufacturers and importers of children's products would be required to certify that their children's products do not contain additive OFRs. Therefore, a rule banning children's products containing these chemicals would impose third party testing costs on these manufacturers. The cost of this testing would depend on factors such as the scope of the rule and the concentration at which the chemicals are regulated. The cost of the third party compliance testing for a rule that prohibited all OFRs above a low, allowable concentration in any children's product that contained FPF or any plastic components would be greater than the cost if the scope of the rule were more limited (*e.g.*, only specific OFRs in the casings of children's electronic devices) and the allowable concentration was greater. Similarly, if the rule were limited to additive organohalogens used as FRs, it might be necessary to develop tests that distinguish the use of organohalogens as FRs from other potential uses of organohalogens.[62] The cost associated with developing new tests could be significant to firms.

5. Conclusions

Previously, OFRs may have been widely used in upholstered furniture, mattresses and mattress pads, children's products, and the plastic casings of electronic devices to meet certain flammability standards, most notably California's TB-117.[63] OFRs may also be used in the plastic casings of electronic devices to meet certain flammability standards. TB 117 was amended in 2013, to reduce the need for FRs to comply, and some states have passed laws

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[61] Memorandum from Mark F. Gill, Directorate for Engineering Sciences, Subject: Petition Requesting Rulemaking on Products Containing Organohalogen Flame Retardants: Electronic Enclosures.

[62] For example, staff could propose a test to limit allowable contamination levels for FR chemicals that are intentionally added to products. Memorandum from Matthew Dreyfus, Directorate for Laboratory Sciences, Subject: Feasibility of Testing Flame Retardant Chemicals under Proposed Petition HP 15-1.

[63] In addition to TB 117, CPSC staff is aware of various states that have chemical regulations or bans on OFRs. See Memorandum from Melanie Biggs, Directorate for Health Sciences, Subject: Health Sciences response to Petition HP-15-1, requesting rulemaking on products containing organohalogen flame retardants for additional information. Tab B.

regulating specific OFRs. As a result of these changes, industry sources assert that the use of OFRs is greatly reduced or not used in upholstered furniture, mattresses and mattress pads, and most children's products. However, OFRs may still be widely used in the plastic casings of electronics devices. CPSC staff has not verified the extent of OFR use in these products. A rule that bans children's products containing these chemicals would require that manufacturers certify that their products do not contain the chemicals after third party testing. Depending on the scope of the rule or testing requirements, third party testing costs could be high.

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TAB G: Directorate for Epidemiology Response to the Petition

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UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MARYLAND 20814

Memorandum

Date: April 3, 2017

TO : Melanie Biggs, Ph.D.
Project Manager, Flame Retardant Petition
Division of Toxicology and Risk Assessment
Directorate for Health Sciences

THROUGH: Kathleen Stralka , Associate Executive Director
Directorate for Epidemiology

Stephen Hanway, Division Director
Division of Hazard Analysis

FROM : Wioletta Szeszel-Fedorowicz, PhD.
Mathematical Statistician
Division of Hazard Analysis

SUBJECT : Incident Data Related to Petition HP 15-1[64]

1. Introduction

This memorandum was prepared in response to petition HP 15-1, requesting that the U.S. Consumer Product Safety Commission (CPSC) promulgate rulemaking on four groups of consumer products containing non-polymeric, additive, organohalogen flame retardants (OFRs): (1) children's products, (2) plastic casings surrounding electronic devices, (3) mattresses or mattress pads, and (4) upholstered furniture. Using CPSC's databases, Epidemiology Hazard Analysis (EPHA) staff was asked to identify consumer incidents specifically associated with

64 This analysis was prepared by CPSC staff, has not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

adverse health effects related to the presence of OFRs in the four above-mentioned product categories.

2. Results and Conclusions

EPHA staff searched two databases: the National Electronic Injury Surveillance System (NEISS) and the Consumer Product Safety Risk Management System (CPSRMS). NEISS is a national probability sample of hospitals in the United States and its territories. Selected NEISS hospitals report information to CPSC on emergency treatments associated with consumer products. CPSRMS combines the data associated with consumer products from the following databases into one searchable incident database: Injury or Potential Injury Incidents (IPII), Death Certificates (DTHS), and In-Depth Investigations (INDP). Neither NEISS, nor CPSRMS databases report cases of adverse health effects related to the presence of OFRs in children's products, plastic casings surrounding electronic devices, mattresses or mattress pads, or upholstered furniture. Therefore, due to insufficient data, staff could not provide the requested evaluation.

TAB H: Staff Response to Comments Received on the Petition and at Public Meeting

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UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
4330 EAST WEST HIGHWAY
BETHESDA, MARYLAND 20814

Memorandum

Date: May 18, 2017

TO	:	Organohalogen Flame Retardant Petition File
THROUGH	:	Alice Thaler, D.V.M., Associate Executive Director Directorate for Health Sciences Michael A. Babich, PhD, Division Director, Directorate for Health Sciences Division of Toxicology and Risk Assessment
FROM	:	Melanie B. Biggs, Ph.D., Project Manager Directorate for Health Sciences Division of Toxicology and Risk Assessment
SUBJECT	:	Response to Comments Received on Petition HP 15-1

1. Introduction

The Consumer Product Safety Commission (CPSC, or Commission) received a Petition requesting the Commission to promulgate rulemaking under the Federal Hazardous Substances Act (FHSA) declaring that children's products, furniture, mattresses, and casing surrounding electronics are banned hazardous substances if they contain any non-polymeric, additive, organohalogen flame retardant (Petition). The Commission published a request for public comment on this Petition in the *Federal Register* on August 16, 2015 (80 FR 50238). The Commission also published a notice of opportunity for oral presentation of comments in the *Federal Register* on October 26, 2015 (80 FR 65174). The Commission also extended the comment period from October 19, 2015 to January 19, 2016, in this *Federal Registe*r notice due to outside requests. Two more *Federal Register* notices were published for corrections to previous notices or provide more information (80 FR 75955 and 80 FR 77591). The Commission received a total of 204 comments from domestic and international bodies; however, some comments included multiple supporter signatures or letters. The public meeting was held at the CPSC on December 9, 2015, or by phone the same date, and 28 panelists spoke. CPSC staff's summary of comments and responses follows.

2. Comments Received from Docket and Public Meeting and Staff's Responses

Docket

The majority of the 204 comments received support granting the Petition (181). Consumer advocate groups submitted the bulk of the supporting comments on the Petition (75). Eleven[65] comments from advocate groups supporting the Petition included signatures or letters from multiple interested parties, which ranged from 2 to 3,800 signers per comment. Comments supporting the Petition were also received from state or city governments, professional associations, consumers, academics, and a standards group. A total of 16 comments, submitted by 13 trade associations, one chemical consultant company, one public policy organization, and one company, support denying the Petition. Three commenters, one trade association, one technological development company, and one academic, did not support or oppose the Petition. Three comments from trade associations asked for the January 2016 extension, and one industry commenter asked to speak at the public meeting. One advocacy group, in response to public meeting comments, clarified what chemicals and products are included in the Petition, evidence of consumer exposure to these chemicals, and thoughts on redundancy of action by CPSC.

Public meeting

Twenty-eight panelists from government, advocacy groups, academia, trade associations, and industry presented to the CPSC Commissioners at the public meeting, including 10 panelists from the organizations representing the petitioners. Fourteen panelists represented affiliations, which also provided written comments to the docket.

Docket and public meeting comment summaries

Many written comments included statements from commenters on their concern about toxic chemicals in consumer products, the health effects associated with this class of chemicals, flame retardants' (FR) migration out of chemicals and into dust, domestic and international hazard studies on selected OFRs, testing results or studies conducted on consumer products and OFR findings, preventing child exposure to toxic chemicals, exposure information relating to petitioners' product categories, and how products with FRs burn and produce smoke, soot, and toxic gases that put residents and firefighters at risk. Ten panelists, who were petitioners, and four more panelists at the public meeting reinforced their Petition by discussing and presenting information on such topics as regrettable substitutions, structural similarity of OFRs, OFR health effects and exposure data, labeling that does not protect human health, socioeconomic injustice, restating the Petition scope and chemicals, and how CPSC has the authority to regulate this class or chemicals under the FHSA. Three panelists discussed the overly broad nature of the Petition, stressed that any work on these chemicals should be risk based, and argued about how the Petition cannot be granted under the FHSA. Two panelists discussed fire safety and provided evidence of OFR impact in fires. The remaining panelists discussed the toxicity of OFRs,

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[65] CSPC-2015-0022-0072, CPSC-2015-0022-0111, CPSC-2015-0022-0159, CPSC-2015-0022-0166, CPSC-2015-0022-0187, CPSC-2015-0022-0192, CPSC-2015-0022-0196, CPSC-2015-0022-0205-207, CPSC-2015-0022-0209.

concern for children exposed to these OFRs, state actions on OFRs, studies where OFRs were measured in some of these products categories, and how some businesses are moving away from OFRs in their products.

Other commenters and panelists provided discussions on a variety of other topics, including:

- OFR use in certain product categories and exemptions should the Petition be granted,
- Fire safety and voluntary standards,
- Other government action on OFRs,
- Economic burden should the Petition be granted,
- Fire science, toxicity and exposure studies, and
- Information on chemical mixtures regulation.

The significant issues raised in the comments and at the public meeting are presented below, followed by staff's responses.

<u>CPSC Authority Under the FHSA</u>

Comment: Several commenters discussed CPSC's authority under the FHSA to grant this Petition. Commenters (Public Meeting (PM)2, PM3, PM7, PM18, PM26, and CPSC-2015-0022-0197) stated that CPSC has the authority under the FHSA to ban the sale of products containing the OFR class. Numerous commenters suggested that the petitioner's requested rulemaking is inconsistent with the requirements of the FHSA. Three commenters (CPSC-2015-0022-0181, CPSC-2015-0022-0198, and PM13) characterized the petitioners' request generally as "an inappropriate and troubling application of the FHSA." Another commenter stated that restricting an entire class of chemicals under the FHSA is very difficult and would establish a dangerous precedent for application of the FHSA. Other commenters (CPSC-2015-0022-0173, CPSC-2015-0022-0176, CPSC-2015-0022-0181, CPSC-2015-0022-0198, CPSC-2015-0022-0201, PM12, and PM13) stated that CPSC does not have the legal authority under the FHSA to grant the Petition because specific findings are required under the FHSA for declaring "banned hazardous substances" (some of which are substantive), adding that as per the FHSA, a Chronic Hazard Advisory Panel would need to be used to determine the hazards presented. One commenter (CPSC-2015-0022-0201) stated that the approach taken in the Petition is inconsistent with the FHSA requirements and could ban all children's products containing any amount of the listed chemicals, regardless of whether there is a hazard or exposure. Two commenters (CPSC-2015-0022-0198 and CPSC-2015-0022-0201) stated that the FHSA requires that a substance cannot be banned unless the CPSC evaluates the substance as it is intended to be used in a household, which means evaluating the finished product, not its individual ingredients.

Response: CPSC has considered the petitioners' request in light of the Commission's regulations regarding petitions for rulemaking, and requirements for rulemaking under the FHSA. Under the FHSA, to declare an article a banned hazardous substance, the Commission must consider whether the substance meets the definition of one of the hazards defined in the Act, how a given product is used, and whether the consumer's exposure to a chemical through the consumer's customary or foreseeably use of the product would result in substantial personal injury or substantial illness. Said otherwise, the FHSA requires consideration of the connection between a substance, exposure to that substance through use of a product, and the resultant injury or illness. Furthermore, the mere presence of even a toxic chemical is not enough to demonstrate the need for regulation under the FHSA.

Comment: Commenters discussed labeling of products containing OFRs. Two commenters (PM7, PM18, and CPSC-2015-0022-0197) stated that warning labels are insufficient to protect children and families from the risks FRs pose. One commenter (CPSC-2015-0022-0198) discussed how cautionary labeling is required under the FHSA on these products and that "CPSC cannot meet its burden of demonstrating a hazard exists to support cautionary labeling." The commenter also states that no determination has been made that "labeling is inadequate to protect public health and safety." The commenter opined that labeling on these products should state that the risk of FR exposure may be outweighed by the risk of injury should the product be part of a fire.

Response: The FHSA requires cautionary labeling on the immediate container of household substances that meet the definition of "hazardous substance" to safely store and use those products and to give consumers information about immediate first-aid steps to take if an accidental exposure occurs. Precautionary labeling is required when it is determined that a substance or mixture of substances is toxic (or presents another of the hazards listed in the FHSA) and customary and reasonably foreseeable use of that substance may present a substantial personal injury or substantial illness. The FHSA is self-executing, which means that the Commission does not need to determine that a substance is a hazardous substance to require labeling. However, when there is question about whether a household substance is a hazardous substance requiring cautionary labeling, the Commission can resolve uncertainty about whether a substance is hazardous through rulemaking. In addition, if the Commission determines that the labeling required by section 2(p)(1) is not adequate for the protection of the public health and safety, the Commission, by rule, can require special labeling for that product.

Comment: One commenter (PM3) discussed how lead is regulated under the Consumer Product Safety Improvement Act (CPSIA) and how this example provides a helpful illustration of how Congress intends the FHSA to be used to protect children and consumers from toxic products. The commenter stated that CPSC should adopt regulations banning children's products and other consumer products if they contain OFRs for the same reasons that Congress determined that lead should be banned from children's products under the FHSA.

Response: In enacting the CPSIA, Congress established lead limits for children's products through statutory action. However, the parameters within which CPSC considers the petitioners' request for rulemaking are contained in the Commission's petition regulations and the FHSA. As discussed, additional information would be needed to support the Petition for rulemaking under the FHSA and the Commission's petition regulations.

Overly Broad Petition; A Thorough Review and Substance Evaluation Needed

Comment: Many commenters (CPSC-2015-0022-0016, CPSC-2015-0022-0067, CPSC-2015-0022-0077, CPSC-2015-0022-0173, CPSC-2015-0022-0176, CPSC-2015-0022-0180, (PM16), CPSC-2015-0022-0181, CPSC-2015-0022-0182, CPSC-2015-0022-0198, CPSC-2015-0022-

0203, PM12, and PM15) discussed the overly broad nature of the Petition with respect to chemicals and products included and that CPSC must regulate based on science and data. They encouraged the CPSC to clearly define the rule's scope as it relates to products and FR chemicals included and to thoroughly review and evaluate the chemicals within this organohalogen class. They emphasized the differing characteristics, structures, and intended uses of these chemicals and how these chemicals may have different toxicological and physical-chemical properties. Others cited the Petition's failure to recognize and account for the highly varied and unique characteristics and exposure patterns of these chemicals and to characterize the health hazards the Petition claims exist within each member of this class. One commenter (CPSC-2015-0022-0198) provided a table demonstrating the chemical diversity of these substances. They urged CPSC to examine closely the FR chemistries to connect chemical properties to specific hazards, instead of insisting on a blanket approach as this Petition recommends. One commenter (CPSC-2015-0022-0150) spoke to how all substances in the Stockholm Convention are OFRs that are persistent, bioaccumulative, and toxic, and undergo long-range transport, which reinforces the intent of the Petition to address these FRs as a class. However, they noted that the United States has not ratified the Stockholm Convention, so its provisions are not legally binding here. These commenters also noted that the United States is one of a few developing countries that have not banned at least some OFRs in consumer products.

Response: The FHSA requires consideration of the connection between the toxicity of a substance, exposure to that substance through customary and reasonably foreseeable use of a product, and resulting substantial personal injury or substantial illness associated with the exposure. Staff considers that OFRs represent a broad class of chemicals defined largely by their functional use and the presence of either a bromine or chlorine. The limited data on OFRs show varying toxicity and exposure potential among individual OFR compounds. These varying properties of individual OFR compounds indicate that OFRs, in fact, represent several subclasses of chemicals that should be examined separately, and one cannot conclude that they all would be considered "hazardous substances" under the FHSA (see Tab B, Section 4). The use of surrogate exposure data (data derived from chemicals with similar chemical properties, such as structure or reactivity, as the chemical of interest) when no exposure data exist for a chemical is discussed in the Commission's chronic hazard guidelines. 16 C.F.R. §1500.135. These guidelines do not address the use of surrogate data for determining toxicity of a chemical where no toxicity data are available. Surrogate exposure data have not been used extensively by the Commission, and surrogate exposure data "should only be used when data concerning a chemical of interest is sparse or unavailable and when there is a reasonable assurance that the surrogate data will accurately represent the chemical of interest." Currently, staff considers the tools that are available to assess the toxicity of a chemical, without data specific to that chemical, are too limited to allow surrogate data to be used for toxicological assessments for regulatory decisions.

Comment: Two commenters (CPSC-2015-0022-0173 and CPSC-2015-0022-0180 (PM16)) discussed the overly broad nature of the Petition regarding electronic devices and the chemical class. Commenters stated their concern that the Petition does not provide a definition of "casing" in electronic equipment or define "electronic devices," leading to an overly broad and ambiguous group of products. One commenter (CPSC-2015-0022-0173) was unclear whether home appliances were included in the electronic device category.

Response: The petitioners have requested a ban on OFRs in the casings of electronic products. Staff takes the word "casings" to mean "enclosures," which is the common term used in the applicable voluntary standards. Staff differentiates electrical products, which include every type of electrical consumer product, from consumer electronic products, and therefore, limits the Petition's scope to consumer electronics, as noted in the Petition. Such products are covered by the voluntary standards UL 60950-1, *Information Technology Equipment - Safety - Part 1*, and UL 60065, *Standard for Audio, Video and Similar Electronic Apparatus - Safety Requirements*.

Comment: One commenter (CPSC-2015-0022-0077) stated that before any rulemaking can proceed, additional studies are needed to understand better what products use FRs, the identity of these FRs, and what dose poses the greatest risk. Another commenter (CPSC-2015-0022-0069) suggested that CPSC ask for the available data and knowledge on a product-by-product basis and then convene a group of experts to review the information, identify data gaps to determine how to present a safe, non-toxic, and affordable solution to the use of OFRs in these product categories.

Response: CPSC staff agrees that more research would be required if the Commission grants the Petition and proceeds with rulemaking. Minimally, the Commission would need to conduct analyses to identify the products that contain OFRs, the specific OFRs used, and at what concentrations. Staff would also need to determine the OFR concentration for intentional use and the concentration for OFR contamination to determine compliance with any proposed rule. Under the FHSA, staff would also have to evaluate whether exposure to the FR chemical exists when using the product and the risks associated with that exposure. Additionally, the Commission would consider the risks associated from not using the chemicals. This evaluation would include, for example, the increased risk of fire and the risk of substitute chemical exposure.

Risk-Based Approach Should be Taken for Assessment

***Comment*:** Many commenters (CPSC-2015-0022-0063, CPSC-2015-0022-0067, CPSC-2015-0022-0173, CPSC-2015-0022-0176, CPSC-2015-0022-0198, CPSC-2015-0022-0201, CPSC-2015-0022-0203, and PM23) stated that a risk-based approach should be taken when looking at each member in this class of chemicals, which includes determining exposure potential and hazard and performing rigorous risk assessments. They also stated that a regulation needs to be based on sufficient data and analyses to justify chemical and application restrictions.

Response: Under the FHSA, to determine whether a substance is a hazardous substance, the product must meet the definition of one of the hazards addressed by the Act, and the product must have the potential to cause substantial personal injury or substantial illness during, or as a result of, any customary or reasonably foreseeable handling or use, including ingestion by children. Therefore, when assessing potential chemical hazards under the FHSA, CPSC staff considers not only the toxicity of the substance, but also exposure and the risk of any adverse health effects associated with the exposure. Although many data gaps exist concerning the toxicity and exposure data for OFRs, the petitioners are asking the Commission to conclude that all OFRs, where limited or no data are available, possess the same toxicity and exposure potential as OFRs where data exist. The petitioners ask the Commission to use these conclusions to determine that products in these four product categories are "banned hazardous substances" if they contain these OFRs. As stated previously, the use of surrogate exposure data is discussed in the Commission's chronic hazard guidelines; however, the use of surrogate toxicity data is not addressed. 16 C.F.R. §1500.135. Surrogate exposure data "should be used only when data concerning a chemical of interest is sparse or unavailable and when there is a reasonable assurance that the surrogate data will accurately represent the chemical of interest." Currently, staff considers the tools available for assessing the toxicity of a chemical with surrogate data are too limited to be used for toxicological assessments for regulatory decisions.

***Comment*:** Many commenters (PM15, CPSC-2015-0022-0173, CPSC-2015-0022-0176, CPSC-2015-0022-0179, CPSC-2015-0022-0180 (PM16), CPSC-2015-0022-0181, CPSC-2015-0022-0189, and CSPC-2015-0022-0198) discussed how exposure should be assessed when evaluating these chemicals and how the presence of a chemical does not indicate exposure or adverse health effects. Two commenters (CPSC-2015-0022-0173 and CPSC-2015-0022-0176) discussed the lack of evidence that potential exposures to the FR chemicals from one category present a similar risk to other product categories. Other commenters (CPSC-2015-0022-0176, CPSC-2015-0022-0179 and CSPC-2015-0022-0198) discussed considering how a chemical is used and the degree of consumer exposure when determining whether a chemical is harmful.

Response: Under the FHSA, any substance or mixture of substances that is "toxic," as defined in FHSA regulations, is considered to be a "hazardous substance," if such substance or substances may cause substantial personal injury or substantial illness during or as a result of reasonable foreseeable handling or use. 15 U.S.C. § 1261(f)(1)(A). Therefore, because a FHSA determination is risk-based, exposure potential to chemicals when used in a household product is also considered when evaluating whether that substance would require precautionary labeling for toxicity under the FHSA.

Comment: Commenters discussed the science of banning an entire chemical class. Several commenters (CPSC-2015-0022-0016, CPSC-2015-0022-0180 (PM16), CPSC-2015-0022-0182, CPSC-2015-0022-0189, and CPSC-2015-0022-0203) deemed banning an entire class of chemicals to be unscientific. Reasons given included that the "read-across" approach to ban an entire class of chemicals is not valid; chemicals within this class have been found safe by other governments; and there is a risk of getting rid of useful chemicals within this class. Conversely, many commenters (PM24, PM25, and PM27) stated that regulating these chemicals together makes scientific sense due to their similar physico-chemical properties, structure, and additivity. One commenter (PM25) referenced a study in which 90 OFRs were examined and data gaps were filled by quantitative structure activity relationship (QSAR) methods and read-across. This commenter stated that the study demonstrated there is sufficient data to show that the whole class is hazardous (by using these methods) and may cause substantial personal injury or illness.

Response: Although many data gaps exist concerning the toxicity and exposure data for OFRs, the petitioners are asking the Commission to conclude that all OFRs, where limited or no data are available, possess the same toxicity and exposure potential as OFRs where data exist. The petitioners ask the Commission to use these conclusions to determine that products in these four product categories are "banned hazardous substances" if they contain these OFRs. As discussed previously, CPSC's guidelines discuss the use of surrogate exposure data; however, they do not address the use of surrogate data for determining toxicity of a chemical where no toxicity data are available. Surrogate exposure data cannot be used to determine the exposure potential of an unstudied OFR for regulatory decision making because chemical specific data would be needed for a robust assessment to support a regulation. Currently, staff considers the tools that are available to assess the toxicity of a chemical, without data specific to that chemical, are too limited to allow surrogate data to be used for toxicological assessments for regulatory decisions. Therefore, these OFRs could not be assessed by staff under the FHSA due to insufficient toxicity data. CPSC staff considers that additional information regarding risks associated with the presence of specific products containing specific OFRs would be needed to proceed with FHSA rulemaking.

Organohalogen Flame Retardant Use in Products

Comment: Several commenters (CPSC-2015-0022-0077, CPSC-2015-002-0179, and CPSC-2015-0022-0182) stated that their manufacturers do not use OFRs. One commenter (CPSC-2015-0022-0077) stated that, due to Technical Bulletin (TB) 117-2013, manufacturers of residential upholstered furniture and related components are, in general, no longer treating their products with FRs to meet TB 117-2013's flammability standard because the standard can be met without the use of FRs. One commenter (PM28) stated that chemical FRs are not needed in upholstered furniture because barrier fabrics or inherently flame-resistant materials are available to meet fire safety standards. One commenter (CPSC-2015-002-0179) stated that U.S. manufacturers of new mattresses do not use OFRs to meet federal mattress flammability standards. Another commenter (CPSC-2015-0022-0182) stated that jewelry producers do not use organohalogen or any other type of FR. They stated that a "CPSC-mandated categorical ban on all OFRs in all children's products would establish a regulation, ban or standard and would directly affect children's jewelry and accessories" because manufacturers would be required to certify that children's jewelry did not contain any OFR.

***Response*:** The statement made by the commenters is consistent with industry information provided to staff on the lack of use of OFRs in upholstered furniture, mattresses and children's jewelry. CPSC has an open rulemaking for upholstered furniture, and currently, there is no federal standard requiring specific components for fire performance and fire safety. TB 117-2013 is the current standard for furniture sold in the state of California, and it is a performance based standard that does not require the use of FR chemicals. While the previous version of TB 117 did not state that FRs must be used to meet the standard, it did contain an open-flame flammability performance test that was usually met by using FR chemicals. Beginning in July 2007, mattresses must comply with an open-flame and smoldering ignition mandatory standards 16 C.F.R. parts 1633 and 1632, respectively. The standards are performance-based standards that do not require specific FR components for compliance. Mattress manufacturers have been able to pass the standards with the use of fiber technologies and barriers, rather than chemical treatments. Children's jewelry products do not have to pass flammability standards, but there are other standards that jewelry products must meet. The CPSC has no additional information to confirm or negate the commenter's statements.

Comment: Three commenters (PM21, PM22, and CPSC-2015-0022-0180 (PM16)) discussed approaches that are being used to achieve compliance with flammability standards with reduced or no use of OFRs. One commenter (CPSC-2015-0022-0180 (PM16)) discussed how the Petition is unnecessary because the technology and electronics sectors are already reducing the use of OFRs, when needed, but also ensuring consumer safety. Additionally, these sectors are continually reassessing the use of materials in their products taking into account the environment, human health, and consumer safety.

Response: The CPSC does not maintain a database of the additives used in the products that it regulates. As stated, the mandatory standards under CPSC's authority are performance-based and do not mandate the use of FRs to meet the performance requirements. These chemicals and their inclusion in the products would require additional study, if the Petition were granted.

Upholstered Furniture

Comment: Many commenters (CPSC-2015-022-0079, CPSC-2015-022-0185, CPSC-2015-0022-0198, and CPSC-2015-022-0152 (PM23)) discussed the role of upholstered furniture in fires in the United States, noting that upholstered furniture is the leading item involved in home fire deaths. They emphasized finding ways to maintain fire safety while also protecting human and environmental health. They urged the Commission not to be dismissive about the human, economic, and environmental impact of fire when assessing this Petition. One commenter (CPSC-2015-022-0152 (PM23)) stated that TB 117-2013 addresses smoldering ignition, which is the leading cause of furniture fire deaths.

Response: CPSC staff is aware of the role that upholstered furniture plays in home fires. Currently, the CPSC is in rulemaking under the Flammable Fabrics Act (FFA) to create a flammability standard for upholstered furniture. Petitioners have requested rulemaking under the FHSA to address potential adverse health effects associated with various classes of products containing OFRs. In conducting FHSA rulemaking to address potential adverse health effects associated with products containing OFRs, the Commission would assess this potential hazard, while also considering costs and benefits of implementing the requested rule, including those related to flammability and fire safety.

Comment: Commenters discussed TB 117-2013 and open-flame standards for upholstered furniture. One commenter (PM8) stated their concern with the approach the National Fire Protection Agency (NFPA) is taking in creating an open-flame standard. The commenter notes that NFPA's approach involves a large open-flame test that would require the application of an increase in the use of FRs in residential upholstered furniture. The commenter also stated that adopting TB 117-2013 as a national standard would not rid OFRs in furniture because it is a performance standard and does not prohibit their use. Two commenters (CPSC-2015-022-0070 and CPSC-2015-0022-0079) discussed TB 117-2013 requirements. One commenter (CPSC-2015-022-0079) discussed five major fire scenarios in fatal fires associated with upholstered furniture and stated that TB 117-2013 only addresses one scenario (cigarette ignition) out of the five. One commenter (CPSC-2015-0022-0070) favors an open-flame test for foams and believes that low-level smolder tests, such as TB 117-2013's, are inadequate. They emphasized that technology is out there to give polyurethane foam flammability protection to pass the open-flame portion of TB 117-1975, and it is environmentally safe.

Response: The CPSC has performance-based standards that address the risk of flammability and that allow the industry to meet these standards in a variety of ways, as determined by the manufacturer. This performance can be achieved with different technologies that do not include the use of FR chemicals.

Comment: Two commenters discussed FRs and escape time. Both referenced the same study that assessed the impact of FR materials on the survivability of the building occupants by comparing the time to untenability in the burn room and referenced other studies comparing upholstered furniture foams treated with and without FRs. One commenter (CPSC-2015-022-0198) stated that the results showed that the average available escape time was more than 15-fold greater for the flame-retardant products than for the non-flame-retardant products; and their other studies verified the efficacy of OFRs. Another commenter (CPSC-2015-022-0152 (PM23)), the author of the referenced study above, stated that these claims are false and that the referenced study was not suitable for consumer products, and other studies verify that OFRs are not necessary.

Response: The petitioners have requested a rulemaking under the FHSA to address potential adverse health effects associated with various classes of products containing OFRs. In conducting FHSA rulemaking to address this issue, the Commission would evaluate the potential hazard and also consider the costs and benefits of implementing the requested rule, including those related to flammability and fire safety.

Comment: One commenter (CPSC-2015-0022-0155) stated that CPSC should finalize the smolder standard it has proposed to ensure fire safety from cigarette-type ignitions, the leading cause of death and injury from furniture fires. The commenter noted that this standard could be finalized without the use of FRs in foam. Another commenter (CPSC-2015-0022-0170) expressed their lack of confidence in the statistics generated by the NFPA and the CPSC regarding the number of deaths arising from fires where upholstered furniture is first ignited. They said they believe these data have limited usefulness for policymaking purposes.

***Response*:** This briefing package assesses existing data for the Commission to grant, deny, or defer the Petition to address adverse health effects from exposure to OFRs in products within these four product categories. The provided comments do not fall within the scope of what the Commission is currently deciding.

The petitioners have requested rulemaking under the FHSA to address potential adverse health effects associated with various classes of products containing OFRs. In conducting FHSA rulemaking to address potential adverse health effects associated with products containing OFRs, the Commission would assess this potential hazard and also consider the costs and benefits of implementing the requested rule, including those related to flammability and fire safety.

<u>Electronic Devices</u>

Comment: Many commenters discussed the use of OFRs in electronic devices to meet mandatory standards. Four commenters (CPSC-2015-0022-0060, CPSC-2015-0022-0173, CPSC-2015-002-0176, CPSC-2015-0022-0180 (PM16), and CPSC-2015-0022-0198) stated that flame- and heat-resistance are inherently necessary characteristics of these devices. These petitioners stated that banning the use of these FRs in electronics could increase consumer exposure to immediate dangers in the home that are not present today, due to the use of these chemicals. Two commenters (CPSC-2015-0022-0060 and CPSC-2015-0022-0173) remarked that some consumer electrical products must meet mandatory flammability standards (and some are designed to voluntary standards) to be sold, distributed, and installed in any state, and FRs are used to meet these standards. They disputed the petitioners' claim that "there are no federal or state regulations requiring the use of FR chemicals in plastic electronic exposures." Some of the performance standards also contain flammability requirements for the materials used in the plastic so that they do not ignite, and they are manufactured with FRs to meet these standards. A commenter (CPSC-2015-0022-0173) also noted how more products are required to meet enhanced levels of safety through greater resistance to fire and fire spread. In addition, the commenter has made proposals to Standard Development Organizations, with CPSC encouragement, to require these higher levels of resistance in areas surrounding electrical connections.

Response: There are no mandatory standards that require the use of OFRs for electronic device casings, but there are increased flammability requirements for various electrical components used in buildings to comply with state and local electrical codes. However, the petitioners limited their request to the plastic casings for electronic devices, excluding the casings for electrical products. The use of a flame-resistant plastic casing (enclosure) is not required by the applicable voluntary standards, UL 60950, "Information Technology Equipment" and UL 60065, "Audio, Video and Similar Electronic Apparatus," but it is optional. Other methods exist for creating an electronic casing, such as using metal. An economic analysis would be necessary to understand the cost/benefits of other methods of creating a casing instead of using a casing made of flame-resistant plastics, considering factors such as cost, ergonomics, weight, and electromagnetic compatibility. Petitioners stated that their Petition does not cover components inside the electronic case, such as electronic components, wiring, connectors, circuit boards, and other structural plastic parts.

***Comment*:** Two commenters (CPSC-2015-0022-0060 and CSPC-2015-0022-0180 (PM16)) discussed the differences between the electronic devices category and the three other categories in the Petition and questioned the merit of reducing one type of risk (chemical) to increase the likelihood of another (fire risk). They stated that (1) electronic and electrical devices are constantly in contact with an electrical current, and it is absolutely imperative that the intrinsic risk of electrical hazards be mitigated; and (2) these products are intended specifically to protect consumers from electrical hazards, similar to car seats, which are exempted in the Petition, presumably because they are intended to perform a protective function, even in the case of a fire.

Response: In accordance with the specific request in the Petition, staff clearly distinguishes "electronic" device casings from "electrical" device casings, with consumer electronic devices being a subset of electrical devices. Consumer electronics broadly includes products classified as information technology, audio, and video equipment. Examples of such equipment are personal computers and computer displays, cell phones, televisions, audio equipment, power adapters, cameras and similar electronic products. The use of plastic casings is an option and not a required construction method for electronic devices covered by the voluntary standards UL

60950, “Information Technology Equipment” and UL 60065, “Audio, Video and Similar Electronic Apparatus.” Essentially, none of the casings of consumer products are in constant contact with electrical current that presents a risk of fire. Other than products covered by the two previously mentioned voluntary standards, products like circuit breakers, arc-fault current interrupters, smoke detectors, and other household appliances have not been included in the Petition.

***Comment*:** One commenter (CPSC-2015-0022-0198) provided data that home structure fires involving electronics have dropped, even when the presence of these devices has increased, partly because of the use of FRs in plastics. The commenter stated there has been an increase in electronic fires in Europe, due to a reduction in the use of these compounds.

Response: CPSC does not have data to produce estimates of structural fires involving electronics. Therefore, CPSC staff cannot confirm or contradict the claim of the commenter that structural fires involving electronics decreased in the United States and increased in Europe over the years.

Comment: One commenter (CPSC-2015-0022-0013) referenced articles on electronics and fires from candles. The commenter stated that fire data do not show a hazard for modern TVs from this type of ignition source, and if a TV were to come in contact with a candle, the TV would not burn with enough heat to cause a room to flash over.

Response: The applicable voluntary standard, UL 60065, “Audio, Video and Similar Electronic Apparatus,” does not have special flammability requirements for televisions due to ignition from external sources, such as candles.

Product Exemptions

Comment: One commenter (CPSC-2015-0022-0060) asked that, in the event CPSC does move forward with rulemaking under the authority of the FHSA, that CPSC include an exemption for either: (1) electrical products that include the OFRs to comply with flammability requirements adopted as part of a state code; or (2) electrical safety products that are intended to protect consumers from electrical and other hazards. Another commenter (CPSC-2015-002-0176) stated that without a viable alternative, these products could present an increased flammability risk in the event of certain electrical fault. This commenter asked that FRs in circuit boards not be considered part of a ban, due to their inaccessibility, and therefore, low-exposure potential.

Response: The petitioners did not include circuit boards in the classes of products for which they request rulemaking in the Petition. Accordingly, CPSC staff did not consider circuit boards.

***Comment*:** One commenter (CPSC-2015-002-0179) stated that the Petition does not meet the requirement of 16 C.F.R. § 1051.5(a)(4) regarding new mattresses made in the United States because the Petition does not establish that the rule is necessary. The commenters requested the Commission to exclude mattresses from any rulemaking initiated from this Petition because U.S. manufacturers of new mattresses do not use OFRs to meet federal mattress flammability standards. Another commenter (CPSC-2015-0022-0077) stated that the Commission should deny the Petition with respect to upholstered furniture because 16 C.F.R. § 1051.9(a) is not met. They stated that the requested rulemaking is not necessary to eliminate or reduce the risk of alleged injury because these chemicals are not being used in upholstered furniture; therefore, failure to initiate the rulemaking on upholstered furniture would not unreasonably expose the petitioners or consumers to the alleged risk of injury.

Response: Staff considered the presence or absence of OFRs in the several product categories listed by petitioners in forming its recommendation to grant or deny petitioner's request for rulemaking with respect to the four product categories of interest.

Comment: Two commenters (CPSC-2015-0022-0176 and PM21) discussed how using recycled plastics can lead to including FRs in products where they weren't intended, such as in toys, and the implications of this use.

Response: Staff acknowledges the potential of recycled plastic to contain FR chemicals and to be present in products where they are not intended. The petitioners included OFRs that had been intentionally added to these products for which they request rulemaking in the Petition, and they did not include OFRs that are present as a contaminant from manufacturing processes. If the Petition were granted, the regulatory limit (decided by CPSC) would need to consider the possibility of contaminant OFRs and what would be considered an excessive amount of contamination.

<u>Standards</u>

Comment: Many commenters discussed fire testing standards. One commenter (PM14) discussed how fire testing standards measure specific properties to achieve specific ratings, and that there are many variants. Many commenters (CPSC-2015-0022-0179, CPSC-2015-0022-0198, and CPSC-2015-0022-0203) stated that the Commission should favor performance-based safety standards and should refrain from setting proscriptive standards like those requested by the petitioners. Some commented that proscriptive standards stifle innovation, which could negatively impact the manufacturer's ability to efficiently implement new safety advances. They suggested that CPSC and stakeholders work cooperatively to encourage innovation and new technologies. One commenter (CPSC-2015-0022-0198) stated that CPSC must consider the existing fire safety standards for the products in this Petition. Commenters discussed the use of voluntary standards to address the fire risks of some of these products (CPSC-2015-0022-0173, CPSC-2015-0022-0176, and CPSC-2015-0022-0189). They stated that relying on voluntary standards groups to proactively address risks when they become evident is a prudent way for CPSC to regulate, by allowing the regulated community to address hazards in a flexible manner. One commenter (CPSC-2015-0022-0144) asked CPSC to ensure that mandatory and voluntary fire safety standards for these consumer products "do no harm," by evaluating whether the OFRs are needed, and if so, to verify that they pose no harm to human health.

Response: Pursuant to CPSC's petition regulations, the staff considers this Petition in light of the requirements of the FHSA. Petitioners seek FHSA rulemaking regarding OFRs in several categories of products to address adverse human health impacts resulting from the presence of these FRs in the petitioner-specified product categories. Accordingly, the relevant analysis regarding this potential hazard would be to examine the presence of voluntary standards that would eliminate or adequately reduce adverse human health impacts associated with the presence of OFRs in the enumerated classes of consumer products. The Commission would also examine this issue, should it proceed with rulemaking in the future, to address potential adverse health impacts related to consumer products that contain specific OFRs.

Economic Burden

Comment: Many commenters (CPSC-2015-0022-0060, CPSC-2015-0022-0173, and CPSC-2015-0022-0198) discussed the potential burden on the supply chain to procure and integrate viable alternatives to comply with these product categories if this ban occurs. The commenters noted that chemical alternatives may not be available in some instances, such as in enclosures for electronic devices. Two commenters (CPSC-2015-0022-0060 and CPSC-2015-0022-0173) also stated materials that are inherently flame/heat resistant may be used to encase electrical wiring inside the product instead of using FRs in the plastic; however, none of these materials has been proven a viable alternative to plastic casings, taking weight, instability and added cost into account. One commenter (CPSC-2015-0022-0198) discussed that a variety of FRs are available due to different material and end-use performance requirements, which is why these FRs are not interchangeable. Two commenters (PM21 and PM22) provided examples in which companies have redesigned and reengineered their products to pass flammability tests without FRs, noting that manufacturers are ready, able and willing to eliminate the use of OFRs. Two commenters (CPSC-2015-0022-0071 and PM28) stated that safer alternatives to OFRs are available in product categories in the Petition, such as upholstered furniture and electronics, and that alternative assessments have been performed on all of the categories mentioned in the Petition. Other commenters (CPSC-2015-0022-0155 and CPSC-2015-0022-0203) stated that CPSC, along with the U.S. EPA, must investigate any identified alternatives to OFRs for use in these products. One commenter (CPSC 2015-0022-150,) asserted that the cost of replacing hexabromocyclododecane is possible and also suggested that the costs of doing so are low.

Response: If the Commission grants the Petition and proceeds with rulemaking, Commission staff would need to prepare a regulatory analysis that examines the costs and benefits of the rule. In order to perform this analysis, Commission staff would need to conduct additional analysis to determine the extent that OFR chemicals are used in consumer products, the benefits of eliminating the chemicals in certain applications, and the costs that could be associated with eliminating the OFR chemicals from certain products where they are used This could involve investigating the costs of not using any FRs in the products, using inherently FR materials, or the potential costs and risks associated with substitute chemicals and potential alternative chemicals. The Commission staff would also need to conduct research to determine the extent to which manufacturers can replace FR chemicals.

Comment: Several commenters (CPSC-2015-0022-0067, CPSC-2015-0022-0158, CPSC-2015-0022-0173, CPSC-2015-0022-0188, and CPSC-2015-0067-0198) noted that if the agency proceeds with rulemaking under the FHSA, the Commission must consider the relationship between costs and benefits in a proposed rule. In addition, the economic analysis should consider regulatory alternatives.

***Response*:** If the Commission grants the Petition and proceeds with rulemaking, staff would conduct an economic analysis to consider the costs and benefits of the proposed rule, as well as alternatives to the rule. The CPSC staff must also conduct an analysis under the requirements of the Regulatory Flexibility Act to determine the potential economic impact on small entities.

***Comment*:** Many commenters expressed concern about the impact of potential third party testing costs on firms if CPSC promulgated rulemaking to ban chemicals listed in the Petition (CPSC-2015-0022-0060, CPSC-2015-0022-0149, CPSC-2015-0022-0176, CPSC-2015-0022-0180 (PM16), CPSC-2015-0022-0182, and CPSC-2015-0022-0203). These commenters asserted that testing costs associated with a ban would have a negative impact on firms, especially small businesses. Two commenters (CPSC-2015-0022-0149 and CPSC-2015-0022-0180 (PM16)) asserted that third party testing costs and certification associated with FR chemicals would be "prohibitively expensive, time consuming and difficult to certify that chemicals are not present in a product"; and in the case of upholstered furniture, testing would be "impractical,"

Another two commenters provided estimates of testing costs: the first commenter (CPSC-2015-0022-0176) asserted that testing costs for one chemical fire retardant could be as much as $650, and the total cost of testing 25 different chemicals could be $16,250. The other commenter (CPSC-2015-0022-0182) asserted that, cumulatively, costs could be in thousands of dollars for a single product line.

***Response*:** According to Section 14 of the Consumer Product Safety Act, manufacturers, importers and private labelers of children's products must certify that their products comply with all applicable children's product safety rules, based upon third party testing. Therefore, if the scope of any rule resulting from this Petition included children's products, manufacturers, importers, or private labelers of those products would have to obtain third party testing of their products to show that their products comply with the regulations. Based upon the cost estimates given in the comments, and based on our knowledge of the costs of other chemical content third party tests, testing for chemical content can be relatively costly. If the Commission promulgated a rule banning OFRs in children's products, the cost of the third party testing could be significant for some companies.

***Comment*:** Commenters (CPSC-2015-0022-0149 and PM3) discussed products with OFRs in people's homes. One commenter (PM3) asked the CPSC to consider what steps would be appropriate to protect children and consumers from products containing toxic polybrominated biphenyl ether (PBDE) FRs found in homes all over this country. The other commenter (CPSC-2015-0022-0149) objected to any remedial action, such as a recall, product exchange or swap, or refund of purchase price, for upholstered furniture items. The commenter stated that any of these actions would lead to enormous costs that have no reasonable relationship to benefits expected.

***Response*:** The Commission considers petitioners' request to address this potential hazard in light of Commission petition regulations and the FHSA. As stated, any future rulemaking regarding potential adverse health effects of products containing OFRs would involve assessing specific OFRs used in consumer products, exposure pathways to these products, and the resulting adverse health effects from these substances. Additionally, such rulemaking would consider the costs and benefits associated with the rulemaking and would need to determine that there is a reasonable relationship between costs and benefits to complete the rule.

Comment: One commenter (CPSC-2015-0022-0198) stated that banning this class of chemicals in these four categories could result in a ban of hundreds or thousands of products.

Response: Staff shares the concern that a broad, class-wide ban could have unintended consequences. Although test methods can determine whether a chemical specified in the Petition is present in a product, testing cannot distinguish whether the chemical was intentionally added as an FR. If, for example, a new organohalogen compound was applied to a product, but not added to provide flame resistance, it is unclear how that product would be regulated.

Comment: One commenter (CPSC-2015-0022-0077) stated that broad rulemaking is not necessary or the least burdensome for the upholstered furniture product category because manufacturers are not using FRs to meet the TB 117-2013 performance standard. The commenter stated the belief that the petitioners' concerns could be addressed through a labeling rule using existing California standard and labeling (SB 1019), and the cost associated with revising warning labels would be less than banning organohalogen chemicals in products.

Response: In deciding to recommend whether to grant, deny, or defer the Petition, staff is considering market changes in response to TB117-2013 with respect to OFR use in upholstered furniture.

Comment: One commenter (CPSC-2015-0022-0176) stated that if this Petition were granted without firm evidence, free trade may be hindered with other countries under the Technical Barriers to Trade agreement.

Response: If the Commission granted the Petition, any standard or ban that resulted would apply to all covered products sold in the United States, regardless of whether the products were manufactured by a domestic or foreign firm. Therefore, it would not be discriminatory. Additionally, the Technical Barriers to Trade agreement recognizes World Trade Organization members' right to implement measures to achieve legitimate policy objectives, such as the protection of human health and safety, or protection of the environment.

Fire safety

Comment: Several commenters discussed fire safety and FRs. The commenter (CPSC-2015-022-0152 (PM23)) stated that there is no meaningful fire safety benefit for FR use in any of the product categories in the Petition. The commenter stated that the loadings used in consumer products are not high enough to provide any fire safety benefit. Several commenters (CPSC-2015-0022-0060, CSPC-2015-0022-0180 (PM16), CPSC-2015-0022-0189, CPSC-2015-0022-0198, CPSC-2015-0022-0203, and PM12) discussed a possible decrease in fire safety with a ban of OFRs. They noted that the potential consequences of the petitioners' request on existing performance flammability standards need to be considered for each class of products. In addition, these commenters suggested that removing these chemicals could undermine consumer safety by eliminating these valuable and studied FRs from the market, along with innovative future uses for these chemicals. A ban on this entire class of FRs may result in a higher loss of life to fires, the commenters proffered. Two other commenters (CPSC-2015-0022-0060 and CSPC-2015-0022-0180 (PM16)) stated that banning these chemicals will have the unintended consequences of altering the fire safety of electronic products and hindering the path forward for new products with respect to fire safety. One commenter (CPSC-2015-0022-0069) stated that the current level of fire safety performance must be maintained while efforts to address human health concerns from exposure to certain chemicals are considered.

Response: Currently, staff is considering whether to recommend granting, denying, or deferring the Petition with respect to adverse health effects of OFRs in these product categories. Aspects of fire safety would be considered later in the rulemaking process, if necessary.

Comment: Commenters discussed ways to improve fire safety. One commenter (PM12) stated that FRs are included in a comprehensive set of fire-safety measures that have contributed to the decline in fires and fire deaths. Another commenter (PM14) stated that fire safety is best achieved when it is composed of multiple layers, such as sprinklers, inherently flame-resistant construction, and protecting products from ignition. One commenter (PM8) stated that health risks associated with the use of these chemicals is greater than the fire risk without using these chemicals. The commenter discussed the use of advanced fire safety technology, such as sprinkler systems, smoke and fire detection systems, and modern early warnings, and the significant reduction in the use of tobacco products as reasons for fire reduction in the United States.

Response: The CPSC staff agrees that fire safety can be improved using a combination of technologies, including sprinklers, inherently flame resistant construction, and protecting products from ignition. The petitioners have requested rulemaking under the FHSA to address potential adverse health effects associated with various classes of products containing OFRs. In conducting FHSA rulemaking to address potential adverse health effects associated with products containing OFRs, the Commission would assess this potential hazard and also consider costs and benefits of implementing the requested rule, including those related to flammability and fire safety.

Flame Retardant Efficacy and Future Uses

Comment: One commenter (CPSC-2015-0022-0189) stated that because these FRs have an important value in consumer products and fire safety, although some are more efficacious than others, CPSC should consider how to use them most effectively instead of banning their use. Future uses may also be found for these chemicals to produce other benefits, which would not be found if they are banned.

Response: This briefing package assesses existing data for the Commission to grant, deny, or defer the Petition to address adverse health effects from exposure to OFRs in products within these four product categories. In conducting FHSA rulemaking to address potential adverse health effects associated with products containing OFRs, the Commission would assess this potential hazard and also consider the costs and benefits of implementing the requested rule, including those related to flammability and fire safety.

***Comment*:** Commenters discussed data on the impact of FRs in these product categories. One commenter (PM14) stated that fire retardants prevent ignition from small ignition sources, slow the rate of fire growth, reduce the peak heat release rate, prevent an item from becoming the first ignited, and create a very slow fire that is a non-event. Two commenters (PM2 and PM24) stated that FRs are ineffective in real-scale fires when large flames are involved, and one commenter (CPSC-2015-022-0152 (PM23)) stated that there is no benefit to using them in any of the four product categories in the Petition.

***Response*:** The petitioners have requested rulemaking under the FHSA to address potential adverse health effects associated with various classes of products containing OFRs. In conducting FHSA rulemaking to address potential adverse health effects associated with products containing OFRs, the Commission would assess this potential hazard and also consider the costs and benefits of implementing the requested rule, including costs related to flammability and fire safety.

***Comment*:** Comments discussed whether OFRs are beneficial in these product categories. One commenter (CPSC-2015-0022-0155) recommended that CPSC examine whether chemical additives to foam and electronic casings are beneficial. They cited a CPSC study, which found that adding these chemicals to foam provided little consistent benefit to fire safety. Two commenters (CPSC-2015-022-0151 and CPSC-2015-022-0152) discussed each product category and how OFRs provide no benefit. One commenter (CPSC-2015-0022-0151) remarked that for FRs to be necessary, products would need to pose a significant fire hazard. Topics raised included how juvenile products were not found to pose a serious fire hazard to infants and children, that FR levels used in upholstered furniture foam cannot significantly delay or prevent fires, that CPSC's mandatory mattress standards typically are met without the use of OFRS, and that FRs are added to electronic casings to protect against ignition by a candle, but in a large fire, they offer no protection.

***Response*:** The applicable voluntary standard UL 60065, "Audio, Video and Similar Electronic Apparatus," does not have special flammability requirements for televisions due to ignition from external sources, such as candles. Overall, consumer electronic devices constitute a fraction of the fuel load in home fires.

The CPSC reviews and adopts performance-based standards to address flammability that allow the industry to meet these standards in a variety of ways, as determined by the manufacturer. This performance can be achieved with the use of different technologies, which do not include the use of FR chemicals.

***Comment*:** One commenter (CPSC-2015-022-0152) stated that OFRs can be counter-productive in consumer products. The commenter cited a CPSC study, which concluded that the addition of commercial amounts of FRs to foam "appears to reduce resistance to smoldering ignition."

***Response*:** The CPSC only has a performance-based standard to address flammability, which allows the industry to meet these standards in a variety of ways, as determined by the manufacturer. This performance can be achieved with the use of different technologies that do not include the use of FR chemicals.

Health effects, Exposure, and Physical Properties of Organohalogen Flame Retardants

Comment: One commenter (CPSC-2015-0022-0189) disputed the petitioners' claims that trace exposures to these FRs produce adverse health effects, such as endocrine disruption, neurodevelopmental effects, and cancer. The commenter cited an Agency for Toxics Substances and Disease Registry study, which stated that none of the PBDEs have been shown to cause health effects in humans exposed to trace amounts from furniture or other consumer products.[66]

Response: If the Petition is granted, CPSC staff would consider data on levels of OFRs measured in these products and in other media, where exposure may occur because levels may indicate exposures that are too low to cause these effects in humans.

Comment: Commenters discussed smoke toxicity and OFRs. Three commenters (CPSC-2015-022-0152 (PM23), PM8 and PM24) discussed increased smoke toxicity from products burning with OFRs and health effects associated with this exposure. One commenter (CPSC-2015-0022-0198) discussed how FRs reduce smoke production during a fire and do not contribute significant or additional toxicity to the smoke. The commenter stated that when flashover occurs, the concentration of combustion byproducts increase, thereby increasing the toxicity of the smoke. The commenter referenced studies comparing smoke from both flame retardant and non-flame-retardant products, and smoke from both sets of products were similar in potency. However, the quantities of toxic gases produced from the flame-retardant products were one-third of the non-retardant.

Response: While FR chemicals reduce ignition potential, FR-treated products may extend the smoldering time, and will ignite if exposed to sufficiently high temperatures. Combustion byproducts produced when products with OFRs burn has been studied. Products, such as carbon monoxide, hydrochloric acid, hydrogen bromide, and dioxins, and furans, have been measured in fire effluents from both FR and non-FR treated products. However, it is debatable whether the smoke toxicity from the combustion of products with OFRs is more toxic to consumers than without FRs and how this toxicity may impact consumers' ability to exit safely from a fire scenario.

Other Government Action on OFRs

Comment: Commenters discussed redundancy of this Petition with action taken by other agencies. Several commenters (CPSC-2015-0022-0173, CPSC-2015-0022-0180 (PM16), CPSC-2015-0022-0181, CPSC-2015-0022-0189, CPSC-2015-0022-0198, and PM13) discussed the duplicate work this Petition would generate because the EPA is assessing FR chemicals (some OFRs) under Toxics Substances Control Act (TSCA). Commenters suggested that instead, CPSC should coordinate with the EPA and look at their assessments before moving ahead with any rulemaking. These commenters also noted that EPA is not assessing the entire class of OFRs, and CPSC should work with EPA on the appropriate breadth of chemicals. One commenter (PM26) stated that granting this Petition would not be redundant because, although

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[66] ATSDR. 2004. Public Health Statement: Polybrominated Diphenyl Ethers. A. Division of Toxicology, editor.

EPA has started looking at clusters of OFRs, this work could take years. The commenter also stated that the revised TSCA would not ensure that EPA would effectively regulate articles or products with existing or new FRs. Another commenter (CPSC-2015-0022-0155) stated that EPA has been unable to keep pace with the new evidence of FR toxicity to human health, and the environment and is unable to ensure that new chemicals developed as replacements for organohalogens do not pose their own risks.

Response: Currently, EPA is evaluating FRs, including OFRs. CPSC and EPA staff are working together to coordinate activities to prevent duplication of effort. Petitioners request rulemaking under the FHSA regarding products that contain OFRs to address potential adverse health effects associated with such products. As such, CPSC considers the petitioners' request in light of the Commission's petition regulations and statutory authority.

***Comment*:** Commenters discussed actions taken by states on OFRs. Three commenters (CPSC-2015-0022-0143, CPSC-2015-0022-0202, and PM20) presented state actions on OFRs. One (PM20) stated how the state actions can only go so far, due to replacement chemicals and a chemical-by-chemical approach, and that CPSC could fix this by granting the Petition. One commenter (PM28) presented their state's work on OFRs, which included testing children's products and finding OFRs. Another commenter (CPSC-2015-0022-0075) stated that the commenter's state has restricted some OFRs in children's products, furniture, and electronics.

***Response*:** CPSC may consider the benefit to federal regulation making consistency for requirements across states that already have requirements in place for certain commodities. CPSC welcomes information from the states on current and pending OFR rulemaking at the state level.

***Comment*:** One commenter (CPSC-2015-0022-0073) stated that, in most other countries, chemicals must be proven to be safe before they can be introduced into the consumer market, and that CPSC should adopt this policy.

***Response*:** CPSC's consideration of proceeding with petitioner's request for rulemaking is governed by the Commission's petition regulations and the statutory requirements of the FHSA, the statute under which petitioners request rulemaking. CPSC notes that the FHSA is, in some respects, self-executing because industry is responsible for determining whether their products are or contain a "hazardous substance" as defined in the FHSA, and if so, that products are properly labelled.

TAB I: Exhibits A through M of the Petition

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A
B

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Statements in Support of Petition for Rulemaking

Exhibit A

Statement of Terrence J. Collins

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September 12, 2013

I, the undersigned, am writing this statement in support of the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. I, Terrence James Collins, am the Teresa Heinz Professor of Green Chemistry in the Department of Chemistry, and the Director of the Institute for Green Science at the Carnegie Mellon University.

My collaboration with environmental health scientists (EHS) has focused on developing appropriate tests to identify chemical properties that give rise to adverse human health effects at low doses through endocrine disruption. Our work has aimed to underpin the development of safe chemicals in general, including safe alternatives to organohalogen chemicals. I have attached a copy of my curriculum vitae and a list of my publications.

In a privately funded collaborative effort spanning five years, my EHS colleagues and I produced and published the Tiered Protocol for Endocrine Disruption (TiPED). This allows green chemists, for the first time, to design with state of the art scientific authority against endocrine disruptors. I am best known for inventing the first small molecule mimics of any of the great families of oxidizing enzymes. My TAML® activators are extensively patented and have been commercialized so I am a friend to the commercial development of chemicals. TAML® activators were TiPED tested in design to ensure no new endocrine disruptor would be commercially produced and those in development have passed all assays as not being endocrine active thus far.

2. Organohalogens used as flame retardants as a class have specific chemical properties that give them a high potential for causing adverse human health effects via multiple mechanisms. Organohalogens tend to bioaccumulate in human and animal tissues. This occurs because halogens, particularly bromine and chlorine, which are broadly used in flame retardants, often cause the organic chemicals to which they are attached to partition from environmental media (particularly water) into living tissues, where they bioaccumulate. This bioaccumulation is driven by the differential solubility of chemicals in fats, oils, lipids (such as what cell walls are made of) and other similar solvents compared with water and aqueous-like media. As organohalogens tend to be more lipophilic (fat-loving) than their non-halogenated analogues, they will bioaccumulate more readily.

3. Depending on the structure of the organic parent compound, the addition of halogen elements can either increase or decrease the compound's reactivity. Either change can impact the compound's toxicological profile leading to an increased risk of adverse health effects in humans. For alkylorganohalogens (such as most chlorinated organophosphate flame retardants), halogens tend to increase reactivity toward the chemical modification of key biomolecules, including DNA and the histone proteins around which DNA is wrapped. These modifications are likely to interfere with gene expression and to increase the likelihood of cancer. For

arylhydrocarbons (carbon ring-like structures with halogens appended, such as most brominated flame retardants), halogens tend to decrease reactivity, impeding the cell's ability to enzymatically break down the arylhydrocarbons thus increasing their lifetime in the cell.

4. Some organohalogen flame retardants are known to be potent endocrine disruptors, so their bioaccumulation leads to additional likelihood of harm to organisms via developmental damage associated with disruption of the endocrine hormone control of cellular development. Arylhydrocarbon organohalogens can mimic natural hormones that at very low concentrations regulate expression of proteins involved in cellular development. This developmental disruption, which appears to occur via disruption of hormone action, is a major cause of human health harm. The adverse health effects are often manifested at very low concentrations (in the range to which people are exposed) and can disrupt development starting *in utero*. Endocrine disruptors can activate gene expression resulting in abnormally high protein production (agonist), or suppress gene expression resulting in abnormal protein deprivation (antagonist). This disruption of the normal expression of control proteins can lead to cells that do not develop and multiply, are less healthy, have altered fates, and are more likely to develop cancer later in the life of the organism. This is one mechanism by which arylhydrocarbon organohalogens such as dioxins function to produce birth defects and cancer. In my professional opinion, such adverse effects should also be anticipated for arylhydrocarbon organohalogen flame retardants.

5. Organohalogen flame retardants can also disrupt DNA function. Arylhydrocarbon organohalogen flame retardants share chemical similarities with compounds that are known to stick to DNA by inserting into the DNA base pair structures. This intercalation can alter the normal function of DNA and can serve as a mechanism for initiating carcinogenesis.

6. When they burn, organohalogen flame retardants produce halogenated dioxins and furans, which are extremely persistent and extremely toxic to humans. This fundamental and thus far inescapable factor in the full life cycle of the entire class of organohalogen flame retardants is a large cause of harm to human health currently and out into the distant future.

7. To summarize, organohalogen flame retardants have highly persistent and toxic combustion by-products, readily bioaccumulate and can resist breakdown inside cells, can modify the DNA or disrupt its function, and can act as endocrine disruptors. To the best of my knowledge, there is no sound evidence showing a lack of health harm for any organohalogen flame retardants studied to date.

8. Based on the above arguments, I would urge the Consumer Product Safety Commission to regulate the use in consumer products of the entire class of non-polymeric additive organohalogen flame retardant chemicals.

Yours sincerely,

Biographical Sketch of Terrence J. Collins

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EDUCATION

University of Auckland, New Zealand
Bachelor of Science—1974
Master of Science with First Class Honors—1975
Doctor of Philosophy—1978
Advisor: Professor Warren R. Roper, FRS
Ph.D. Thesis: Thiocarbonyl Complexes of Ruthenium and Osmium.
Stanford University
Postdoctoral, with Professor James P. Collman—1978–1980

PROFESSIONAL EXPERIENCE

Carnegie Mellon University
Teresa Heinz Professor of Green Chemistry, 2010–present
Director, Institute for Green Science, 2008–present
Thomas Lord Professor of Chemistry, 2001–2010
Director, Institute for Green Oxidation Chemistry, 2001–2007
Professor of Chemistry, 1993–2001
Associate Professor of Chemistry, 1988–1992
California Institute of Technology
Assistant Professor of Chemistry, 1981–1987
Auckland Technical Institute
Lecturer (part-time), 1974–1977

PRIZES, AWARDS AND DISTINCTIONS

2013 – Fellow of the American Chemical Society
2011 – Chairman, Science Advisory Council, The Heinz Center
2011 – Trustee, The Heinz Center, Washington, DC (6-yr appointment)
2010 – Heinz Award for the Environment
2008 – Honorary Fellow of the Royal Society of New Zealand
2008 – Charles E. Kaufman Award of the Pittsburgh Foundation
2007 – Award of the New York Metropolitan Catalysis Society
2007 – Distinguished Alumnus Award, University of Auckland, New Zealand
2006 – Fellow of the International Union of Pure and Applied Chemists
2004 – Pittsburgh Award of the American Chemical Society
2004 – Award of the Baylor University ACS Students Affiliates for Outstanding Achievements in Green chemistry
2002 – Golden Goggles Award, Middle Tennessee State University
2001 – Honorary Professor, University of Auckland, 2001–present
1999 – Presidential Green Chemistry Challenge Award (1998)
1998 – Award of the Japanese Society of Pure and Applied Coordination Chemistry (1997) for leadership research in green chemistry.
1998 – Visiting Professor, Graduate School of Science, Osaka-City University
1996 – Distinguished Visiting Professor, University of Auckland
1986 – Alfred P. Sloan Research Fellow to 1988
1985 – Camille and Henry Dreyfus Teacher-Scholar to 1990
1982 – Occidental Research Corporation (Junior Faculty Award)
1977 – Lindsay Heathcote Briggs Memorial Prize (Best Ph.D. Thesis in Chemistry)
1975 – Postgraduate Scholarship in Chemistry

1973 – Senior Prize in Chemistry

RESEARCH INTERESTS

- Green chemistry
- Inorganic chemistry
- Homogeneous oxidation catalysis
- Design of green oxidants
- Alternative chemistry for oxidation processes that produce persistent pollutants
- Removing endocrine disrupting chemicals from technology
- Bioinorganic chemistry of high oxidation state transition metal species
- Toxicity and ecotoxicity of chemical processes and products
- Preparation of multinuclear transition metal ions with predetermined magnetic exchange coupling properties

PUBLICATIONS

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143. Clark, G. R., T. J. Collins, D. Hall, S. M. James, W.R. Roper, A four-membered osmium metallocycle from inter-ligand reaction between thiocarboxamido- and thiocarbonyl ligands structure of $Os(CS_2CNMe\text{-}p\text{-}tolyl)H(CO)(PPh_3)_2$, *J. Organometal. Chem.*, **1977**, *141*, C5.

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145. Collins, T. J., W. R. Roper, Neutral and cationic dithiocarbonyl complexes of osmium(II), *J. Organometal. Chem.* **1977**, *139*, C9.

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148. Collins, T. J., K. R. Grundy, W. R. Roper, and S. F. Wong, Cyclic transition metal carbene complexes from ring-closing reactions on the π-bound substrates CS_2 and CSe_2 1,3-dithiolan-2- ylidene and 1,3-diselenolan-2-ylidene complexes of ruthenium(II) and osmium(II), *J. Organometal. Chem.*, **1976**, *107*, C37.

149. Collins, T. J., W. R. Roper, Thioformyl and formyl complexes of osmium(II), *J. Chem. Soc., Chem. Comm.* **1976**, 1044.

150. T. J. Collins, W. R. Roper, K. G. Town, Synthesis of low-valent thiocarbonyl complexes via 1,2-elimination of methylthiol from cis-metal-hydridodithiomethyl-ester complexes. $Os(CS)(CO)_2(PPh_3)_2$ and $IrCl(CS)(PPh_3)_2$, *J. Organometal. Chem.* **1976**, *121*, C41.

151. Clark, G. R., T. J. Collins, S. M. James, W. R. Roper, K. G. Town, Triphenyl phosphoniodithiocarboxylato-SS'-carbonylbis(triphenylphosphine)iridum(I) tetra-fluoro borate: X- ray structure of an apparent π-CS2 complex of iridium, *J. Chem. Soc., Chem. Comm.* **1976,** 47.

Educational Leadership

- Creator of first university course in green chemistry: Introduction to Green Chemistry, 1992—first by many years.

- Founder and principal lecturer in free web course on green chemistry: Introduction to Green Chemistry, see: http://igs.chem.cmu.edu/ About 10% of the total envisioned course had been produced and uploaded by March 2012.

Introduction to Green Chemistry

Course Overview: Over the past 150 years the field of chemistry has fostered almost no formal training in toxicity or ecotoxicity. We continue to train chemists to create new products and processes, but not educate them to be aware of the need to protect themselves, other people or the ecosphere from the results of their hard work. Green chemistry offers an alternative. The field was best defined by Paul Anastas in the 1990s as "the design of chemical products and processes that reduce or eliminate the use and generation of hazardous compounds." Stated broadly, this course helps students understand the notion of sustainability and how it applies to chemistry. It also explores the history of chemistry, outlines critical need for green chemistry, and the holistic principles that guide its practice as an emerging and important field of science.

Conference Best Papers/Posters

- Gupta, S. S., D. Lenoir, T. J. Collins, Rapid Destruction of Chlorophenols by Activated Hydrogen Peroxide in Presence of TAML Catalysts, IPOC 16, 16th International Conference on Physical Organic Chemistry, August 4–9, **2002**, San Diego, CA – Best Poster Award.
- Hangun-Balkir, Y., L. Alexandrova, S. K. Khetan, C. Horwitz, A. Cugini, D. D. Link, B. Howard, T. J. Collins, Oxidative desulfurization of fuels through TAML® activators and hydrogen peroxide, Pittsburgh-Cleveland Catalysis Society Meeting, Fortieth Annual Spring Symposium, May 10, **2002**, Pittsburgh PA – Best Paper Award.
- Wingate, K. G., M. J. Robinson, T. R. Stuthridge, T. J. Collins, L. J. Wright, Color and AOX Removal from Bleached Kraft Mill Wastewaters Using Catalytic Peroxide Activators, TAPPI International Environmental Conference, April 7-10, **2001**, Montreal, Canada - Best Paper from Water Quality Category.

SYMPOSIA ORGANIZED

- Member of International Advisory Board, Materials and technologies for green chemistry" in Tallinn, Estonia, September 5-9, 2011
- International Conference on Environment 2010, Green Technologies for Benefit of Bottom Billions, Penang, Malaysia, December 13–15, 2010
- Member of International Advisory Board, International Union of Pure And Applied Chemistry Conference 2010—Chemistry for Sustainable Development, Mauritius, July 26–30, 2010
- Member of International Advisory Board. Third International Conference on Green & Sustainable Chemistry, Delft, The Netherlands, July 1-5, 2007
- Advisory Board, Green Chemistry and Engineering Conference, Washington DC, 2005
- Member of International Advisory Board. Canada-US Joint Workshop on Innovative Chemistry in Clean Media, May 20-21, 2004
- Co-Chair, Green Chemistry and Engineering Conference, Washington DC, 2004
- Member of International Advisory Board. First International Conference on Green & Sustainable Chemistry, Tokyo March 13-15, 2003
- Co-Chair, Green Chemistry and Engineering Conference, Washington DC, 2003
- Member, National Advisory Board for the International Conference on Macrocyclic Chemistry, Lawrence, Kansas, scheduled for June 1994
- Chairman, 1986 Industrial Associates Conference on Oxidation Chemistry, Caltech, February 25–27, 1986.
- 1984 International Chemical Congress of Pacific Basin Societies, Symposium Organizer with Eiichi Kimura and Chris Reed of the Symposium on ``New Developments in Coordination Chemistry: Oxygen and Oxidation", Honolulu, Hawaii, December 16 – 21, 1984

- Member, International Advisory Board and Report Editor, the International Workshop on "Activation of Dioxygen Species and Homogeneous Catalytic Oxidations", Galzignano (Padova) Italy, June 28-29, 1984.

OTHER PROFESSIONAL ACTIVITIES (FROM 1998 ON) ***selected examples***

- Interviewed by David Lemberg for "Science and Society", June 21, **2007**. Podcast available at http://www.scienceandsociety.net/audio/collins.mp3
- Lecture, "Green Chemistry; Sustaining a High Technology Civilization", Environmental Health Lecture Series, Town Hall, Seattle, WA, January 24, **2007**, broadcasted on NPR.
- Interviewed by Diane Horn (Producer and Host) of National Public Radio affiliate NEXP, Seattle for program "Mind Over Matters"
- Creating a New Chemistry, Air date: Week of 04/18/2007, Story length: 7:17, Producer: Reid R. Frazier, The Allegheny Front: environmental radio for Western PA
- Interviewed by Sarah Bennett of the Listener leading to the article, "Toxic Inheritance," May 5– 11, **2007.**
- Interviewed by Kim Hill for Radio New Zealand on Green Chemistry (37 minutes), Broadcast February 24, **2007**
- Interviewed and profiled for the website of the Collaborative on Health and the Environment, 2006, http://www.healthandenvironment.org/articles/homepage/614
- Greening on Chemical World, December 13, 2006, Jennifer McGuiggan on GC and the Institute for Green Oxidation Chemistry, http://www.popcitymedia.com/features/41greenchem.aspx
- American Associate Editor of the Royal Society Journal, *Green Chemistry*—2001-2004.
- Member of Editorial Advisory Board of C&E News—2003-2005.
- Support of GC development for society in general and for less advantages states: Member of ACS Environmental Affairs Committee, Consultant to EPSCOR States on how to develop viable centers in green chemistry research, convener of International Conference on GC, Mumbai January, **2004**.
- Brief to the National Academy of Sciences Committee investigating technologies for killing anthrax on letter supporting machines at Army facilities, November **2003**.
- Member of the Advisory Group, National Academy of Sciences Roundtable on *Science and Technology in Support of a Transition Toward Sustainability*, March **2003**.
- Instructor on the DVD of the ACS and Green Chemistry Institute "Green Chemistry: Meeting Global Challenges", **2003**.
- PI on grant from ACS-PRF that brought 22 winners of the Presidential Green Chemistry Challenge Award to Congress to meet with legislators and explain the progress and potential of green chemistry. Participated in what were regarded as highly successful meetings with three other Pennsylvania winners personally Senators Santorum and Specter and Congressmen, Doyle and Murphy, explaining the promise of Green Chemistry, November 28-29, **2003**.
- Member, ACS Committee on Environmental Improvement, **2002** –, Associate Member, ACS Committee on Environmental Improvement, 1999 – 2001
- Featured on video of the ACS and the EPA, "Green chemistry: Innovations for a Cleaner World".
- Quoted widely on the eight-hour 2002 TV component of the multimedia workshop for teacher professional development, "Reactions in Chemistry", funded by CPB and the Annenberg Foundation.
- National Public Radio Interview with Ira Flatow <http://www.npr.org/rundowns/segment.php?wfld=1447823>
- Integration and Transfer of Knowledge: Since 1998, delivered 145 lectures (>20 international conference plenary lectures and named lectures) outside Carnegie Mellon University on Green Chemistry as a field and the Collins Group research program, including >40 to the general public (279 outside lectures throughout career).
- Consultant for the Green Chemistry Gordon Conferences
- Member of the DOE panel to advise the government on how to spend ca. $10 M per year for the funding of green chemistry.
- Member of the IUPAC Working Party on Green Chemistry. International consultant helping to script the workshop report for the Organization for Economic Cooperation and Development. Member of writers and coordinators for IUPAC white paper on Green Chemistry.
- United States Representative to the Organization for Economic Cooperation and Development Workshop on the Funding of Sustainable Chemistry, Tokyo, October **2000**
- Member of International Advisory Committee for Japanese Green Chemistry Symposia Series.
- Published first definition of Green Chemistry - 'Green Chemistry', Collins, T. J. *Macmillan Encyclopedia of*

Chemistry, Volume 2, Simon and Schuster Macmillan, New York, **1997**, 691-697.
- Published one of first educational articles in GC, "Introducing Green Chemistry in Teaching and Research", T. J. Collins, *J. Chem. Ed.*, **1995**, *72*, 965–966.
- Participant at many national and international meetings designed to further green chemistry education as noted above.
- Developed first university course on Green Chemistry (taught since 1992).
- Member ACS, Royal Society of Chemistry, Royal Society of NZ, Technical Association of the Pulp and Paper Industry.
- Many interviews and expert opinions expressed in books, magazines and newspapers.

Video Presentations
- Professor Collins course "Introduction to Green Chemistry" is being developed for world-wide distribution—see http://igs.chem.cmu.edu/ for a demo that shows the general idea—the final site will be approximately 10 times bigger and will include further world leading scholars as teachers for the different areas.
- The Collins Group Presidential Green Chemistry Challenge Award was featured on the ACS video: "Green Chemistry: Innovations for a Cleaner World"
- Professor Collins makes multiple appearances discussing green chemistry and sustainability science on an 8-hour educational series produced by Sally Heldrick under funding from the Annenberg Foundation and the Corporation for Public Broadcasting called "Reactions in Chemistry", a Professional Development series for High School Teachers— http://www.learner.org/channel/workshops/chemistry/
- Professor Collins videotaped an online instruction course in green chemistry (July 23, 2004): http://mts.sustainableproducts.com/modules/greenchem.html

INVITED LECTURES, COLLOQUIA AND WEBINARS (in Reverse Chronological Order)

1. July 21, 2014,
2. July 9, 2014,
3. July 8, 2014,
4. July 8, 2014,
5. June 30, 2014,
6. May 21, 2014, Building the Chemical Dimension of a Sustainable Civilization Part II: How should university chemists train the sustainability leaders of the future, Great Lakes Green Chemistry Network and Michigan Green Chemistry Clearinghouse Webinar.
7. February 21, 2014, On "Introduction to Green Chemistry" at Carnegie Mellon University, The University Masters in Sustainability, Brunel University, Uxbridge, UK
8. February 20, 2014, Building the Chemical Dimension of a Sustainable Civilization: the compass and the code, Brunel University, Uxbridge, UK
9. November 25, 2013, Building the Chemical Dimension of a Sustainable Civilization, 1-hr Presentation to 180 H&SS students in Nico Slate Class on Innovation and Social Change, Carnegie Mellon University, Pittsburgh PA
10. November 18, 2013, TAML Activators: high performance peroxidase mimics for rapidly removing chemical (especially endocrine disruptors) and biological contaminants from water, EcoChem Conference, Basel, Switzerland
11. November 13, 2013, Building the Chemical Dimension of a Sustainable Civilization, 1-hr Presentation to freshman chemistry students in Newell Washburn's Honors Chemistry Class, Carnegie Mellon University, Pittsburgh PA
12. November 6, 2013, Building the Chemical Dimension of a Sustainable Civilization, 2-hr Presentation to Architecture Students in Hartkopf Class, Carnegie Mellon University, Pittsburgh PA
13. November 3, 2013, **STUDENT SEMESTER INVITED LECTURE**, TAML• Activators: design, mechanisms of action and applications of the first full functional, small molecule peroxidase mimics, Chemical Engineering Department, Stanford University, Stanford, CA
14. November 3, 2013, **STUDENT LUNCHTIME PRESENTATION/DISCUSSION**, Building the Chemical Dimension of a Sustainable Civilization, Stanford University, Stanford, CA
15. October 24. 2013, The Design of Green Oxidation Catalysts for Environmental Solutions, **KEYNOTE LECTURE**, Michigan Green Chemistry & Engineering Conference Grand Rapids, MI
16. October 24. 2013, Building the chemical dimension of a sustainable civilization: reorienting the compass, resetting the thinking, Panel Presentation, Michigan Green Chemistry & Engineering Conference, Grand Rapids MI
17. October 15, 2013 Building the Chemical Dimension of a Sustainable Civilization, A 2-hour lecture to ca. 600 students, Central Catholic High School, Pittsburgh PA
18. October 3, 2013, TAML Activators: full functional peroxidase mimics for DoD projects, The Chemical and Biological

Defense Program's 2013 Enzyme Colloquium and Program Review, CSC Fairview Park Facility, Falls Church, VA.

19. September 25, 2013, Building the Chemical Dimension of a Sustainable Civilization, II International Congress of Green Chemistry and Engineering, Monterrey, Mexico, 9/25/2013

20. August 20, 2013, High Performance Peroxidase Mimics for Rapidly Removing Chemical and Biological Threats from Water, International Seminars on Planetary Emergencies and Associated Meetings – 46th Session, Erice, Sicily.

21. June 20, 2013, Testing the tiered protocol for endocrine disruption (TiPED) with TAML activators, ACS Green Chemistry and Engineering Conference, The Bethesda North Marriott Hotel and Conference Center, Bethesda, MD

22. April 7, 2013, Two Approaches for Designing Against Endocrine Disruptors, ACS National Conference. Division of Organic Chemistry SESSION: Advances in Green Chemistry

23. March 21, 2013, TAML® Activators: design, mechanisms of action and applications of small molecule H_2O_2-activating catalyst, Chemistry Department Seminar, Carnegie Mellon University, Pittsburgh PA

24. February 27, 2013, TAML® Activators: design, mechanisms of action and applications of small molecule H_2O_2-activating catalysts, Harvard-MIT Inorganic Colloquium, MIT, Boston, MA

25. February 12, 2013, A Code of Sustainability Ethics, Evening Public Lecture, Environmental Research Center, University of West Virginia, Morgantown, WV

26. January 10, 2013, Two approaches for designing as green chemists against endocrine disruptors, QAFCO-TAMUQ CHEMISTRY CONFERENCE 2013, GREEN CHEMISTRY AND GREEN ENGINEERING, Texas A&M University at Qatar, Doha, Qatar

27. December 11, 2012, Setting the Stage: The Frontier of Toxicology and Molecular Design, Toxicology and Sustainable Molecular Design Conference University of Connecticut, Storrs, CT

28. November 19, 2012, Little Green Solutions to Pharmaceutical Pollution, delivered for me in combination with Susan Jobling, European Environment Agency European and the Center for Environment & Human Health (U. Exeter) Workshop on Strategies to Reduce Emissions of Pharmaceuticals and Metabolites to the Environment, Newquay, Cornwall.

29. November 13, 2012, Intellectual and practical challenges of building a sustainable marketplace, **KEYNOTE LECTURE**, Catching the Wave - Green Chemistry and Economic Development in the Great Lakes Region, Hyatt Regency, Chicago IL

30. November 8, 2012, Sustainability, Central Catholic High School, Pittsburgh, PA—90 minute lecture to ca. 350 students.

31. October 26, 2012, Honoring the Vision of Rachel Carson: On Behalf of the American Chemical Society, 6th Rachel Carson Legacy Conference, *Our Planet and Our* Health, Chatham University, Pittsburgh PA

32. October 25, 2012, On The Health and Global Environmental Consequences of Fracking the Marcellus Shale, Pittsburgh Filmmakers Melwood Screening Room, Pittsburgh, PA

33. October 4, 2012, Sustainability is the Premier Chemical Technology Challenge of the 21st Century, **PLENARY LECTURE**, Holiday Inn, Moon PA

34. September 13, 2012, Successful Degradation of 17α-Ethinylestradiol and other Pharmaceutical Contaminants with Fe-TAML/H_2O_2, Terrence J. Collins*, Susan Jobling, Karla I. Arias Salazar, Matthew R. Mills, Alice Baynes, Nicola Beresford, Jonathan Porras, *POSTER PRESENTATION*, Low Dose Effects and Non-Monotonic Dose Responses for Endocrine Active Chemicals: Science to Practice, Benjamin Franklin Campus Charié-Universitätsmedizin, Berlin

35. June 18, 2012, What/How should Green Chemists Teach in Toxicity and Ecotoxicity?—Integrating fields to teach sustainability. Symposium on Green Chemistry Education: Teaching Toxicology and Molecular Design, Washington Marriott Wardman, Washington, DC

36. June 12, 2012, Energy and Sustainability, Health Care Without Harm— Symposium on Climate Change and Health, Mellon Institute Auditorium, Carnegie Mellon University, Pittsburgh, PA

37. June 6, 2012, What/How should Green Chemists Teach in Toxicity and Ecotoxicity? Integrating fields to teach sustainability. Symposium on Green Chemistry Education: Teaching Toxicology and Molecular Design, Washington Marriott Wardman

38. May 11, 2012, TAML Activators: purifying water of endocrine disruptors in a new (more cost-effective?) way, UKWIR (UK Water Industry Research), Queen Anne's Gate, London, England

39. May 10, 2012, TAML Activators: purifying water of endocrine disruptors in a new (more cost-effective?) way, Safeguarding Spring Symposium - Brunel University's Institute for the Environment Queen's Anniversary Prize Award Celebration, Brunel University, Uxbridge England

40. April 24, 2012, Green Chemistry: sustaining a high technology civilization, Pittsburgh Chemist's Club and Pittsburgh Environmental Working Group of the American Chemical Society, Spaghetti Warehouse, Pittsburgh, PA

41. April 6, 2012, Green Chemistry: setting the compass toward a sustainable future, Slippery Rock University, Slippery Rock, PA

42. March 26, 2012, TAML® Activators: mechanisms of action and applications, Symposium on Sustainable Inorganic Chemistry, ACS National Meeting, San Diego, CA

43. March 4, 2012, Green Chemistry: setting the compass toward a sustainable future, Wallace Stegner Center, S.J. Quinney College of Law University of Utah, Salt Lake City, UT

44. February 27, 2012, Green Chemistry and Sustainability, Carlow University, Pittsburgh PA

45. February 1, 2012, Green Chemistry: sustaining a high technology civilization, **THE SECOND HORIZONS@HEINZ ENVIRONMENTAL SALON**, The University Club, Washington, DC

46. December 12, 2011, TAML Activators: Design, mechanisms of action and applications of the first effective peroxidase mimics—cleaning water of chemical contaminants as nature would do it, Brunel University, Uxbridge, England
47. November 19, 2011, Compass, TEDx Pittsburgh, Nemacolin PA
48. November 8, 2011, The challenge of developmental disruptors for the chemical enterprise, University of Strasbourg, Strasbourg, France
49. November 8, 2011, Sustainability for Chemists: what does it mean? University of Strasbourg, Strasbourg, France
50. November 2, 2011, TAML Activators: Design, mechanisms of action and applications of the first effective peroxidase mimics—cleaning water of chemical contaminants as nature would do it, University of Strasbourg, Strasbourg, France
51. October 7, 2011, Green Science: on the responsibility of chemists to advance science with human health and the environment in mind Mid-Atlantic Association of Liberal Arts Chemistry Teachers Conference, **KEYNOTE**, Hamilton College, Clinton NY
52. September 22, 2011 Oxidizing organic chemicals with TAML catalysts and hydrogen peroxide: design, mechanisms of action and applications of faithful peroxidase mimics, **PLENARY**, Butlerov Congress—Kazan, Tatarstan, Russia
53. September 16, 2011, Green Chemistry: building a chemical economy that works for sustainability, Sustainable Chemistry Summit: from lab to market, **PLENARY**, Kingston, Ontario, Canada
54. August 29, 2011, Integrating Green Chemistry into the Wider Context of Sustainability Creating Innovation by Collaboration in Green Chemistry Among Industry, University Centers and Students, ACS Meeting—Denver
55. August 18, 2011, New green approaches to disinfection and water purification: or the future leaders who did the work. Green Chemistry Leadership Summit—Green Technologies for Developing Nations Workshop, Montego Bay, Jamaica,
56. June 9, 2011, Green Chemistry: what is it?, Presentation to Trustees and Staff of the Heinz Center, Washington, DC
57. May 4, 2011, The Design of TAML® Activators: effective small molecule mimics of the peroxidase enzymes, Blekinge Technical Institute, Sustainability Studies Group, Karlskrona, Sweden
58. May 4, 2011, Green Chemistry: on the responsibility of chemists to advance science with human health and the environment clearly in mind, Blekinge Technical Institute, to the Sustainability Studies students, Karlskrona, Sweden
59. April 8, 2011, Green Chemistry: on the responsibility of chemists to advance science with human health and the environment clearly in mind, **CRUM LECTURE: UNIVERSITY CONVOCATION ADDRESS**, Gordon College, Wenham, MA
60. April 7, 2011, The Design of TAML® Activators: effective small molecule mimics of the peroxidase enzymes, to the Science Students of Gordon College and environs, Wenham, Ma
61. March 24, 2011, TAML® Activators: design, mechanisms of action and applications of Effective peroxidase mimics, **DISTNGUISHED SCIENTIST SEMINAR**, Scripps Institute, March 22, 2011, La Jolla, CA
62. March 21, 2011, Why we need systematic, evolving methodology for assaying endocrine disruption properties to build a meaningful field of Green Chemistry, **OPENING ADDRESS**, Symposium on Linking Green Chemistry and Environmental Health Sciences, Cavallo Point, CA
63. December 7, 2010, Green Chemistry: sustaining a high technology civilization, Central Catholic High School, Pittsburgh, PA
64. December 2, 2010, Green Chemistry as a Strategy for Reducing Hazardous Chemicals in the Environment, Department of Environmental Medicine, University of Rochester Medical Center, Rochester, NY
65. December 1, 2010, Green Chemistry: sustaining a high technology civilization, Rochester Institute of Technology, Rochester, NY
66. November 4, 2010, Green Chemistry: sustaining a high technology civilization, **UNIVERSITY CONVOCATION**, Ohio Wesleyan University, Lecture to Science Faculty and Students, Delaware Ohio.
67. November 4, 2010, Green Chemistry: making water safer, Ohio Wesleyan University, Lecture to Science Faculty and Students, Delaware Ohio.
68. October 14, 2010, TAML Activators as Mimics of Peroxidase Enzymes: design, mechanisms of action and applications, **PLENARY LECTURE**, 2010 Pfizer Green Chemistry Symposium, San Diego CA
69. October 8, 2010, Molecular Design for Hazard Reduction and Remediation, United States Geological Survey Laboratory, Columbia, MO
70. October 7, 2010, Molecular Design for Hazard Reduction and Remediation, Symposium on Green Chemistry: Integrating Environmental Health Research and Chemical Innovation, University of Missouri–Columbia, MO
71. September 24, 2010, Rachel Carson Legacy Conference, Pittsburgh PA
72. Ausust 24, 2010, Iron–TAML activators: Designing ligands to achieve peroxidase mimics, Fall ACS Meeting, Boston, MA
73. August 12, 2010, Green Chemistry: on the Responsibility of Chemists to Advance Science with Human Health and the Environment Clearly in Mind. 21st International Conference on Chemical Education), **PLENARY LECTURE**, Taipei, Taiwan
74. August 5, 2010, Green Chemistry: Sustaining a High Technology Civilization, Indian Institute of Technology, Kanpur, India
75. August 4, 2010, The Design of TAML Activators: effective small molecule mimics of the peroxidase enzymes, Indian Institute of Technology, Kanpur, India
76. August 3, 2010, Green Chemistry: Sustaining a High Technology Civilization, Indian Institute of Technology, Mumbia, India

77. August 2, 2010, The Design of TAML Activators: effective small molecule mimics of the peroxidase enzymes, National Chemistry Laboratory, Pune, India
78. July 30, 2010, Green Chemistry: Sustaining a High Technology Civilization, National Chemistry Laboratory, Pune, India
79. July 26, 2010, Green Chemistry: Sustaining a High Technology Civilization, Chemistry for Sustainable Development (ICPAC 2010), **PLENARY LECTURE**, Mauritius
80. July 5, 2010, The Design of TAML Activators: Effective Small Molecule Mimics of the Peroxidase Enzymes, International Conference on Porphyrins and Phthalocyanines, ICPP-6, Grand Hyatt Tamaya Resort, Santa Ana Pueblo, New Mexico
81. June 15, 2010, TAML Activators: New Hope for Cleaner Water, Green Remediation Conference, University of Massachusetts, Amherst
82. June 15, 2010, Green Remediation: The Environmental Perspective, **PLENARY**, Green Remediation Conference, University of Massachusetts, Amherst
83. May 27, 2010, Green Chemistry: sustaining a high technology civilization, A Rachel Carson Celebration of Biodiversity Honoring E. O. Wilson, Carnegie Music Hall, Pittsburgh, PA
84. May 3, 2010, Green Chemistry: chemists working to acknowledge, learn about and adapt to endocrine disruption, Endocrine Disruption **GORDON CONFERENCE**, Les Diablerets, Switzerland
85. April 20, 2010, Promise and Progress in Green Technology to Protect Future Generations, Second Annual Symposium–Environmentally Literate Healthcare Providers, University of Pittsburgh School of Medicine Center for Continuing Education in the Health Sciences and the Magee-Womens Hospital, Pittsburgh, PA
86. April 15, 2010, Green Chemistry and the Future: the example of iron-TAML activators, Bethany College, Bethany, WV
87. March 23, 2010, Iron-TAML activators of hydrogen peroxide: probing novel approaches for reducing and eliminating recalcitrant pollutants in water, Symposium on the Sustainability of Water Quality, ACS Conference, Moscone Center, San Francisco, California
88. March 23, 2010, Green Chemistry: the example of iron–TAML activators, Symposium on Chemical Applications of Mössbauer Spectroscopy, ACS Conference, Moscone Center, San Francisco, California
89. March 18, 2010, Policy Issues and the reform of the Toxic Substances Control Act (TSCA), Oxford Union Style Debate, Collins as Questioner, Green Chemistry Roundtable Series Manufacturing a Sustainable Economy, New Hazlett Theater, Pittsburgh PA
90. March 1, 2010, Green Chemistry and the Future: the example of iron-TAML activators, 90 minute interview with Terry Collins conducted by Lou Guillette and students, University of Florida, Gainesville, Florida
91. February 29, 2010, Green Chemistry and the Future: the example of iron-TAML activators, University of Tampa, Tampa, Florida
92. February 13, 2010, Green Chemistry in Pesticide Development and Degradation, **PLENARY**, Pesticide Stewardship Alliance, Hyatt Regency, Savannah, Georgia,
93. January 13, 2010, Green Chemistry Roundtable Series Manufacturing a Sustainable Economy—commentator—John Ehrenfeld address: author of Sustainability by Design, Collins as Questioner, ALCOA Headquarters, Pittsburgh, PA
94. December 7, 2009, Iron–TAML Activators: successful mimics of peroxidase enzymes that can transform water purification, University of Michigan, Ann Arbor, Michigan
95. November 29, 2009, Iron–TAML Activators: highly successful mimics of peroxidase enzymes for green chemical applications, **PLENARY LECTURE,** Inorganic Discussion Weekend, University of Guelph, Guelph, Ontario, 11/29/09
96. November 12, 2009, Green Chemistry: the bottom line must adapt to the germline, Philadelphia Area Alumni, University of Philadelphia, Philadelphia PA
97. November 11, 2009, Green Chemistry: the bottom line must adapt to the germline, Princeton Area Alumni, Hamilton, NJ
98. November 9, 2009, Green Chemistry: sustaining an high technology civilization, Pittsburgh Society for Coatings Technology, Harmer, PA
99. November 3, 2009, Green Chemistry: sustaining an high technology civilization, **HUGH AND NANCY LONG LECTURE**, Westminster College, New Wilmington, PA
100. October 30, 2009, Green Chemistry and the Future: the example of Iron-TAML Activators, Department of Chemistry, Cleveland State University, Cleveland,
101. October 23, 2009, Green Chemistry at Carnegie Mellon University: our approach to the tectonic importance of endocrine disruption e-hormone Conference, Tulane and Xavier Universities, New Orleans
102. October 14, 2009, Green Technologies for the Environment: Stimulating Eco Innovation for the Coming Sustainability Revolution, **PLENARY LECTURE**, Sheraton Bradley Hotel, Windsor Locks, CT
103. September 25, 2009, Green Chemistry: Sustaining an High Technology Civilization, **PLENARY LECTURE**, Rachel Carson Legacy Conference, When Chemicals Disrupt: Managing Our Risk, Manchester Craftsmen's Guild, Pittsburgh, Pennsylvania
104. September 15, 2009, Green Chemistry: Sustaining an High Technology Civilization, **UNIVERSITY PUBLIC LECTURE**, University of California, Berkeley, Berkeley, CA
105. September 14, 2009, Green Chemistry and the Future: the example of TAML activators, Department of Chemistry,

University of California, Berkeley, Berkeley, CA
106. September 14, 2009, Green Chemistry and the Future: the example of Iron-TAML Activators, Department of Chemistry, University of California, Berkeley, Berkeley, CA
107. August 23, 2009, Rethinking Remediation, 42nd Session of the International Seminars on Planetary Emergencies, Erice, Sicily, Italy
108. August 21, 2009, Moving the chemical enterprise toward sustainability: Key issues, 42nd Session of the International Seminars on Planetary Emergencies, Erice, Sicily, Italy
109. July 21, 2009, Iron-TAML activators with peroxide: an effective green chemical approach to the degradation of pharmaceutical agents in water, Green Pharma Summit, Ritz-Carlton Hotel, Philadelphia, PA
110. July 8, 2009, Green Chemistry and the Future: the example of Iron-TAML Activators, Department of Chemistry, McGill University, Montreal, Canada
111. May 16, 2009, It's Your World After All, Graduation Ceremony Mellon College of Science Honors Graduates, **KEYNOTE ADDRESS**, Carnegie Mellon University, Pittsburgh, PA
112. May 16, 2009, It's Your World After All, Phi-Beta-Kappa Initiation Convocation **PLENARY**, Carnegie Mellon University, Pittsburgh, PA
113. April 22, 2009, Green Chemistry: Sustaining an High Technology Civilization, Edinboro University of Pennsylvania, **UNIVERSITY LECTURE**, Edinboro, PA
114. December 10, 2008, Iron-TAML activators: highly successful mimics of peroxidase enzymes for green chemical applications, **PLENARY LECTURE**, Blueprints for Sustainable Infrastructure, University of Auckland, New Zealand
115. December 8, 2008, Iron-TAML Activators: effective small molecule mimics of peroxidase enzymes, Centre of Theoretical Chemistry and Physics, The New Zealand Institute for Advanced Study, Massey University Auckland, North Shore City, December 8, 2008
116. November 13, 2008, Green Chemistry and the Future, Carnegie Mellon Alumni, LA Chapter, MEIM Center, LA
117. November 15, 2008, Building the Technological Dimension of a Sustainable Civilization, **PLENARY LECTURE**, Siemens Science Competition, Heinz History Center, Pittsburgh, PA
118. November 11, 2008, Pursuing Sustainable Technologies: People change people, Central Catholic High School, Pittsburgh PA
119. October 16, 2008, Green Chemistry and Worker Health and Safety Training, NIEHS, Sheraton Chapel Hill, NC
120. October 8, 2008, Environmental Health Sciences and Green Chemistry: Problems Meet Solutions—In Summary, **PLENARY LECTURE**, Beckman Center, Irvine CA
121. September 19, 2008, Sustainability Determinants, Conference Introduction as Conference Co- Chair, Rachel Carson Legacy Conference, Duquesne University, Pittsburgh, PA
122. September 17, 2008, Iron-TAML Activators: effective small molecule mimics of peroxidase enzymes, Department of Chemistry, University of Wisconsin, Madison
123. August 18, 2008, Design, performance and mechanistic chemistry of FeIII-TAML activators, Graduate Student Symposium: Transitioning into Green Chemistry, ACS National Meeting, Sheraton Philadelphia City Center Hotel, Philadelphia, PA
124. July 18, 2008, Green Chemistry and Technology Futures, Presented to the leadership of the United Steelworkers Union, New Haven, CT
125. July 17, 2008, Iron-TAML activators: highly successful mimics of peroxidase enzymes—Lessons from kinetic and mechanistic studies, **INORGANIC CHEMISTRY GORDON CONFERENCE**, Salve Regina University, Newport, RI
126. June 4, 2008, Green Chemistry and the Future, Presented to the University of Minnesota electronically from Yale University, New Haven, CT
127. May 28, 2008, Green Chemistry and the Future, Presentation to Bobby Vagt, President, Heinz Endowments and several other officers, Pittsburgh, PA
128. May 2, 2008, Green Chemistry and the Future, **UNIVERSITY CONVOCATION ADDRESS**, St. Olaf College, Northfield, Minnesota
129. April 28, 2008, Green Chemistry and the Future, Presentation to the Upper School, Winchester Thurston Academy, Pittsburgh, PA
130. April 16, 2008, Green Chemistry and the Future, Rachel Carson Spirit & Nature Conference, Chatham University, Pittsburgh, PA
131. April 14, 2008, A life in search of sustainability: People change people, **JOURNEYS LECTURE**, Carnegie Mellon University, Pittsburgh, PA
132. April 7, 2008, Undergraduate researchers excel in green chemistry and oxidation catalysis, **BECKMAN SCHOLARS 10-YEAR ANNIVERSARY PRESIDENTIAL PLENARY SYMPOSIUM**, ACS National Meeting, New Orleans
133. March 17 2008, Green Chemistry and the Future, **CHARLES E. KAUFMAN AWARD ADDRESS**, Bridgeville, PA
134. March 18 2008, Green Chemistry and the Future, North Central West Virginia American Chemical Society, Fairmont State University, Fairmont, WV
135. March 14, 2008, Green Chemistry and the Future, Good Jobs, Green Jobs Conference, Convention Center, Pittsburgh, PA
136. February 19, 2008, Green Chemistry and the Future, **AFTER-DINNER KEYNOTE LECTURE**, American Institute of Chemical Engineers, University of Pittsburgh, Pittsburgh, PA

137. February 14, 2008, Green Chemistry and the Future, Presentation to the Maine Legislature Standing Committee on Maine Resources, State Capitol, Augusta, ME
138. November 29, 2007, Green Chemistry and the Future, **KEYNOTE LECTURE,** *Health and Environmental Funders Network,* Airlie Conference Center, Warrenton, VA,
139. November 19, 2007, Learning and Developmental Disabilities Initiative National Teleconference, Priming for Prevention, Cyberspace, USA
140. November 14, 2007, The Vision, Research and Educational Program of the Institute for Green Oxidation Chemistry, Citizens for Global Solutions Pittsburgh and the Global Studies Program of the University Center for International Studies at the University of Pittsburgh, Pittsburgh, PA
141. October 26, 2007, Green Chemistry and the Future, **PLENARY LECTURE**, La Roche College, Pittsburgh, PA
142. October 26, 2007, The Vision, Research and Educational Program of the Institute for Green Oxidation Chemistry, Central Catholic High School, Pittsburgh, PA
143. October 10, 2007, The Vision, Research and Educational Program of the Institute for Green Oxidation Chemistry, Central Catholic High School, Pittsburgh, PA
144. October 4, 2007, Yale University, Green chemistry: sustaining a high technology civilization, New Haven, CT
145. September 26, 2007, Green Chemistry and Life Cycle Analysis, EPA Conference on "Pollution Prevention through Nanotechnology", Arlington, VA
146. September 25, 2007, GreenOx Catalysts, Inc.: the green chemistry behind a new Pittsburgh startup, Commercial Development and Marketing Association for the Chemicals Industry Annual Conference, Pittsburgh, PA
147. September 21, 2007, Green chemistry: sustaining a high technology civilization, **PLENARY LECTURE**, The Fire Retardant Dilemma Conference Series: Part 3, Berkeley, CA
148. September 20, 2007, Green chemistry: sustaining a high technology civilization, The Energy and Resources Group Fall 2007 Colloquium Series, U.C. Berkeley, Berkeley CA
149. September 11, 2007, Green Chemistry and the Future: Part B, Innovation Day 2007, Society of the Chemical Industry–Chemical Heritage Foundation, Philadelphia, PA
150. September 11, 2007, Green Chemistry and the Future: Part A, Innovation Day 2007, Society of the Chemical Industry–Chemical Heritage Foundation, Philadelphia, PA
151. August 29, 2007, Green Chemistry and the Future, **PLENARY LECTURE**, 20th Rocky Mountain Regional ACS Meeting (Joint with AIChE), Denver, CO
152. August 19, 2007, Green chemistry and sustainability: essential elements for chemical pedagogy, Boston ACS Meeting in Symposium on Green Chemistry as an Integral Component of Academic Sustainability Centers, Boston MA
153. August 8, 2007, Iron-TAML activators: effective green chemistry catalysts for the oxidative decomposition of Pharmaceuticals and Personal Care Products, 2007 Northeast Water Science Forum, Pharmaceuticals and Personal Care Products: state of the science, Portland, ME
154. August 6, 2007, Certain chemicals are disrupting your hormone system: what can GreenChemistry do protect you and your family? Workshop on Endocrine Disrupting Chemicals, Steelworkers Health, Safety and Environment Conference and the Steelworkers Joint Health, Safety and Environment Conference, Dearborn, MI
155. July 16, 2007, Green Chemistry: Sustaining an High Technology Civilization, University of Pittsburgh, Center on Race and Social Problems, School of Social Work, Pittsburgh, PA
156. July 16, 2007, Green Chemistry: Sustaining an High Technology Civilization, Lunch and Learn, Center for Environmental Oncology, Herberman Auditorium, UPMC Cancer Pavilion, Pittsburgh, PA
157. June 2, 2007, Iron-TAML activators: effective green chemistry catalysts for peroxide activation, Pan American Studies Institute in Green Chemistry, Universidad Iberoamericana, México City, México
158. June 1, 2007, Toxicity and Ecotoxicity: the vital GC challenge of the endocrine disruptors, Pan American Studies Institute in Green Chemistry, Universidad Iberoamericana, México City, México
159. June 6, 2007, Green Chemistry: Sustaining an High Technology Civilization, **KEYNOTE LECTURE**, First Israeli International Conference on Green Chemistry, Porter School of Environmental Studies, Tel Aviv University, Israel
160. May 31, 2007, Green Chemistry: "an ethical imperative", Pan American Studies Institute in Green Chemistry, Universidad Iberoamericana, México City, México
161. May 16, 2007, Iron-TAML activators: effective green chemistry catalysts for peroxide activation, **AWARD ADDRESS**, Catalysis Society of Metropolitan New York, Somerset, NJ
162. May 16, 2007, Green Chemistry: Sustaining an High Technology Civilization, ExxonMobil Research and Engineering Co, Annandale, NJ
163. April 23, 2007, Green Chemistry and the Future, King County Wastewater Treatment Authority and People for Puget Sound, Seattle, WA
164. April 23, 2007, Green Chemistry and the Future, Department of Ecology of Washington State, Olympia, WA
165. April 20, 2007, Green Chemistry and the Future, Women's Health and the Environment: new science, new solutions, Pittsburgh, PA
166. August 6, 2007, Green Chemistry: Sustaining an High Technology Civilization, **PLENARY LECTURE**, Steelworkers Health, Safety and Environment Conference and the Steelworkers Joint Health, Safety and Environment Conference, Dearborn, MI
167. April 4, 2007, Iron-TAML® activators: effective green chemistry catalysts for peroxide activation, Centre College,

Danville, KY
168. March 26, 2007, Iron-TAML® activators: effective green chemistry catalysts for peroxide activation, Eckard Münck Bader Award Symposium, Chicago ACS, Chicago IL
169. March 23, 2007, Converging Landscapes: Chemistry meets Toxicology meets the Environment — with a little emphasis on pharmaceuticals, Gordon Cain Conference 2007, New Chemical Bodies: Bio-Monitoring, Body Burden and the Uncertain Threat of Endocrine Disruptors, Chemical Heritage Foundation Conference, Philadelphia, PA
170. February 27, 2007, Green Chemistry; Sustaining a High Technology Civilization, SCION, Rotorua, New Zealand
171. February 22, 2007, Green Chemistry: In Search of an Ethics for the Technological Age, IPENZ and Engineers for Social Responsibility, University of Auckland, New Zealand
172. February 21, 2007, Green Chemistry; Sustaining a High Technology Civilization, **AWARD AND UNIVERSITY LECTURE**, Maidment Theater, University of Auckland, Auckland, New Zealand
173. January 25, 2007, Green Chemistry; Sustaining a High Technology Civilization, Lunch Round table Discussion, Summit on Environmental Challenges to Reproductive Health and Fertility, University of California, San Francisco, San Francisco, CA
174. January 25, 2007, Green Chemistry; Sustaining a High Technology Civilization, Oregon Environmental Council Health Sciences Series, Multnomah Athletic Club, Portland, OR
175. January 24, 2007, Green Chemistry; Sustaining a High Technology Civilization, Environmental Health Lecture Series, Town Hall, Seattle, WA
176. January 24, 2007, Iron-TAML® activators: effective green chemistry catalysts for peroxide activation, University of Washington, Seattle, WA
177. December 14, 2006, Green Chemistry and the Future, Presentation to Birchmere, VC, Pittsburgh, PA
178. December 7, 2006, Green Chemistry and the Future, Presentation to the VC Firm Draper-Triangle, Pittsburgh, PA
179. December 1, 2006, Green Chemistry and the Future, Presentation to the VC Firm Pennsylvania Early Stage Partners, Pittsburgh, PA
180. November 15, 2006, Green Chemistry: Sustaining a High Technology Civilization, Greenbuild 2006, Denver, CO
181. October 30, 2006, The Design and Development of Green Oxidation Catalysts: real steps toward a less polluted world, Presentation to 40 Venture Capitalists, Carnegie Mellon University, Pittsburgh, PA
182. October 27, 2006, The Design and Development of Green Oxidation Catalysts: real steps toward a less polluted world, Louisiana State University, Baton Rouge, LA
183. October 25, 2006, Green Chemistry and the Future, Presentation to the Heinz Endowments Board of Trustees, Carnegie Mellon University, Pittsburgh, PA
184. October 17, 2006, Design, Study and Applications of Green Oxidation Catalysts, Kenyon College, Gambier, OH
185. October 3, 2006, Green Chemistry: a personal view of the challenges and an update on TAML® activator chemistry, Presentation to 10 Classes of Central catholic High School, Pittsburgh, PA
186. September 12, 2006, Greening Chemistry: what is it?, Egyptian First International Conference in Chemistry, Chemistry for Human Needs in Developing Countries, Sharm El-Shiekh, Egypt
187. September 12, 2006, Greening Oxidation Catalysis, Egyptian First International Conference in Chemistry, Chemistry for Human Needs in Developing Countries, Sharm El-Shiekh, Egypt
188. October 16, 2006, Green Chemistry: Sustaining a High Technology Civilization, **UNIVERSITY CONVOCATION ADDRESS**, Kenyon College, Gambier, OH
189. September 14, 2006, Green Chemistry and Sustainability, Egyptian First International Conference in Chemistry, Chemistry for Human Needs in Developing Countries, **LEADER OF 2.5 HOUR ADDRESS AND DISCUSSION,** Sharm El-Shiekh, Egypt
190. August 27, 2006, The Design and Development of Green Oxidation Catalysts: real steps toward a less polluted world, Green Chemistry **GORDON CONFERENCE**, Magdalen College, Oxford, United Kingdom
191. August 17, 2006, The Design and Development of Green Oxidation Catalysts: real steps toward a less polluted world, Auckland University, Auckland, New Zealand
192. August 16, 2006, The Design and Development of Green Oxidation Catalysts: real steps toward a less polluted world, Waikato University, Hamilton, New Zealand
193. August 9, 2006, The Design and Development of Green Oxidation Catalysts: real steps toward a less polluted world, Monash University, Melbourne, Australia
194. August 9, 2006, Designing Green Catalytic Oxidation Processes, Monash University Student Lecture, Melbourne, Australia
195. July 3, 2006, TAML Oxidant Activators: Design, Chemistry and Applications, ICPP-4, Rome, Italy
196. June 26, 2006, Green Oxidation Catalysis, 2006 Summer School on Green Chemistry, Washington, DC
197. June 22, 2006, Solutions Science in Academia: green chemistry and what it offers biodiversity, Consultative Group on Biodiversity, Estes Park, CO
198. June 6, 2006, Green Chemistry: making it in the real world, Collaborative on Health and the Environment Web Lecture Series
199. May 18, 2006, Green Chemistry: systematically dealing with toxics, Great Lakes Binational Toxics Strategy Meeting, Delta Chelsea Hotel, Toronto, Canada
200. May 9, 2006, Green Chemistry 101 Primer, NSCMP Core Group, Holiday Inn Rosslyn at Keybridge, Arlington VA

201. May 3, 2006, Green Chemistry and Sustainability, Pittsburgh Chemistry Olympics-Chevron Science Center, Pittsburgh, PA
202. April 25, 2006, The Design of Green Catalytic Oxidation Processes, Dickinson College, Carlisle PA
203. March 21, 2006, Green Chemistry 101, Veolia Water Leadership, Moon Township, PA
204. March 7, 2006, Green Chemistry: developing sustainable alternatives to polluting technologies, Society of Toxicologists Meeting, San Diego, CA
205. January 30, 2006, Green Chemistry 101, Presentation to >80 Environmental Advocate Organizations, Hotel Washington, Washington, DC
206. January 30, 2006, Green Chemistry 101, Presentation to ≈ 40 Environmental and Health Funding Foundations, Hotel Washington, Washington, DC
207. January 20, 2006, Green Chemistry at Carnegie Mellon University and Thinking about How to Make Pittsburgh the Capital City of the Sustainable Economy *Pittsburgh Green Drinks, Buffalo Blues*, Pittsburgh, PA
208. January 11, 2006, Degradation of Lipitor and Zoloft with Fe-TAML/H2O2 presentation with Dr. Yan Xiang, Pfizer Central Research, Groton, CT
209. December 14, 2005, Designing Green Oxidation Processes, Joint Japan-US Workshop on Sustainable Chemical Synthesis, Honolulu, HI
210. November 30, 2005, Design, Study and Applications of Green Oxidation Catalysts, Penn State Erie-The Behrend College, Erie, PA
211. November 5, 2005, Sustaining a High Technology Civilization, Elk Regional Health Center Women's Health Conference, St. Mary's, PA
212. November 4, 2005, Sustaining a High Technology Civilization, Carnegie Mellon University International Festival, Pittsburgh, PA
213. October 28, 2005, Designing Green Oxidation Technologies, Midwest Regional ACS Meeting— Green Chemistry Symposium, October 28, 2005, Joplin, MO
214. October 20, 2005, Design, Study and Applications of Green Oxidation Catalysts, Stanford University, Stanford CA
215. October 14, 2005, Greening Our Civilization Through Science, Bioneers Conference, San Rafael, CA
216. October 7, 2005, Greening Our Civilization Through Science, **PLENARY LECTURE**, Chemistry Discipline Faculty Workshop 2-year and 4-year Colleges of Minnesota State Colleges and Universities System, Minnesota Minneapolis Community and Technical College, Minneapolis MN
217. October 6, 2005, Green Chemistry and the Building of the Sustainable Economy, Activated Carbon Conference, **PLENARY LECTURE**, Moon Township, PA
218. October 4, 2005, Making Pittsburgh the Capital City of the Sustainable Economy, Technology Transfer Conference for Foundations and Economic Development Organizations, Carnegie Mellon University, Pittsburgh PA
219. September 21, 2005, Ethics, Toxicity, Ecotoxicity, Persistence, Bioaccumulation and Green Chemistry, Central Catholic High School, Pittsburgh, PA
220. August 29, 2005, TAML Green Oxidation Catalysis for Safely Destroying Pollutants and Microbes in Water, ACS Meeting, Washington, DC
221. July 30, 2005, Moderator of Panel Presentations on Green Chemistry, The Beckman Scholars Conference, Irvine, CA
222. July 11, 2005, Ethics, Toxicity, Ecotoxicity, Persistence, Bioaccumulation and Green Chemistry: Part II, Exxon Summer School on Green Chemistry, McGill University, Montreal, Canada
223. July11, 2005, Ethics, Toxicity, Ecotoxicity, Persistence, Bioaccumulation and Green Chemistry: Part I, Exxon Summer School on Green Chemistry, McGill University, Montreal, Canada
224. July 9, 2005, Greening Oxidation Catalysis, Exxon Summer School on Green Chemistry, McGill University, Montreal, Canada
225. June 23, 2005, Designing Green Catalytic Oxidation Technologies, 2nd International Green Chemistry and Engineering Conference, Washington, DC
226. June 22, 2005, The Need for Incorporating Understanding of Toxicity and Ecotoxicity into Chemistry, 2nd International Green Chemistry and Engineering Conference, Washington, DC
227. June 21, 2005, Green Decontamination System for Chemical and Biological Weapons of mass Destruction, 2nd International Green Chemistry and Engineering Conference, Washington, DC
228. June 20, 2005, Greening Oxidation Catalysis—Student Workshop, 2nd International Green Chemistry and Engineering Conference, Washington, DC
229. June 17, 2005, Design, Mechanism of Action, and Applications of Green Oxidation Catalysts, **PLENARY LECTURE**, Annual Meeting of the Pittsburgh-Cleveland Catalysis Society, Pittsburgh, PA
230. June 1, 2005, Greening Oxidation Catalysis, Conference on Knowledge-Based Materials and Technologies for Sustainable Chemistry, **PLENARY LECTURE**, Tallinn, Estonia
231. May 30, 2005, Understanding Homogeneous Oxidation Catalysis: mechanistic investigation of the stability and function of iron-TAML peroxide activators, Eotvos University, Budapest, Hungary
232. May 26, 2005, A Green Oxidative Approach for Rapid Total Degradation of Thiophosphate Pesticides, 8TH HCH and Pesticides Forum for Central European and Eastern European, Caucasus and Central Asia Countries, Sofia, Bulgaria
233. May 19, 2005, Designing Green Oxidation Technologies" Lecture to Environmental Commissioner of Maine (Dawn Gallagher) and leaders of the Maine DEP and pulp and paper industry, Augusta, ME

234. July 29, 2005, **PLENARY LECTURE**, Bayer School of Natural and Environmental Sciences Undergraduate Research Symposium, Duquesne University, Pittsburgh PA
235. April 19, 2005, Sustainability Ethics and Chemistry: How to build a sustainable technology base, **PLENARY LECTURE**, Symposium on Universal Relationships and Responsibilities: Sustainable living practices for social and cultural wellbeing, Perth, Australia
236. March 31, 2005, Designing Green Oxidation Technologies, Commonweal Retreat on Green Chemistry, Bolinas, CA
237. March 30, 2005, Green Chemistry: Solving the Technical Challenges of Sustainability, Commonweal Retreat on Green Chemistry, Bolinas, CA
238. March 13, 2005, Green Oxidation Catalysts for Environmental Applications, Symposium on Environmental Applications of Inorganic Chemistry, San Diego ACS Meeting, San Diego, CA
239. February 25, 2005, Green Chemistry and Agriculture, **PLENARY LECTURE**, Southeastern Leadership Conference, Department of Agriculture, Savannah, GA
240. February 15, 2005, A Superior Decontamination System for Chemical and Biological Warfare and Defense, **KEYNOTE LECTURE**, Rydges Hotel, Melbourne, Australia
241. February 2, 2005, Greening Civilization through Science, lecture to the science students and Pennsylvania-Ohio Border Section of the ACS, New Wilmington, PA
242. December 9, 2004, Designing Green Oxidation Technologies, **PITTSBURGH AWARD ADDRESS**, Sheraton Hotel, Pittsburgh, PA
243. December 3, 2004, Greening Civilization Through Science, To the Science Students, Illinois Wesleyan University, Bloomington, IL
244. November 29, 2004, Designing Green Oxidation Technologies, To Governor John Baldacci & DEP Leadership, Augusta, ME
245. November 29, 2004, Designing Green Oxidation Technologies, To Commissioner Dawn Gallagher & DEP Leadership, Augusta, ME
246. November 18, 2004, Green Chemistry, Steinbrenner Institute Carnegie Mellon University, Pittsburgh, PA
247. November 13, 2004, A Novel Catalytic Oxidative Decontamination System for Chemical and Biological Warfare Defense, SERMACS, Durham, NC
248. November 3, 2004, Greening Our Civilization Through Science, Chatham College, Pittsburgh, PA
249. November 1, 2004, Research in Green Chemistry, SURG Lunch Seminar Series, Carnegie Mellon University, Pittsburgh, PA
250. October 21, 2004, Greening Our Civilization Through Science, **KEYNOTE LECTURE**, Mid-Atlantic Association of Liberal Arts College Teachers Annual Conference, Juniata College, Huntingdon, PA
251. October 20, 2004, The Design, Development and Utility of TAML Activators, Society of Environmental Journalists, Carnegie Mellon University, Pittsburgh, PA
252. October 20, 2004, Greening Our Civilization Through Science, Society of Environmental Journalists, Carnegie Mellon University, Pittsburgh, PA
253. October 19, 2004, Greening Our Civilization Through Science, **UNIVERSITY LECTURE**, Bowdoin College, Brunswick, ME
254. October 19, 2004, Designing Green Oxidation Technology, Bowdoin College, Brunswick, ME
255. October 8, 2004, Designing Green Oxidation Technology, Arch Chemicals, Southington, CT
256. September 30, 2004, Greening the Planet through Science, The Covenant at South Hills, Bower Hill Road, Mt. Lebanon, PA
257. September 20, 2004, Persistence, Bioaccumulation and Endocrine Disruption in Understanding Pollutants and How to Deal with Them, Faculty Workshop, Clemson University, Clemson, SC
258. September 20, 2004, Designing Green Oxidation Technology, Science Technology and Society University Lecture, Clemson University, Clemson, SC
259. September 20, 2004, Green Chemistry: Sustaining a High Technology Civilization, Honors Students Lecture, Clemson University, Clemson, SC
260. August 26, 2004, Greening the Planet through Science, **KEYNOTE LECTURE**, MCS Orientation, Carnegie Mellon University, Pittsburgh, PA
261. August 22, 2004, Designing Green Oxidation Technologies, **PLENARY LECTURE**, Symposium on Sustainability in the Chemical Industry—IEC, 228th ACS Conference, Philadelphia, PA
262. August 22, 2004, Understanding the Persistent Pollutant, Symposium on Green Chemistry for Graduate Students, 228th ACS Conference, Philadelphia, PA
263. August 6, 2004, The Ethics of Green Chemistry, ACS-PRF Green Chemistry Summer School, Carnegie Mellon University, Pittsburgh, PA
264. August 6, 2004, Designing Green Oxidation Technologies, ACS-PRF Green Chemistry Summer School, Carnegie Mellon University, Pittsburgh, PA
265. August 5, 2004, Understanding the Persistent Pollutant, ACS-PRF Green Chemistry Summer School, Carnegie Mellon University, Pittsburgh, PA
266. August 3, 2004, Greening Energy, ACS-PRF Green Chemistry Summer School, Carnegie Mellon University, Pittsburgh, PA

267. May 18, 2004, A Novel Catalytic Oxidative Decontamination System for Chemical and Biological Warfare Defense, Decontamination 2004 Conference, Palm Harbor, FL
268. May 5, 2004, Designing Green Oxidation Technologies, Department of Agriculture, Florence, SC
269. April 30, 2004, Green Chemistry: Sustaining a High Technology Civilization, University of Mexico, Mexico City, Mexico
270. April 21, 2004, Green Chemistry: Sustaining a High Technology Civilization, ACS Student Affiliates Lecture, Bethany College, WV
271. April 14, 2004, Green Chemistry: Sustaining a High Technology Civilization, CleanMed 2004 Conference, Philadelphia, PA
272. March 29, 2004, Green Oxidation Catalysts: Iron-TAML Activators of Oxygen and Peroxides, ACS Symposium on Non-Heme Iron Chemistry in Biology, 227th ACS National Meeting, Anaheim, CA
273. March 27, 2004, Green Chemistry: Sustaining a High Technology Civilization, After-Dinner Lecture DivCHED Annual Banquet, 227th ACS National Meeting, Anaheim, CA
274. March 27, 2004, The Precautionary Principle and Endocrine Disruption: Connections, Lecture to the ACS Committee on Environmental Improvement, 227th ACS National Meeting, Anaheim, CA
275. March 19, 2004, Designing Catalysts for Green Oxidation Technologies, Department of Chemistry, Eotvos University, Budapest, Hungary
276. March 18, 2004, Designing Catalysts for Green Oxidation Technologies, Department of Chemistry, University of Debrecen, Debrecen, Hungary
277. March 13, 2004, Techniques for Attracting Manuscripts, Royal Society of Chemistry Editor's Symposium, Glasgow, Scotland
278. March 5, 2004, Green Chemistry: Sustaining a High Technology Civilization, Department of Chemistry, Baylor University, Waco, TX
279. March 3, 2004, The Problem of the Persistent Pollutant, Southern Methodist University, Dallas, TX
280. March 2, 2004, The Design and Development of Green Oxidation Processes, Southern Methodist University, Dallas, TX
281. March 29, 2004, Designing Catalysts for Green Oxidation Technologies, Society Committee on Education, **EMINENT SCIENTIST LECTURE**, 227th ACS National Meeting, Anaheim, CA
282. March 4, 2004, Designing Chemical Technologies for Sustainability, **UNIVERSITY CONVOCATION ADDRESS**, Baylor University, Waco, TX
283. March 1, 2004, Green Chemistry: Sustaining a High Technology Civilization, Gartner Honors Lecture Series, **UNIVERSITY CONVOCATION ADDRESS**, Southern Methodist University, Dallas, TX
284. February 26, 2004, Green Chemistry: Sustaining a High Technology Civilization, Berea College, Berea, KY
285. February 25, 2004, Designing Chemical Technologies for Sustainability, **UNIVERSITY CONVOCATION ADDRESS**, Berea College, Berea, KY
286. February 20, 2004, The Design and Development of Green Oxidation Processes, ACS Affiliates Lecture, University of Pittsburgh, Pittsburgh, PA
287. February 5, 2004, The Design of Green Oxidation Processes, Science and Humanities Scholars, Carnegie Mellon University, Pittsburgh, PA
288. January 21, 2004, The Design of Green Oxidation Processes, ALCOA Sigma Xi Chapter, New Kensington, PA
289. December 13, 2003, Designing Catalysts for Green Oxidation Technologies, Department of Chemistry, University of Hawaii at Manoa, HI
290. December 2, 2003, Design of Techniques and Technologies that Unite the Future of Chemistry with the Pursuit of a Sustainable Civilization, New Zealand Institute of Chemistry Conference, **PLENARY LECTURE**, Nelson New Zealand
291. November 27, 2003, The Design and Development of Green Oxidation Technologies, Society of Pure and Applied Coordination Chemistry (JAPAN)-10, **PLENARY LECTURE**, Auckland New Zealand
292. November 24, 2003, Designing Catalysts for Green Oxidation Technologies, Department of Chemistry, University of Western Australia, Perth, Australia
293. November 21, 2003, Sustainability Ethics: directions for green chemistry education/R&D, **WHOLE STUDENT BODY LECTURE**, Miranda College, Delhi University, New Dehli, India
294. November 20, 2003, Development of Green Oxidation Catalysis for Water Purification, Indo-US S&T Forum Workshop on Green Chemistry, Connaught Hotel, Delhi, India
295. November 18, 2003, The Design of Green Oxidation Catalysts, Indo-US S&T Forum Workshop on Green Chemistry, Connaught Hotel, Delhi, India
296. November 17, 2003, Sustainability Ethics: directions for green chemistry education/R&D, Indo- US S&T Forum Workshop on Green Chemistry, Connaught Hotel, Delhi, India
297. November 13, 2003, Green Chemistry: Sustaining a High Technology Civilization, Department of Chemistry, University of Leiden, Netherlands
298. November 6, 2003, C&E News Editorial Advisory Board, Sustainability and Innovation: the good future for chemistry, **FOCUS LECTURE FOR BOARD MEETING**, American Chemical Society Headquarters, Washington, DC
299. November 3, 2003, Designing Catalysts for Green Oxidation Technologies, Pfizer Conference on Green Chemistry,

Groton, CT

300. October 31, 2003, Designing Catalysts for Green Oxidation Technologies, Department of Chemistry, University of North Carolina, Chapel Hill, NC
301. October 15, 2003, Design to Unite Chemical Research with the Pursuit of a Sustainable Civilization, **PLENARY LECTURE**, Annual Conference of the Brazilian Society of Analytical Chemists, Sao Luis, Brazil
302. October 7, 2003, Design to Unite Chemical Research with the Pursuit of a Sustainable Civilization, **COLLEGE CONSORTIUM ADDRESS**: Twelve Small Colleges in the Chicago area at Benedictine University, Lisle, IL
303. October 6, 2003, The Importance of *Sustainability Ethics, Toxicity* and *Ecotoxicity* in the Training of Future Chemists, Otterbein College, Columbus, OH
304. October 5, 2003, Sustaining Ethics and Green Chemistry: Developing a Sustainable High Technology Civilization, **UNIVERSITY CONVOCATION**, Otterbein College, Columbus, OH
305. October 2, 2003, Green Chemistry: Sustaining a High Technology Civilization, Hendrix College, Conway, AR
306. October 1, 2003, Design to Unite Chemical Research with the Pursuit of a Sustainable Civilization, **UNIVERSITY CONVOCATION ADDRESS**, Hendrix College, Conway, AR
307. September 25, 2003, Design to Unite Chemical Research with the Pursuit of a Sustainable Civilization, **KECK ENDOWED LECTURE**, Allegheny College, Meadville PA
308. July 8, 2003, Sustainability Ethics, Pan American Advanced Studies Institute on Green Chemistry, Montevideo, Uruguay
309. July 8, 2003, Persistence and Bioaccumulation in Understanding Pollutants and How to Deal with Them, Pan American Advanced Studies Institute on Green Chemistry, Montevideo, Uruguay
310. July 8, 2003, The Importance of Moral and Sustainability Ethics in the Chemical Industry: Reflections on "Trade Secrets," Pan American Advanced Studies Institute on Green Chemistry,
311. Montevideo, Uruguay
312. July 8, 2003, Considerations on Safe Energy: Reflections on "Meltdown at Three Mile Island," Pan American Advanced Studies Institute on Green Chemistry, Montevideo, Uruguay
313. July 11, 2003, "The Design of Green Oxidation Catalysts", Pan American Advanced Studies Institute on Green Chemistry, Montevideo, Uruguay
314. July 8, 2003, Pan American Advanced Studies Institute on Green Chemistry, Montevideo, Uruguay
315. June 29, 2003, "The Importance of Sustainability Ethics, Toxicity and Ecotoxicity in the Training of Future Chemists", in ACS Blue Ribbon Education Conference "Exploring the Molecular Vision Washington, DC"
316. June 26, 2003, Training in Sustainability Ethics, Toxicity and Ecotoxicity: Fundamentals of a Safe America, Roundtable on Safety, Green Chemistry & Engineering Conference, Washington, DC
317. May 24, 2003, New Iron Oxygen Chemistry, Eckard Münck 65th Birthday Symposium, Carnegie Mellon University, Pittsburgh, PA
318. May 1, 2003, Designing Green Oxidation Catalysts, Massachusetts Green Chemistry Conference, Andover, MA
319. April 26, 2003, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, Society of Analytical Chemists of Pittsburgh Symposium on Green Chemistry, Duquesne University, Pittsburgh, PA
320. April 30, 2003, Eliminating Persistent Pollutants with Green Catalysis, **PLENARY LECTURE**, Massachusetts Green Chemistry Conference, Andover, MA
321. April 10, 2003, Green chemistry: Sustaining a high-technology civilization, **UNIVERSITY CONVOCATION ADDRESS**, University of Tennessee, Martin, TN
322. April 10, 2003 The Problem of Endocrine Disruptors, University of Tennessee at Martin (Honors Students), Martin, TN
323. April 10, 2003 The Problem of The Persistent Pollutant, University of Tennessee at Martin (Honors Students), Martin, TN
324. April 9, 2003, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, Kentucky Lake Section of ACS, Union City, TN May 19, 2003, "Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes", **PLENARY LECTURE**, EU COST Workshop on GC and EU Conference on GC, Poitiers, France
325. March 23, 2003, Green chemistry: Sustaining a high-technology civilization, Division of Information Science, Symposium: Librarian Watch: Introduction to New Hot Areas in Chemistry, 225th ACS National Meeting, New Orleans, LA
326. February 4, 2003, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, **PLENARY LECTURE**, Australia/New Zealand Biennial Conference on Inorganic Chemistry, University of Melbourne, Melbourne, Australia
327. January 11, 2003, Designing Catalysts for Green Oxidation Technologies, **KEYNOTE ADDRESS**, New York Division of the American Chemical Society, Columbia University, New York, NY
328. November 22, 2002, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, New York Academy of Sciences, New York, NY
329. November 12, 2002, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, 3rd Green Chemistry Conference of Spain, Barcelona, Spain
330. November 5, 2002, Designing Catalysts for Green Oxidation Technologies, Department of Chemistry, University of Rochester, Rochester, NY
331. October 31, 2002, Green Chemistry: Sustaining a High Technology Civilization, Lectureship Series in Environmental Studies, Brown University, Providence, RI

332. October 24, 2002, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, 37th Annual Midwest ACS regional Conference, Symposium on Green Catalysis, Lawrence, KS
333. October 15, 2002, Green Chemistry: Achieving a Sustainable Economy, Roundtable Discussion, Conference on Nuevas tecnologías y sostenibilidad, Universidad Internacional Menéndez Pelayo, Valencia, Spain
334. October 16, 2002, Green Chemistry: Sustaining a High Technology Civilization, Conference on Nuevas tecnologías y sostenibilidad, Universidad Internacional Menéndez Pelayo, Valencia, Spain
335. October 9, 2002, Green Chemistry: Sustaining a High Technology Civilization, Central catholic High School (90 mim. Presentation to 8 classes), Pittsburgh, PA
336. September 26, 2002, Green Chemistry: Sustaining a High Technology Civilization, Denison University, Granville, OH
337. September 23, 2002, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, **BAYER LECTURE**, Notre Dame University, South Bend, IN
338. September 16, 2002, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, Center for Environmental Research and Technology, University of Bremen, Germany
339. September 8, 2002, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, Green Chemistry **GORDON CONFERENCE**, Queens College Oxford, United Kingdom
340. August 15, 2002, Designing Catalysts for Green Oxidation Technologies, NSF Workshop on Environmentally Benign Process Research Needs, Jiminy Peak Resort, Berkshires, MA
341. July 26, 2002, Catalysis as a Tool for Replacing Polluting Processes with Green Chemical Technologies, Sixth Annual Beckman Scholars Symposium, Arnold and Mabel Beckman Center of the National Academies of Sciences, Irvine, CA
342. July 22, 2002, Sustainability Science and the Economy of the Future, First German Summer School on Green and Sustainable Chemistry, Freising, Germany
343. July 22, 2002, Designing Catalysts for Green Oxidation Technologies, **PLENARY LECTURE**, First German Summer School on Green and Sustainable Chemistry, Freising, Germany
344. June 26, 2002, Activation of Hydrogen Peroxide for Green Chemical Processes, **PLENARY LECTURE**, Sixth Green Chemistry and Engineering Conference, Georgetown University, Washington, DC
345. May 28, 2002, Activation of Hydrogen Peroxide for Green Chemical Processes, University of Hong Kong, Hong Kong
346. May 22, 2002, Activation of Hydrogen Peroxide for Green Chemical Processes, **PLENARY LECTURE**, 5th International Symposium on Green Chemistry—China, Hefei City, Anhui Province, China
347. May 15, 2002, Green Chemistry: Sustaining a High Technology Civilization, Central Catholic High School, Pittsburgh, PA
348. May 13, 2002, Green Chemistry: Sustaining a High Technology Civilization, Chemical Sciences Roundtable of the national Academy of Sciences, Georgetown, DC
349. April 10, 2002, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, Symposium on Agricultural Application in Green Chemistry, 223rd National Meeting of the American Chemical Society, Orlando, FL
350. April 16, 2002, Green Chemistry: Sustaining a High Technology Civilization, **GOLDEN GOGGLES AWARD ADDRESS**, Middle Tennessee State University, Murfreesboro, TN
351. April 7, 2002, Novel Green Chemical Applications of TAML Activators of Hydrogen Peroxide, Symposium on Catalysis in Green Chemistry, 223rd National Meeting of the American Chemical Society, Orlando, FL
352. April 5, 2002, Darkness in El Dorado: interpretations for a better future, **PLENARY LECTURE**, International Conference on "Darkness in El Dorado", Cornell University, Ithaca, NY
353. April 4, 2002, Green Chemistry: Sustaining a High Technology Civilization, **UNIVERSITY CONVOCATION ADDRESS**, Augustana College, Rock Island, IL
354. March 27, 2002, Green Chemistry at Carnegie Mellon University, Dept. of Biological Sciences, Carnegie Mellon University, Pittsburgh, PA
355. February 14, 2002, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, Dept. of Chemical Engineering, Carnegie Mellon University, Pittsburgh, PA
356. December 5, 2001, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, National Conference on Molecules for Life, Joint Meeting of the NZ Society for Biochemistry and Molecular Biology, NZ Institute of Chemistry and the NZ Biotechnology Association, Napier, New Zealand
357. November 19, 2001, Sustainability Science and the Economy of the Future, Osaka City University, Osaka, Japan
358. November 17, 2001, Sustainability Science and the Economy of the Future, Commemorative Symposium for KYOUSEI Center, Nara Women's University, Nara, Japan
359. November 16, 2001, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, Green Chemistry Forum, Kyoto, Japan
360. November 15, 2001, Sustainability Science and the Economy of the Future, Osaka Prefecture University, Osaka, Japan
361. November 14, 2001, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, Osaka City University, Osaka, Japan
362. October 26, 2001, Allegheny College, Meadville, PA
363. October 19, 2001, Shippensburg University, Shippensburg, PA
364. August 20, 2001, MCC-8: Symposium on metal ions, complexes and clusters in macromolecular systems, Polytechnic University, Brooklyn, NY
365. July 5, 2001, Green Chemistry: Sustaining an High Technology Civilization, Public Lecture, The Museum of Otago,

Dunedin, New Zealand
366. July 5, 2001, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, Department of Chemistry, University of Otago, Dunedin, New Zealand
367. July 2, 2001, 2001, Science and the Ethics of Sustainability, ChemEd Conference 2001, University of Canterbury, Christchurch, New Zealand
368. June 28, 2001, Green Chemistry: On the responsibility of chemists to promote sustainability, 90 Minute Lecture to Canterbury High School Teachers, St. Margaret's College, Christchurch, NZ
369. June 28, 2001, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, Department of Chemistry, University of Canterbury, Christchurch, New Zealand
370. June 18, 2001, Green Chemistry: Sustaining an High Technology Civilization, Reckitt-Benkiser, Montvale, NJ
371. December 5, 2001, Green Chemistry and the Economy of the Future, **KEYNOTE LECTURE**, National Conference on Molecules for Life, Joint Meeting of the NZ Society for Biochemistry and Molecular Biology, NZ Institute of Chemistry and the NZ Biotechnology Association, Napier, New Zealand
372. November 13, 2001, Catalytic Activation of Hydrogen Peroxide for Green Chemical Processes, **KEYNOTE LECTURE**, Second National Symposium of the Green & Sustainable Chemistry Network (GSCN), Yokohama, Japan
373. July 4, 2001, Green Chemistry: Sustaining an High Technology Civilization, **PLENARY LECTURE**, ChemEd Conference 2001, Department of Chemistry, University of Canterbury, Christchurch, New Zealand
374. June 29, 2001, Green Chemistry: On the responsibility of chemists to promote sustainability, **MELLOR LECTURE** of the New Zealand Institute of Chemistry and the Royal Society of New Zealand, Wellington, New Zealand
375. May 11, 2001, Green Chemistry: Sustaining an High Technology Civilization, Applied Physics Laboratory, Johns Hopkins University, Baltimore, MD
376. April 24, 2001, Green Chemistry: Sustaining an High Technology Civilization, **KEYNOTE ADDRESS** at the Innovation and pioneering celebration of Bayer USA, Moon, PA
377. April 12, 2001, Green Chemistry: Sustaining an High Technology Civilization, Department of Chemistry, University of Illinois, Urbana-Champaign, IL
378. April 2, 2001, Green Chemistry: On the responsibility of chemists to promote sustainability, 90 Minute Workshop given under auspices of the Society and Education Division, ACS National Meeting, San Diego, CA
379. March 7, 2001, Green Chemistry: Sustaining an High Technology Civilization, Oberlin College, Oberlin, OH
380. January 18, 2001, Green Chemistry: Sustaining an High Technology Civilization, Indian Institute of Technology,, Khargpur, India
381. January 17, 2001, Green Chemistry: Sustaining an High Technology Civilization, Indian Association for the Cultivation of Science, Jadavpur, Calcutta, India
382. January 15, 2001, Green Chemistry: Sustaining an High Technology Civilization, Indian Institute of Technology, Kanpur, India
383. January 13, 2001, Green Chemistry: Sustaining an High Technology Civilization, US Environmental Protection Agency Research Laboratories, Cincinnati, OH
384. January 11, 2001, Green Chemistry: Sustaining an High Technology Civilization, IUPAC Conference on Green Chemistry, **PLENARY LECTURE**, New Dehli, India
385. November 7, 2000, Catalytic Activation of Hydrogen Peroxide for Environmentally Significant Problems, Geneva College, Beaver Falls, PA
386. October 3, 2000, Catalytic Activation of Hydrogen Peroxide for Environmentally Significant Problems, Unilever Research, Chester, England
387. November 1, 2000, Catalytic Activation of Hydrogen Peroxide for Environmentally Significant Problems, Johns Hopkins University, Baltimore, MD
388. October 24, 2000, Catalytic Activation of Hydrogen Peroxide for Environmentally Significant Problems, Yale University, New Haven, CT
389. October 3, 2000, Catalytic Activation of Hydrogen Peroxide for Environmentally Significant Problems, Unilever Research, Chester, England
390. September 22, 2000, Catalytic peroxide activation: Pulp bleaching, color and AOX abatement, 8th International Activated Carbon Conference, Moon Township, PA
391. August 24, 2000, TAML® Peroxide Activators: Chemistry and Applications in Paper and Textile Effluent Treatment, 220th ACS National Meeting, Washington, DC
392. August 10, 2000, Catalytic Activation of Hydrogen Peroxide for Environmentally Significant Problems, Atofina Corporation, King of Prussia, PA
393. August 1, 2000, Green Chemistry: On the Responsibility of Chemists to Promote Sustainability, Bieenial Conference on Chemical Education, Ann Arbor, MI July 19, 2000, Catalytic Activation of Hydrogen Peroxide for Environmentally Significant Problems, **GORDON CONFERENCE** on Green Chemistry, (Moderator of this conference for the Gordon Conference Trustees), New London, CT
394. July 11, 2000, Sustaining a High Technology Civilization, Public Lecture 7:30–9:00 pm, Dunedin Public Library, Dunedin, New Zealand
395. July 2–6, 2000, SCICON Conference of New Zealand Science Educators, 90 MINUTE WORKSHOP, Green Chemistry: On the Responsibility of Chemists to Promote Sustainability, June 5, Massey University, Palmerston North,

New Zealand
396. July 2–6, 2000, SCICON Conference of New Zealand Science Educators, **PLENARY LECTURE**, Sustaining a High Technology Civilization, June 4, Massey University, Palmerston North, New Zealand
397. July 4, 2000, Sustaining a High Technology Civilization, The Royal Society of New Zealand, The Science Museum, Palmerston North, New Zealand
398. June 29, 2000, Sustaining a High Technology Civilization, Public Lecture 7:30–9:00 pm, University of Auckland, Auckland, New Zealand
399. April 20, 2000, Green Chemistry and Sustainability, Environmental Club, Carnegie Mellon University, Pittsburgh, PA
400. March 28, 2000, Catalytic peroxide activation: Pulp bleaching, color and AOX abatement, 219th ACS National Meeting March 26-30, 2000, San Francisco, CA
401. February 22, 2000, The Design of Green Oxidation Systems, Department of Chemistry, University of Michigan, Ann Arbor, MI
402. February 16, 2000, The Design of Green Oxidation Systems, Synthetic Organic Chemical Manufacturers Association Annual Conference, New Orleans, LA
403. January 28, 2000, The Design of Green Oxidation Systems, Department of Chemistry, Youngstown State University, Youngstown, OH
404. January 12, 2000, The Design of Peroxide-Activating Catalysts, Unilever Research Headquarters, Port Sunlight, England
405. November 19, 1999, The Design of Green Oxidation Systems, Department of Chemistry, Virginia Polytechnical University, Blacksburg, VA
406. November 18, 1999, Green Chemistry: Sustaining a High Technology Civilization, Washington and Lee University, Lexington, VA
407. November 2, 1999, Catalysis is a Key to a Better Future for the Pulp and Paper Industry, TAPPI Pulping Conference, Renaissance Orlando, Orlando, FL
408. October 26, 1999, Green Chemistry: Sustaining a High Technology Civilization, Pittsburgh Chemist's Club, Durantes Restaurant, Pittsburgh, PA
409. October 16, 1999, Green Chemistry: Sustaining a High Technology Civilization, Carnegie Mellon Parents Day, Carnegie Mellon University, Pittsburgh, PA
410. October 15, 1999, Green Chemistry: Sustaining a High Technology Civilization, Allegheny Erie Society of Toxicology, Moon, PA
411. September 30, 1999, The Design of Green Oxidation Systems, Department of Chemistry and Biochemistry University of Pennsylvania, Philadelphia, PA
412. September 29, 1999, The Design of Green Oxidation Systems, Rohm and Haas Corporation, Springhouse, PA
413. September 23, 1999, Green Chemistry: Sustaining a High Technology Civilization, Central Catholic High School, Pittsburgh, PA
414. September 13, 1999, The Design of Green Oxidation Systems, Department of Biochemistry, University of Wisconsin, Madison, WI
415. September 8, 1999, The Design of Chemistry Labs of the 21st Century, Meeting of Architectural Firms and Govt. Agencies, Boston MA
416. August 12, 1999, The Design of Sustainable Oxidation Systems, GSF Research Center of Münich, Ingolstadter Landstr.1, 85764 Neuherberg, Germany
417. July 23, 1999, Green Chemistry: Sustaining a High Technology Civilization, Pennsylvania Governor's Science Institute, **PLENARY LECTURE**, Carnegie Mellon University, Pittsburgh, PA
418. July 1, 1999, The Seven Promises of Catalysis in the Pulp and Paper Industry, Green Chemistry and Engineering Conference, National Academy of Sciences, Washington, DC
419. April 26, 1999, The Seven Promises of Catalysis in the Pulp and Paper Industry, Lecture to the Bleaching Committee of TAPPI, Hattiesburg MS
420. April 22, 1999, The Design of Green Oxidants, To the Chemistry Teachers of Pittsburgh and their most gifted students, Central Catholic High School, Pittsburgh, PA
421. January 28, 1999, The Design of Green Oxidants, **GORDON CONFERENCE** on Metals in Biology, This 2 hour lecture was the Thursday evening after diner speech that both closed the Metals in Biology Gordon Conference and opened the young scientist Gordon Conference on Metals in Biology
422. January 25, 1999, Green Up or Clean Up: The Design of Green Oxidants, Conference on Organometallic Chemistry in the South Pacific to honor Warren Roper on the occasion of his 60th birthday, Auckland, New Zealand
423. November 5, 1998, The Design of Green Oxidants, University of Vermont, Burlington, VT
424. October 28, 1998, New Efficient, Selective, Totally Chlorine Free Wood Pulp Bleaching Technology, 1998 TAPPI Pulp Conference, Montreal, Canada
425. October 23-25, 1998, Green Chemistry: Sustaining a High Technology Civilization, EPA/NSF Green Chemistry Education Kick-off Meeting, National Academy of Sciences, Washington, DC
426. October 20, 1998, The Design of Green Oxidants, Unilever Research, Port Sunlight, England
427. August 25, 1998, New, Selective, Efficient, Totally Chlorine-Free Wood Pulp Bleaching Technology, Symposium to Honor Career of Daryle Busch (Current President-Elect of ACS), 216th ACS Meeting, Boston, MA

428. August 23, 1998, Green Chemistry Education, Green Chemistry Education: International Perspectives, ACS Symposium, ACS Meeting, Boston, MA
429. July 28, 1998, Green Chemistry: Sustaining a High Technology Civilization, **THE PLENARY LECTURER** to Gifted High School Students of Osaka at symposium on Green Earth Science, Osaka-City University, Osaka, Japan
430. July 27, 1998, The Design of Green Oxidants, Department of Material Science Osaka-City University, Osaka, Japan
431. July 25, 1998, The Design of Green Oxidants, **THE PLENARY LECTURER** 5th International Symposium of the Society Of Pure And Applied Coordination Chemistry of Japan, "Molecular Design of Functional Metal Complexes for Green Earth Science", Kogakuin University, Tokyo Japan, July 25, **AWARD LECTURE** for the 1997 Prize of Society of Pure And Applied Coordination Chemistry of Japan
432. July 22, 1998, The Design of Green Oxidants, **GORDON CONFERENCE** on Inorganic Chemistry, Salve Regina College, Newport, RI
433. July 1, 1998, The Design of Green Oxidants, Green Chemistry and Engineering Conference, National Academy of Sciences, Washington, DC
434. June 12, 1998, The Design of Green Oxidants, NSF Inorganometallic Workshop, Knoxville, TN
435. May 12, 1998, Development of Long-Lived Hydrogen Peroxide Activators for Pulp Bleaching, Annual Spring Meeting of the Pulp Bleaching Committee of the Association of The Pulp and paper Industry, Wisconsin Rapids, WI
436. January 30, 1998, The Design of Green Oxidants, **KEYNOTE LECTURE**, Annual Meeting of the Chemistry Department Heads and Full Professors of Australia, Canberra, Australia
437. September 30, 1997, "The Development of Green Oxidants": **PLENARY LECTURE**, International Conference on Green Chemistry: Challenging Perspectives, Venice, Italy
438. June 23, 1997, "The Development of Green Oxidants": **PLENARY LECTURE**, 1997 Green Chemistry and Engineering Conference, Implementing Vision 2020 for the Environment, National Academy of Sciences, Washington, DC
439. 1996, Designing Ligands for Oxidizing Complexes, Department of Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh, PA
440. November 6, 1996, Academy of Life-Long Learning, Carnegie Mellon University, Pittsburgh, PA
441. September 3, 1996, The Design of Green Oxidants, Department of Chemistry, Victoria University, Wellington, New Zealand
442. September 3, 1996, Ligand-Design Based Approaches for Controlling Exchange Coupling, Department of Chemistry, Victoria University, Wellington, New Zealand
443. July 29–August 30, 1996 Ten lectures, Distinguished Visitor, Department of Chemistry, University of Auckland, Auckland New Zealand
444. August 14, 1996, Distinguished Scientist Seminar, Department of Chemistry, University of Auckland, Auckland New Zealand
445. July 27, 1996, Invited speaker at the First **GORDON CONFERENCE** on Environmentally Benign Organic Chemistry, New England College, Henneker, NH
446. August 7, 1996, Distinguished Scientist Seminar, Department of Chemistry, University of Auckland, Auckland New Zealand
447. March 27, 1996, Massachusetts Institute of Technology, Boston, MA
448. March 17, 1996, North Carolina State University, Raleigh, NC
449. January 30, 1996, International Meeting on Macrocyclic Chemistry, Wellington, New Zealand
450. September 17, 1995, NATO Workshop, *Magnetism: A Supramolecular Function*, Carcans,
a. France
451. June 27, 1995, First Midwest Meeting in Bioinorganic Chemistry Meeting, Minneapolis, MN
452. May 25, 1995, Clorox Chemical Company, Pleasanton, CA
453. May 24, 1995, Electrochemical Society International Meeting, Reno, NV
454. February 24, 1995, Hamilton College, Clinton, NY
455. February 8, 1995, University of Delaware, Newark, DE
456. July 1994, Industrial and Government visitors to the Environmental Open House, Carnegie Mellon University, Pittsburgh, PA
457. September 15, 1994, University of Vermont, Burlington, VT
458. August 2, 1994, 13th Biennial Conference on Chemical Education, Bucknell University, Lewisburg, PA
459. July 13, 1994, EPA Workshop on Green Design, Cincinnati, OH
460. Jan 19, 1994, Air Products Corporation, Allentown, PA
461. October 15, 1993, Baylor University, Waco, TX
462. October 13, 1993, University of Texas, Austin, TX
463. September 30, 1993, Columbia University, New York, NY
464. September 29, 1993, Princeton University, Princeton, NJ
465. September 28, 1993, University of Pennsylvania, Philadelphia, PA
466. March 5, 1993, University of Kansas, Lawrence, KS
467. March 4, 1993, Kansas State University, Manhattan, KS

468. February 26, 1993, ARCO Chemical Company, MD
469. January 19, 1993, Air Products, Allentown, PA
470. October 15, 1992, Gettysburg College, Gettysburg, PA
471. October 1, 1992, Rensselaur Polytechnic Institute, Troy, NY
472. May 7-8, 1992 – Participant in NSF National Workshop on the teaching of Chemistry in Undergraduate Laboratories, Washington, DC
473. April 27, 1992 – ARCO Chemical Company, MA
474. April 8, 1992 – Invited speaker in the Symposium on New Reagents in Inorganic and Organometallic Chemistry, National ACS Meeting, San Francisco, CA
475. November 11, 1991 – Departmental Colloquium, University of Chicago, Chicago, IL
476. October 1, 1991 – Yale University, New Haven, CT
477. April 18, 1991 – Inorganic seminar to faculty and students of University of Akron, Kent State University, Mt. Union College, and several other colleges, Kent, OH
478. March 28, 1991 – Indiana University, Bloomington, IN
479. March 1, 1991 – ARCO Chemical Company, MD
480. February 1, 1991 – **PLENARY LECTURE,** International Conference on Inorganic Chemistry, University of Waikato, Hamilton, New Zealand
481. August, 27 1990 – National ACS Conference – Symposium on ``Ligand Design in Regulating Redox Reactions", Washington, DC
482. April 19, 1990, Pittsburgh/Cleveland Catalysis Soc., Cleveland, OH
483. April 17, 1990 – Pennsylvania State University, College Station, PA
484. †April 27, 1990: Seminar on *ITEC* to Pennsylvania High School and College Teachers at the University of Pittsburgh, Pittsburgh, PA
485. †April 6, 1990 – Seminar on *ITEC* to Pennsylvania Science Educ. Soc. Allegheny College, Meadville, PA
486. †January 11, 1990 – Education Directorate Officers, NSF, Washington, DC
487. December 6, 1989 – University of Delaware, Newark, DE
488. October 24, 1989 – University of Maryland, College Park, MD
489. October 6, 1989 – Duquesne University, Pittsburgh, PA
490. November 18, 1988 – Santa Clara University, Santa Clara, CA
491. †October 11, 1989 – Lord Corporation and Foundation Executives, Pittsburgh, PA
492. †July 26, 1989 – Pittsburgh High School Teachers, Pittsburgh, PA
493. †May 24, 1989 – Presentation to Merck Repesentatives at CMU (leading ultimately to Corporate Grant), Pittsburgh, PA
494. †May 22, 1989 – Select Group of CMU Trustees, Pittsburgh, PA
495. †March 21, 1989 – International Conference on Global Crises, Chicago, IL
496. November 10, 1988 – W. R. Grace Company, MD
497. October 27, 1988 – Clemsen University, Clemsen, SC
498. October 4, 1988 – Mellon College of Science Research Seminar, Pittsburgh, PA
499. †September 19, 1988, Duquesne University Presentation to High School Teachers, Pittsburgh, PA
500. †July 21 1988, The Chemical Manufacturers Association, The National Science Foundation, The American Chemical Society, Washington, DC
501. †June 28, 1988, The Mobay Corporation Administration, Pittsburgh, PA
502. †May 18, 1988, The Kresge Foundation, Detroit, MI
503. †May 11, 1988, Calgon Carbon Company, Pittsburgh, PA
504. April 20, 1988 – Bucknell University, Lewisburg, PA
505. April 7, 1988 – Kent State University, Kent, OH
506. †April 4, 1988, The Duquesne Club presentation to Pittsburgh Corporate Executives (leading ultimately to Corporate Grant), Pittsburgh, PA
507. †March 29, 1988, The Dreyfus Foundation, New York, NY
508. March 23, 1988 – The University West Virginia, Morgantown, WV
509. February 11, 1988 – The University of Pittsburgh, Pittsburgh, PA
510. December 4 1987 – Baylor University, Waco, TX
511. January 1987 – Standard Oil, Cleveland, OH
512. January 1987 – The University of Southern California, Los Angeles CA
513. November 20, 1986 – Carnegie Mellon University, Pittsburgh, PA
514. November 14, 1986 – Amoco Chemical Company, Chicago, IL
515. November 4, 1986 – Dow Chemical Company, Midland, MI
516. November 3, 1986 – Dow Chemical Company, Midland, MI
517. October 7, 1986 – University of Southern California, Los Angeles, CA
518. September, 1986 – University of Nebraska, Lincoln, NE
519. February 25–27, 1986 – Organizer of and speaker in the Industrial Associates Conference on Oxidation Chemistry held

at Caltech, Pasadena, CA
520. December 4, 1985 – Simon Fraser University, Burnaby, British Columbia, Canada
521. December 3, 1985 – Departmental Seminar at the University of British Columbia, Vancouver, British Columbia, Canada
522. December 2, 1985 – University of Washington, Seattle, WA
523. November 22, 1985 – University of California, Berkeley, Berkeley, CA
524. November 20, 1985 – University of California, Davis, Davis, CA
525. November 19, 1985 – Stanford University, Stanford, CA
526. November 16, 1985 – Northwestern University, Evanston, IL
527. November 15, 1985 – Northwestern University, Evanston, IL
528. November 14, 1985 – Hope College, Holland, MI
529. November 12–13, 1985 – University of Illinois, Champaign–Urbana, IL
530. November 11, 1985 –SOHIO, Cleveland, OH
531. November 6, 1985 – University of Chicago, Chicago, IL
532. October 24, 1985 – Carleton College, Northfield, MN
533. October 23, 1985 – 3M Company, St. Paul, MN
534. October 22, 1985 – ACS Inorganic Topical Group Seminar, University of Minnesota, St. Paul, MN
535. October 21, 1985 – University of Wisconsin, Madison, Madison, WI
536. October 17, 1985 – Ohio State University, Columbus, OH
537. October 16, 1985 – Iowa State University, Ames, IA
538. October 15, 1985 – University of Iowa, Iowa City, IA
539. October 14, 1985 – Washington University, St. Louis, MO
540. October 10–11, 1985 – Invited speaker in Symposium on Oxidation Chemistry at Monsanto Company, St. Louis, MO
541. July 29–August 2, 1985–Invited speaker at the Organometallic **GORDON CONFERENCE**, Hawthorne College, Antrim, NH
542. June 10–12, 1985 – Invited speaker in Symposium on Unusual Oxidation States at the ACS Regional Meeting, Purdue University, West Lafayette, IN
543. May 24, 1985 – Harvard/MIT joint seminar in Inorganic Chemistry, Cambridge, MA
544. May 21, 1985 – University of California, Los Angeles, Los Angeles, CA
545. May 17, 1985 – Exxon Research and Engineering Company, Annandale, NJ
546. May 15, 1985 – GTE Laboratories, Waltham, MA
547. May 14, 1985 – Texaco Inc., Beacon Hill, NY
548. May 13, 1985 – Air Products and Chemicals, Inc., Allentown, PA
549. April 22–26, 1985 – Invited speaker at the US/USSR Symposium on Environmentally Related Catalysis, Moscow, USSR
550. April 19, 1985 – Rohm and Haas Company, Spring House, PA
551. April 18, 1985 – Columbia University, New York, NY
552. January 24, 1985 – Departmental Seminar, Harvey Mudd College, Claremont, CA
553. October 26, 1984 – University of California, Santa Barbara, Santa Barbara, CA
554. December 16–21, 1984 – 1984 International Chemical Congress of Pacific Basin Societies, (One of the organizers of and speakers in the Symposium on ``New Developments in Coordination Chemistry: Oxygen and Oxidation"), Honolulu, HI
555. September 24–28, 1984 – Invited participant at the Fourth International Symposium on Homogeneous Catalysis, Leningrad, USSR
556. July 9, 1984 – Cambridge University, Cambridge, England
557. July 5, 1984 – Oxford University, Oxford, England
558. June 24–29, 1984 – Member of the International Advisory Committee and speaker in the International Oxidations", Padova, Italy Symposium and Advanced Research Workshop on "Activation of Dioxygen Species and Homogeneous Catalytic Oxidation Chenistry"; Report Editor
559. June 8, 1984 – Rohm and Haas Company, Spring House, PA
560. June 6, 1984 – Invited speaker at the symposium entitled ``Advances in Catalytic Science – New Eyes/New Insights," University of Delaware, Newark, Delaware and participant in the annual review meeting of the Center for Catalytic Science and Technology, DE
561. June 4, 1984 – E. I. du Pont de Nemours and Company, Wilmington, DE
562. May 30–June 2, 1984 – Invited speaker at the 1984 National Science Foundation Organometallic Chemistry Workshop, The University of North Carolina, Chapel Hill, NC
563. May 29, 1984 –Dow Chemical Company, Midland, MI
564. May, 1984 – University of California, San Diego, La Jolla, CA
565. April 17, 1984 – University of Southern California, Los Angeles, CA
566. April 8–12, 1984 – Invited speaker in Symposium on Carbon Dioxygen Chemistry at the 187th National ACS Meeting, St. Louis, MO

567. March 15, 1984 – University of California, Irvine, Irvine, CA
568. August 8–12, 1983 – Invited speaker at the 1983 Inorganic Chemistry **GORDON CONFERENCE**, (Brewster Academy), Wolfeboro, NH
569. April 15, 1983 – California State University, Northridge, Northridge, CA
570. March 20–25, 1983 – Session Chairman, 185th National ACS Meeting, Seattle, WA
571. March 20–25, 1983 – 185th National ACS Meeting, Seattle, WA
572. March 16–18, 1983 – Invited speaker at the Conference on Frontiers of Catalysis, California Institute of Technology, 22 Gates, Pasadena, CA
573. February 28, 1983 – Loma Linda University, La Sierra Campus, Loma Linda, CA
574. June 23–26, 1981 – Invited speaker at the 1981 NSF National Organometallic Chemistry Workshop, Asilomar, Pacific Grove, CA

Exhibit B

Statement of Miriam L. Diamond

Earth Sciences
UNIVERSITY OF TORONTO

February 6, 2015

I, Miriam L. Diamond, am writing this statement in support of the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. Personal Information. I am a Professor in the Department of Earth Sciences at the University of Toronto with cross appointments in the Department of Chemical Engineering and Applied Chemistry, Dalla Lana School of Public Health, School of the Environment, and Department of Physical and Environmental Sciences at the University of Toronto. I received a B.Sc. from the University of Toronto in 1976, a M.Sc. in Zoology from the University of Alberta in Edmonton Alberta in 1980, a M.Sc.Eng. in Mining Engineering from Queen's University in Kingston, Ontario, and a PhD. in Chemical Engineering and Applied Chemistry from University of Toronto in 1990. My research concerns the sources, emissions and fate of environmental chemicals and exposure of these chemicals to humans and ecosystems. I am a Fellow of the Royal Geographic Society. I have served on the Board of Directors and Executive Committee of the Society of Environmental Toxicology and Chemistry, and have been an Associate Editor of the journal *Environmental Science and Technology*, the leading journal in the field, since 2012. I have held the INNOLEC Science Guest Chair in Chemistry, Masarykova Univerzita, Czech Republic, been a visiting scholar in the Department of Applied Environmental Science at Stockholm University, and the Joseph R. Meyerhoff Visiting Professorship at the Weizmann Institute in Israel. In 2008 I was appointed by the Minister of Environment of the Province of Ontario to co-chair the Toxics Reduction Scientific Expert Panel that brought in Canada's first Toxic Reduction Act. I have served on numerous advisory panels for the U.S. Environmental Protection Agency and on a National Academies of Sciences expert panel, and I am a member of the Canadian Chemicals Management Plan Science Committee. I have attached my CV and list of publications.

2. Personal Expertise. A major focus of my research has been documenting emissions and fate of semi-volatile organic compounds or SVOCs (those with boiling points between 240° and 400°C according to WHO 1997[1]) in the indoor and outdoor urban environments. In 2005 we published the first paper to show that household dust, and not diet, was a major exposure route of the flame retardant polybrominated diphenyl ethers (PBDEs). This marked a radical shift in understanding sources and pathways of these and other SVOCs that are used in consumer products.[2] We were also the first to quantitatively estimate the emissions and fate of PBDEs in an indoor environment using a mathematical model that we developed[3,4] and, in conjunction with Prof. Stuart Harrad of the University of Birmingham, we measured house dust levels of organohalogen flame retardants.[5,6,7] Additionally, we documented the release into the indoor environment of deca-BDE, although it had not been expected to migrate from the products to which it was added because of its very low vapour pressure.[8]

3. Working with colleagues, we have measured concentrations of PBDEs in indoor dust, and in indoor and outdoor air that originate from indoor products and building materials.[9,10,11,12] Our data show that PBDEs migrate from consumer products into the indoor air and dust, and from there make it into the outdoor environment. In this study, we measured the geographic pattern of PBDE outdoor air concentrations at locations across Toronto, Canada, and found that it coincides with the inventory of PBDE-containing products found indoors.[13,14,15] In other words, we determined that PBDEs were migrating from consumer products into the indoor air, and then into outdoor air. The only plausible explanation for this spatial pattern of PBDEs in outdoor air is that the PBDEs migrated out of consumer products, as industries using PBDEs do not have this geographic pattern in Toronto.

4. Other organohalogen flame retardants in addition to PBDEs migrate from consumer products into the indoor environment, including into house dust. We determined this by sampling and analyzing 12 additive organohalogen flame retardants plus PBDEs in the surface wipes of casings of electronic and electrical equipment and the dust of 35 homes in the Toronto area.[16] We found particularly elevated concentrations of penta-, octa- and decaBDE mixtures, tris(1,3-dichloro-2-propyl)phosphate (TDCPP), tetrabromobenzotriazole (TBB), bis(2-ethylhexyl) tetrabromophthalate (TBPH), decabromodiphenyl ethane (DPDPE) and octabromotrimethylphenylindane (OBIND) in both surface wipes and house dust samples.[17,18,19]

5. In points 3 and 4, I explained that specific organohalogen flame retardants migrate from consumer products to indoor and outdoor air based on evidence from measurements. We know that organohalogen flame retardants as a class (not just the specific chemicals we identified in house dust) tend to migrate out of consumer products because they are typically used in additive form (i.e. not chemically bonded to the materials containing them) and because of their physical-chemical properties.[20] The first critical physical-chemical property is that organohalogen flame retardants are semi-volatile organic compounds (SVOCs) and the second property is that these compounds are persistent indoors:

> i) Organohalogen flame retardants as a class are SVOCs[20]. According to the U.S. EPA,[21] a chemical can be classified as a SVOC if its boiling point (a physical-chemical property) is greater than that of water and may vapourize (change from liquid or solid phase to vapour phase as measured by a chemical's vapour pressure) at or above room temperatures. A SVOC can exist simultaneously in a solid phase (i.e., as a flame retardant in a polymer), AND in the vapour phase (i.e., in air). The significance of these flame retardants being SVOCs is that over time, some of the molecules of an organohalogen flame retardant added to a polymer will migrate into air. The migration is purely a function of the chemical being a SVOC and that it is added to, rather than reacted with or bound to, the polymer.
>
> ii) Organohalogen flame retardants are persistent indoors. Their persistence is a desired property for a flame retardant, i.e., the molecule will not break down during the life time of the product to which it has been added. However, the implication of this persistence is that the chemical will not break down indoors after it has migrated from the product.

6. The phenomenon of human exposure to constituents in house dust has been well established in the asthma and allergy field.[22] As noted above, our exposure analysis demonstrated that house dust is also a major source of human exposure to penta- and octaBDEs.[23] This finding has been corroborated by other exposure studies, including studies of organohalogen flame retardants in addition to PBDEs.[24,25,26,27] However, the most recent research suggests that organohalogen concentrations in house dust may be a proxy for another exposure pathway, that of direct transfer from product-to-hand, followed by hand-to-mouth transfer.[28,29] In other words, the most recent research indicates that humans are exposed to organohalogen flame retardants by touching consumer products in which these chemicals are present in additive form and by touching house dust which also contains organohalogen flame retardants. The measurement of organohalogen flame retardants in house dust is thus an indicator of the levels of organohalogen flame retardants in the home that residents come into contact with, both when they touch consumer products containing these chemicals and when they touch or inhale the dust itself.

7. In summary, there is a sufficient body of knowledge to conclude that all organohalogen flame retardants – because they are SVOCs – will tend to migrate out of the consumer products in which they are present in

additive form, resulting in human exposure. Once released indoors, organohalogen flame retardants will accumulate in indoor dust, and they are persistent in the indoor environment. Humans are exposed to organohalogen flame retardants as a result of direct contact with consumer products and with indoor dust containing these compounds. The inevitability of this human exposure, combined with the evidence showing that these compounds have toxicity, leads to the conclusion that all organohalogen flame retardants present in consumer products in additive form pose significant risks to human health.

I therefore urge the CSPC to ban the use of additive organohalogen flame retardants in the four consumer product categories covered in this petition.

Miriam Diamond

Miriam Diamond, Ph.D.
Professor,
University of Toronto

[1] WHO, World Health Organization. 1997. Environmental Health Criteria 192, International Programme on Chemical Safety. Geneva. 81 p. ISBN 9241571926.
[2] JONES-OTAZO H, JP CLARKE, ML DIAMOND, JA ARCHBOLD, G FERGUSON, T HARNER, MG RICHARDSON, JJ RYAN, B WILFORD. 2005. Is house dust the missing exposure pathway for PBDEs? An analysis of urban fate and human exposure to PBDEs. *Environ Sci Technol.* 39:5121-5130.
[3] ZHANG X., ML DIAMOND, SJ HARRAD, C IBARRA. 2009. Multimedia modeling of PBDE emissions and fate indoors. *Environ Sci Technol.* 43(8):2845-2850.
[4] ZHANG X, M ROBSON, ML DIAMOND, C IBARRA, SJ HARRAD. 2011. Polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) indoors in Toronto: concentrations, air/dust distribution, sources and emissions. *Environ Sci Technol.* 45:3268-3274.
[5] ABDALLAH MA-E, S HARRAD, C IBARRA, M DIAMOND, L MELYMUK, M ROBSON, A COVACI. 2008. Hexabromocyclododecanes in indoor dust from Canada, the United Kingdom and the United States. *Environ Sci Technol.* 42(2):459-464.
[6] HARRAD S, C IBARRA, M DIAMOND, L MELYMUK, M ROBSON+, J DOUWES, L ROOSENS, AC DIRTU, A COVACI. 2008. Polybrominated diphenyl ethers in domestic indoor dust from Canada, New Zealand, United Kingdom and United States. *Environ Internat.* 34:232-238.
[7] HARRAD S, C IBARRA, M ROBSON, L MELYMUK, X ZHANG, M DIAMOND, J DOUWES. 2009 Polychlorinated biphenyls in indoor dust from Canada, New Zealand, United Kingdom and United States: implications for human exposure. *Chemosphere.* 76(2):232-238.
[8] BUTT CM, ML DIAMOND, J TRUONG, MG IKONOMOU, AFH TER SCHURE. 2004. Spatial distribution of polybrominated diphenyl ethers in southern Ontario as measured in indoor and outdoor window organic films. *Environ Sci Technol.* 38:724-731.
[9] HARRAD S, C IBARRA, M DIAMOND, L MELYMUK, M ROBSON, J DOUWES, L ROOSENS, AC DIRTU, A COVACI. 2008. Polybrominated diphenyl ethers in domestic indoor dust from Canada, New Zealand, United Kingdom and United States. *Environ Internat.* 34:232-238.
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[13] MELYMUK L, M ROBSON, PA HELM, ML DIAMOND. 2012. PCBs, PBDEs and PAHs in Toronto air: spatial and seasonal trends and implications for contaminant transport. *Sci Total Environ.* 429:272-280.
[14] MELYMUK L, M ROBSON, PA HELM, ML DIAMOND. 2013. Application of land use regression to identify sources and assess spatial variation in urban SVOC concentrations. *Environ Sci Technol.* 47(4):1887-1895.
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[18] GOOSEY E., A SAINI, S CHAUDHURI, ML DIAMOND. 2013. Assessment of the prevalence and exposure to new flame retardants (NFRs) in Canadian indoor environments. Report to Health Canada. 93 pp.

[19] ABBASI G, SAINI, A, GOOSEY, E, DIAMOND M. Forthcoming. 2014. Halogenated flame retardants in Canadian house dust. *Integr Environ Assess Manag.*

[20] SERODIO, D. 2015. Novel halogenated and organophosphate flame retardants: do novel flame retardants have the same environmental fate as the compounds they are replacing? M.A.Sc. Thesis, Department of Earth Sciences, University of Toronto.

[21] http://www.epa.gov/reg3hwmd/bf-lr/regional/analytical/semi-volatile.htm

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[24] JOHNSON PI, STAPLETON HM, SJODIN A, MEEKER JD. 2010. Relationships between polybrominated diphenyl ether concentrations in house dust and serum. *Environ Sci Technol.* 44:5627-5632.

[25] KARLSSON M, JULANDER A, VAN BAVEL B, HARDELL L. 2007. Levels of brominated flame retardants in blood in relation to levels in household air and dust. *Environ Int.* 33(1):62-69.

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[28] WATKINS DJ, MCCLEAN, MD, FRASER AJ, WEINBERG J, STAPLETON HM, SJODIN A, WEBSTER TF. 2011. Exposure to PBDEs in the office environment: evaluating the relationships between dust, handwipes, and serum. *Environ Health Persp.* 119:1247-1252.

[29] STAPLETON HM, EAGLE S, SJOEDIN, WEBSTER TF. 2012. Serum PBDEs in a North Carolina toddler cohort: associations with handwipes, house dust, and socioeconomic variables. *Environ Health Persp.* 120(7):1049-1054.

September 12, 2014

MIRIAM LEAH DIAMOND - CURRICULUM VITAE

A. BIOGRAPHICAL INFORMATION

1. PERSONAL

Name:	**Miriam Leah Diamond**
University address:	Department of Earth Sciences University of Toronto 22 Russell St. Toronto, Ontario M5S 3B1 CANADA
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Phone:	(416) 533-1303
Citizenship:	Canadian

2. DEGREES

B.Sc., 1976, Biology, University of Toronto, Toronto, Ontario

M.Sc., 1980, Zoology, University of Alberta, Edmonton, Alberta
"Plumage variability in redpolls (*Carduelis flammea* and *C. hornemanni*, L): A test of Rohwer's status signalling hypothesis".
Thesis supervisor: W.A. Fuller.

M.Sc.Eng., 1984, Mining Engineering, Queen's University, Kingston, Ontario
"An environmental investigation of the Kognak River at Cullaton Lake Gold Mine".
Thesis supervisor: J.A. Meech

Ph.D., 1990, Chemical Engineering and Applied Chemistry, University of Toronto, Toronto, Ontario
"Modelling the fate and transport of arsenic and other inorganic chemicals in lakes".
Thesis supervisor: D. Mackay

3. EMPLOYMENT

2012-present	Associate Editor, *Environmental Science and Technology*
2012-present	Professor, University of Toronto, Department of Earth Sciences
2012-present	Cross-appointed to School of the Environment
2010-present	Cross-appointed to Department of Physical and Environmental Sciences, University of Toronto at Scarborough
2003-present	Cross-appointed, University of Toronto, Dalla Lana Faculty of Public Health Sciences
2007-2012	Cross Appointed to Centre of the Environment
2007-2008	Research Director, Centre for Environment
2002-2012	Professor, University of Toronto, Department of Geography
2001-2002	Acting Director, Collaborative Program in Toxicology, Institute for Environmental Studies
1997-2002	Associate Professor, University of Toronto, Department of Geography.
1997-present	Member, School of Graduate Studies.
1999-2003	Associate, Center for Environmental Research, Education and Training, University of Maryland, Baltimore County
1993-1997	Assistant Professor, University of Toronto, Department of Geography.
1992-present	Cross-appointed Professor, Department of Chemical Engineering and Applied Chemistry.
1995-1997	Public Health Associate, City of Toronto Department of Public Health.
1991-1993	Assistant Professor, University of Toronto, Innis College and Department of Geography.
1990-1991	Research Associate, University of Toronto, Institute for Environmental Studies.
1990	Post-Doctoral Fellow, University of Toronto, Institute for Environmental Studies.
1989	Lecturer, University of Toronto, Institute for Environmental Studies.
1985-present	Consultant, Self-Employed: • California Air Resource Board, review of proposal for diesel fuel additive 2010. • Lake Onondaga Review panel, 2007-present. • Environment Canada, 2004. • United States Environmental Protection Agency, 2003. • CH2M Hill, Subcontractor for Carson River Superfund Site, 2000-2003. • Expert witness, Ontario Municipal Board Hearing, Oak Ridges Moraine, 2001-2002. • Health Promotion and Environmental Protection Office, City of Toronto, 2000-2001. • Environment Canada, National Water Research Institute, 1998-1999. • Environment & Ecology, Inc., Technical Advisor and subcontractor for Carson River Superfund Site, Spring 1993-1998. • Minnesota Pollution Control Agency, 1993-1994, 1995-1996. •Technical advisor to project funded by the Ontario Min of the Environment, Bay of Quinte RAP, 2001-2003. • Ontario Ministry of Environment, Water Resources Branch, 1989-1990. • City of Toronto, Environmental Protection Office, 1990, 1991. • Environment Canada, National Water Research Institute, 1989-1990. • Environment Canada, National Water Research Institute, 1989. • Environment Canada, Inland Waters Directorate April-June, 1988. • Federal Department of Energy, Mines and Resources, Canada Centre for Remote Sensing, 1985.
1984	Limnologist, Ontario Ministry of Natural Resources, Ontario Geological Survey, Geophysics/Geochemistry Section, Toronto, Ontario.

Maternity leaves Sept to Dec 1991, and Feb to May 1995.
Sabbatical leaves January to December 1998, July to Dec 2002, July 2008 to June 2009.

4. HONOURS AND AWARDS

2014	Visiting Scientist, Stockholm University, Department of Applied Environmental Science.
2011	INNOLEC Science Guest Chair in Chemistry, Masarykova Univerzita, Czech Republic.
2010	Fellow of the Royal Geographical Society
2007	Canadian Environmental Scientist of the Year, Royal Canadian Geographical Society.
2005	Joseph R. Meyerhoff Visiting Professorship. Weizmann Institute, Israel.
1999-02, 04, 05	Dean's Excellence Award, Faculty of Arts and Science, University of Toronto
1999 2003	Premier's Research Excellence Award, Province of Ontario.
1990	Ontario Ministry of the Environment Excellence in Research Award to Students.
1989-1990	George Burwash Langford Prize for distinctive contributions to environmental research and services to the Institute for Environmental Studies.
1988	John Brown Memorial Prize for Research in Environmental Science and Occupational Health, University of Toronto.
1981-1982	Max Bell Scholarship for Northern Studies, McGill University.
1976	Innis College Medal.

5. PROFESSIONAL AFFILIATIONS AND ACTIVITIES

Current Memberships:

Society of Environmental Toxicology and Chemistry
American Chemistry Society
International Association for Great Lakes Research
Canadian Association on Water Quality

Activities:

2014-	Binational Chemicals of Mutual Concern Identification Task Team (ITT) under the Annex 3 of the Great Lakes Water Quality Agreement
2013-2016	Member, Canadian Chemicals Management Plan Science Committee
2013-	Member, The Anthoropocene Project: Anthropocene Curriculum. Sponsored by Haus der Kulturen der Welt (HKW) in cooperation with the Max Planck Society, Deutsches Museum, the Rachel Carson Center for Environment and Society, and the Institute for Advanced Sustainability Studies.
2012-2013	Co-chair, Ontario Ministry of Environment, "Toxics Reduction Program Living List Multi-Stakeholder Group" (part of activities under the Toxic Reduction Act)
2011	Member, US EPA Science Advisory Board Panel, Review of Technical Support Document, "National-scale Mercury Risk Assessment Supporting the Appropriate and Necessary Finding for Coal- and Oil-Fired Electric Generating Units.
2010-2011	ILSI Risk 21 Project, Working Group on Exposure Science. Sponsored by HESI.
2010-2011	Member, Committee on Blue Water Navy Vietnam Veterans and Agent Orange Exposure. National Academies, Institute of Medicine, U.S. May 2010-June 2011.
2009- ,	Member, Board of Directors, Canadian Environmental Law Association
2009	US EPA, Review Panel Member, Environmental Sciences Division, May 2009, Las Vegas, Nevada
2008	Co-chair, Toxics Reduction Scientific Expert Panel.
2007-2010	Co-chair, Organizing committee, Annual conference of the International Association of Great Lakes Research held in Toronto May 2010
2007-2011	Member, Science Advisory Board of the International Joint Commission
2006-2013	Member, Canadian Environmental Assessment Agency, Review Panel for Participant Funding Program.
2007-2008	Member, Health-Environment Linkages Expert Panel organized by Statistics Canada

2006-2007	Member, Environmental Assessment Working Group sponsored by Health Canada and Environment Canada
2006-2011	Member, Editorial Advisory Board, *Environmental Science and Technology*
2006-2008	Member of review panel, Water Quality Model of Onondaga Lake.
2006	Panel member, Science Advisory Board, U.S. Environmental Protection Agency. Review of EPI Suite models.
2005-2008,	Member, Board of Directors, Canadian Environmental Law Association
2003-2005	Member of local organizing committee, Dioxin 2005. International Conference held in Toronto August 2005.
2003-2006	Physical Environment Research Interest Group Director, Centre for Urban Health Initiatives, 6 year support from Canadian Institutes for Health Research.
2003	Review committee, Lake Ontario Mass Balance Project
2000-2001	Hearing of the Ontario Municipal Board, Oak Ridges Moraine. Expert witness for Save the Rouge Inc.
2001-2003	Executive Committee, Board of Society of Environmental Toxicology and Chemistry
2000-2003	Board member of Society of Environmental Toxicology and Chemistry
1998-2000	Member of Expert Resource Group, for review of Copper and Zinc Smelting Guidelines, Canadian Environmental Protection Act, Environment Canada.
1998-2000	Member of Peer Review Panel of Hudson River PCBs RI/FS Phase 2 Reports, Preliminary Model Calibration Report. Sponsored by U.S. EPA.
1998-2001	Member of Steering Committee, "How Healthy is the Moira?". In conjunction with the Frost Centre and Environment and Resource Management Dept. of Trent University.
1998-2001	Member of Science Review Panel, Lake Michigan Mass Balance Model Project. Sponsored by U.S. EPA.
1997-2000	Member of Publications Committee, International Association for Great Lakes Research
1996-present	Member of Working Group on Fate and Exposure Modeling sponsored by SETAC.
1996	Invited participant in 26th Pellston Workshop "Reassessment of Metals Criteria for Aquatic Life Protection: Priorities for Research and Implementation", Society of Environmental Toxicology and Chemistry, Pensacola, Florida, Feb 10-14, 1996.
1994-1999	Associate Editor of *Water Quality Research Journal of Canada.*
1994-1998	Vice-Chair, Canadian Standards Association Committee on Life Cycle Impact Assessment of Pulp & Paper Production Phase.
1993-1994	Member of Working Group on Site Remediation, Waterfront Regeneration Trust.
1993-1994	Member of Technical Advisory Committee, International Association of Great Lakes Research.
1992	Invited participant in "ASEAN Conference on Women and Technology", CIDA, Bankok, Thailand.
1991-2001	Board Member of the Canadian Environmental Law Association.
1991-1992	Member of "Gender, Science and Development", international working group of IFIAS.

B. ACADEMIC HISTORY
6. a. RESEARCH ENDEAVORS

Fate and transport of inorganic and organic contaminants in the environment.

1. Fate of contaminants in lakes.
    a. Field, experimental and mass balance modelling analysis of the fate and transport of arsenic in Moira Lake, focusing on role of contaminated sediments and sediment-water exchange processes.*
    b. Experimental analysis of chemical sediment-water exchange and sorption processes.*

c. Field and experimental analysis of trace metal fate and sediment-water exchange in urban aquatic systems, e.g., stormwater detention ponds.*
d. Mass balance modelling of mercury fate in lakes (Great Lakes, shield lakes), and contaminated systems (Lahontan Reservoir, Nevada).*
e. Mass balance modelling of contaminants in Arctic and Subarctic lakes and food webs.*
   i. Collaborator in the Amituk Lake Project, Northern Contaminants Program of the Arctic Environmental Strategy, Dept. of Indian Affairs and Northern Development (1993-1995).*
   ii. Fate of organic contaminants and mercury in lakes and food webs of the Upper Yukon River Basin and lakes on Bear Island, arctic Norway.*
   iii. Collaborator in Bear Island (Norway) Project, lake and food web modeling*.
   iv. Measurement of current use chemicals in Arctic air and water
f. Mass balance modelling of contaminants and polyunsaturated fatty acids in Great Lakes and food webs, "Areas of Concern" Bay of Quinte, Hamilton Harbour and Spanish Harbour, and Lake Winnipeg. Contributor to development of Remedial Action Plans (RAPs) and Lake Wide Management Plans (Lake Erie, Lake Ontario).
g. Coupling our multispecies mass balance model with chemical speciation-complexation and toxicity models.

2. Fate of contaminants in urban areas.
   a. Determining ambient concentrations and fate processes of semi-volatile organic contaminants (and metals*) in urban media, including development of analytical methods and event-based sampling of urban streams
   b. Developing Multimedia Urban Model (MUM) with application to Toronto. Includes spatial and temporal resolution, merging air dispersion module, linkage to GIS.
   c. Exploring the composition, rate of accumulation, chemical exchange rates, and effects on overall contaminant fate, of thin films on impervious surfaces.*
3. Fate of contaminants in indoor environments and human exposure.
   a. Measurement of indoor concentrations and fate of semi-volatile organic compounds, notably halogenated and organophosphate flame retardants, phthalates and PAH.
   b. Development of Multimedia Indoor Model or MIM.
   c. Development of indoor passive air sampling methods.
4. Contaminated site remediation*
   d. Evaluating environmental and health impacts of site remediation processes.*
   e. Life-cycle assessment, developing a method to evaluate impacts of site remediation processes. In collaboration with Environmental Protection Office, City of Toronto. *

Exposure and Health Effects of Contaminants in the Environment

5. Evaluating potential health effects
   a. Collaboration on the toxicology of complex mixtures from urban areas.*
   b. Development of integrated ecological and human health risk assessment models for the estimation of the effects of urban contaminants.*
   c. Balancing potential health benefits and risks from omega 3-fatty acids and contaminants in fish.
6. Estimating human exposure
   a. Estimating human exposure to indoor.
7. Urban agriculture*
   a. Evaluating health benefits and potential risks from urban agriculture, e.g., Kampala Uganda, Toronto, Ontario.*
8. Life Cycle Assessment
   a. See 4f.

b. Within Life Cycle Impact Assessment, development of characterization factors for metals including fate and effects modelling (related to 1g)

Chemical Management

9. Quantifying inventories and Material Flow Analysis of regulated chemicals (PCBs, PBDEs).
10. Analysis of policies, legislation and regulations related to chemical management, as well as flammability codes and standards.
11. Measurement and estimation of physical-chemical properties of semi-volatile organic compounds of concern
12. Planetary Boundary for Chemical Pollution.
13. Chemical Footprint

* Currently inactive

6. b. RESEARCH AWARDS AND CONTRACTS

Awards:

2014-2015	NSERC Equipment Grant, "Chemical analysis of semi-volatile organic compounds in outdoor and indoor environments" \$150,000. With G Evans, J Wallace, J Siegel.
2014-2016	Chemical Management Plan (CMP) of Health Canada and Environment Canada. CMP Monitoring and Surveillance Fund. Monitoring Organophosphorus Flame Retardants in Canadian homes. M Diamond, L Jantunen, S Harris. \$100,000 over 2 years.
2014-2017	Health Canada. Clean Air Regulatory Agenda (CARA) "Monitoring and modelling of residential indoor semi volatile organic compounds." S Harris (Cancer Care Ontario), Miriam Diamond, Paul Villeneuve (Health Canada), Liisa Jantunen (Environment Canada), \$507,100 over 3 years split between University of Toronto and Cancer Care Ontario
2013-2015	Ontario Ministry of Environment "Characterizing organophosphorus flame retardants in the air and surface water of the Greater Toronto Area", ML Diamond with P Helm (Ontario Ministry of Environment), L Jantunen (Environment Canada), \$59,280 over 2 years.
2013-2014	CIHR Catalyst Grant. "Early-life environment and chronic allergic disease: leveraging a prospective study to discover the epigenetic signature." AK Ellis (Queen's), ML Diamond, JR Brook (Environment Canada), MS Kobor (University of British Columbia), ML North (Queen's), \$100,000 for 1 year. My share is 31%.
2013-2014	Health Canada "Passive air sampling and personal monitoring for semi-volatile organic compounds" ML Diamond, \$9999.
2013-2014	Northern Contaminants Program. Dept of Aboriginal Affairs and Northern Development. Polycyclic aromatic compounds, flame retardants and other persistent organic pollutants in Canadian Archipelago air and water. \$33,000 for 1 year. L. Jantunen PI. 5 investigators.
2012-2013	Health Canada, "Multimedia Indoor Model, literature search and beta version of model", \$9 360 for 1 year.
2012-2013	Health Canada, "Passive air sampling and personal monitoring for semi-volatile organic compounds", \$10,000 for 1 year.
2012-2013	International Aluminum Institute, "Freshwater Ecotoxicity Characterization Factor for Aluminum – Addressing effects of speciation on fate, exposure & toxicity in Life Cycle Impact Assessment", \$69,000 for 1 year.
2012-2015	NSERC Accelerator award, \$40,000/yr for 3 years.
2012-2017	NSERC Discovery, "Emissions, fate, exposure and management of chemical

	contaminants indoors, outdoors and globally." $34,000/yr.
2012-2019	Industry Canada, AllerGen Network Centre of Excellence, $36,500,000. J Denburg PI.
2011-2012	Great Lakes Research Initiative, funded by the U. S. Environmental Protection Agency. "Great Lakes Polybrominated Diphenyl Ether (PBDE) Institutional Reduction". A. Soehl, M. Diamond, M. Murray. $65,000 to Diamond as subcontractor.
2011-2012	Health Canada, Sources, "Concentrations and Route of Exposure to New Flame Retardants", M. Diamond $24,499 for 1 year.
2011-2012	AllerGen NCE, Strategic Initiatives Research Funding Opportunities Program. "Method for measuring phthalate concentrations representative of exposure". M. Diamond, J. Brook, T. Takaro, A. Wheeler, $32,900 for 1 year.
2009-2012	Hudson Bay Mining and Smelting "Assessment of metal dynamics and ecotoxicity in Ross Lake (MB, Canada) using a coupled metal fate/transport, speciation toxicity (TRANSPEC-Tox) model", M Diamond, $64,818 total.
2011	Environment Canada "Reconnaissance study of coal tar sealcoat application in the GTA and an estimate of related PAH emissions". M Diamond, $22,000 for 1 year.
2010-2012	Great Lakes Commission, Great Lakes Atmospheric Deposition program "How effective are our chemical management policies in reducing Lake Ontario fish contaminant burdens?", M Diamond, P Helm, S. Backus, L Jantunen, M Shoeib $90,000 US over 3 fiscal years.
2010-2011	Ontario Ministry of Environment, Canada-Ontario Agreement, "Determination of Contaminant Loadings from Toronto's Tributaries", M Diamond, $36,000 over 2 years
2010	Canada Foundation for Innovation. "The Canadian Aerosol Research Network (CARN): Climate, air pollution and human health in 2020", J. Abbott, G. Evans et al., $15148327.
2009-2011	Canadian Chemical Management Plan, through Health Canada, via AllerGen Network Centre of Excellence "Novel Approaches for Assessing Exposure to Phthalates" R Allen, M Brauer, J Brook, M Diamond, G Evans, T Takaro $702,426 over 2 years.
2009-2010	Ontario Ministry of Environment "Determination of the relative importance of urban contaminant input pathways to Lake Ontario for selected contaminants", M Diamond, $50,000.
2008-2010	Ontario Ministry of Environment "The testing, optimization and validation of an in-situ large volume surface water sampling device" M. Diamond, $50,000.
2008-2013	CIHR Emerging Collaborative Grant "Santé tenant compte du genre et du sexe", D Mergler, E Balka, K Lippel, K Messing, SA Ritz, J Saint-Charles, M Diamond et al. $1 million over 5 years.
2007-10	NSERC Collaborative Research & Development Grant "LCIA for metals: Improving toxicity characterization factors and applying it to the Canadian environmental context", M Diamond, D Mackay, $144,985 over 3 years.
2007-09	Great Lakes Commission, Great Lakes Atmospheric Deposition program "Urban sources and loadings of toxics to Lake Ontario from an Integrated Measurements and Modelling Approach", M Diamond, P Helm, P Blanchard, S. Backus, $149,450 US over 2 years.
2007-2012	NSERC Discovery, "Connecting chemical sources, emissions, fate and exposure", $31,090/yr.
2006	Environment Canada, National Water Research Institute "Modeling the distribution and fate of pharmaceuticals in Hamilton Harbour", M Diamond $10,000.
2006-09	SETAC-UNEP "Improvement of characterisation factors in Life Cycle Impact Assessment of ecotoxicity (Fate – Exposure – Effects)", M Diamond, D Van De Meent, et al. $265,500 over 3 years.
2005-06	Health Canada "Contaminant and nutrient concentrations in specialty raw and cooked fish and shellfish", $20,000.
2004-06	Environment Canada "Cities: Contaminant fate and effects" M Diamond, $18,000.

2005-06	Toronto and Region Conservation Authority "Toronto tributary study", $30,000.
2005-06	Ontario Ministry of Environment "Toronto tributary study, pilot study". $50,000.
2005	Ontario Ministry of Environment "Modelling of polychlorinated naphthalenes in the Lake Ontario food web", $9000.
2004-05	Ontario Ministry of Environment "Mass balance modelling of metals in Spanish Harbour", $27,000.
2004-05	Ontario Ministry of Environment "Mass balance modelling of PCBs in Hamilton Harbour". $57,000.
2004	NSERC Research Tools and Instruments "Analysis of persistent organic pollutants in impacted systems by GC-MS". $113,564.
2004-2008	CIHR Research Centre Grant "Centre for Urban Health Initiatives", $400,000 per year for 6 years. J. Myles PI, Co-applicant.
2004-2006	CORILA (Consortium for Coordination of Research Activities Concerning the Venice Lagoon System) "Contaminant fate in the Venice Lagoon: development of an integrated fate model". 30,000 Euros per year for 3 years.
2004-2006	Quinte Conservation Council "Updating the existing model of contaminant fate in the Bay of Quinte", $65,000.
2003	Ontario Ministry of the Environment "Review of mercury modelling work drafted for contaminated sediment conditions in Peninsula Harbour". $10,000.
2003-2007	NSERC Discovery Grant "Multimedia contaminant fate and effect in impacted systems", $26,500 per year for 4 years.
2003	Canadian Network of Toxicology Centres, Metals in the Environment (MITE), "Modelling of Metal Speciation and Movement in a Shield Watershed and Lake", with G. Spiers (Laurentian University), $11,000.
2002-2006	NSERC Strategic, "Cities: Contaminant fate and effects", $411,218 over 4 years, with Co-investigators B. Branfireun and T. Harner.
2002-2005	CRESTech, "Contaminant fate and effects in urban areas: development of a decision-support model", $150,000 over 3 years.
2002-2003	NSERC, Collaborative Research and Development Grant, "Development of a lake systems fate model", $17,392 per year for 2 years, with MDA Consulting.
2002-2005	CIDA, "Urban agriculture in Kampala, Uganda – health impact assessment and options for improvements", $150,000, Prain G, Cole, DC, Lee-Smith D, Diamond M, Kapinga R.
2001-2004	CFCAS, "Improvements to air quality models: airborne pollutant-surface film interactions." $320,000 total over 3 years, James Donaldson, PI (UofT Chemistry) and Paul Makar (Environment Canada).
2001-2002	Canadian Chlorine Coordinating Committee (C4), "Sources and fate of semi-volatile organic compounds in urban and surrounding areas." $78,500 total, with G.A. Stern, Freshwater Institute.
2000-2002	NSERC, Collaborative Research and Development Grant, "Modelling metal speciation and fate in mine impacted lakes", $26,087 per year for 2 years, with L. Evans, Univ. of Guelph.
2000-2002	Hudson Bay Mining and Smelting Co. Limited, "Modelling metal speciation and fate in mine impacted lakes", $15,000 per year for 2 years, with L. Evans, Univ. of Guelph. $10,000 in 2002.
2000	NSERC Equipment Grant, Gas chromatograph with ECD/FID detector, $47,195.
1999-2004	Premier's Research Excellence Award, $20,000 per year for 5 years.
1999-2002	Toxic Substances Research Initiative, "Urban air toxics: Source signature and health effects", $148,750 per year for 3 years, PI, with B. McCarry (McMaster), T. Harner, T. Bidleman and T. Dann (Environment Canada), P.Harper (Hospital for Sick Children).
1999-2003	NSERC Operating Grant, "Multimedia contaminant fate and dynamics in impacted

	systems", $17,850 per year for 3 years.
1999	NSERC Equipment Grant, Hydrolab Datasonde 4 (with K. Bolton, J. Desloges, B. Branfireun), $18,776.
1999	Dean's Instructional Initiative Grant, "Development of innovative teaching methods for non-science students", $1,000.
1999-2001	Canadian Network of Toxicology Centres, Metals in the Environment (MITE), "Modelling of Metal Speciation and Movement in a Shield Watershed and Lake", with L. Evans (Univ of Guelph), $56,500 per year.
1995-2000	NSERC Operating Grant, "Contaminant fate and dynamics in aquatic systems", $14,300 per year.
1998-2000	Canadian Chlorine Coordinating Committee, "Multimedia fate and toxicological impacts of chlorinated organic compounds in urban areas", $49,500 per year for 2 years, PI, with McCarry (McMaster), Muir (National Water Research Institute), Stern (Freshwater Institute), Harper (Hospital for Sick Children).
1999-2002	Minnesota Department of Transportation "Developing a decision tool to predict the ecotoxicological impacts of transportaiton-related chemicals", $US100,000 per year for 3 years, with co-PI D. Biesboer (University of Minnesota).
1998-1999	Canadian Network of Toxicology Centres, Metals in the Environment (MITE), "Modelling of Metal Speciation and Movement in a Shield Watershed and Lake", $6,133.
1998-1999	Department of Indian and Northern Affairs, "Contaminant dynamics in lakes of the Upper Yukon River Basin", $15,000.
1995-1997	Ontario Ministry of Environment & Energy, "Full cycle assessment of environmental and health impacts of site remediation options", $50,000.
1995-1996	Ontario Ministry of Environment & Energy, "Quantifying chemical release from in-place pollution", $18,000.
1995-1997	Friends of the Spanish River, "Spanish Harbour sediment mass balance study - enhanced application of the QWASI fugacity/aquivalence model", $25,000
1993, 94, 97 98	Department of Indian and Northern Affairs, student travel grant, $1,500; $2,000, $1900, $2200.
1993	Dean's Instructional Initiative Grant, "Development of environmental science curriculum for non-science students", $1,000.
1993	NSERC Equipment Award to J. Desloges (V.R. Timmer, J. Gerits, M. Diamond).
1993	Ontario Ministry of the Environment, "Hamilton Harbour sediment mass balance study: enhanced application of the QWASI fugacity/aquivalence model", $10,000.
1992-1997	Department of Indian and Northern Affairs, "Modelling inorganic and organic contaminants in Arctic freshwater lakes", 1992, $22,000; 1993, $23,000; 1994 $28,000; 1995 $9,000; 1996, $24,000, $1997 $20,000.
1992-1995	NSERC Operating Grant, "Study of the fate and transport of contaminants in aquatic systems", $19,000 per year.
1992, 1993	Environmental Youth Corps, $4,000 each year, 1993 jointly held with E. Fawcett, Dept. of Physics.
1991-1993	Connaught Fund, University of Toronto, Phase 1 New Staff Grant, $10,000.

Contracts:

2014	Environment Canada and Health Canada, Chemical Management Plan. "Review of Draft Screening Assessment Report from the Petroleum Sector Stream"
2006-07	Toronto Public Health and International Joint Commission. "Review of air pollution-traffic-health connections", $4,500.
2004	Environment Canada "Review of mercury contamination in Peninsula Harbour", $22,000.

2003	United States Environmental Protection Agency, "Guidance document on ecological risk assessment for metals: metal sediment chemistry". $2,000.
2002	International Joint Commission, "Forecast and analysis of urban development in the Great Lakes Basin", $5,000 for our subcontract with GHK International.
2001	Bay of Quinte Conservation Authority, Bay of Quinte Remedial Action Plan, "Assessing the feasibility of updating the Bay of Quinte mass balance model", $10,000.
2001	Environment Canada, "Analysis of Urban Development Impacts", $5,000.
2001-2002	CH2M Hill, Sacramento, California, "Lahontan Reservoir Mercury Project", $46,900
2000-2001	City of Toronto, Health Promotion and Environmental Protection, "Conducting a feasibility study for an environmental GIS for the City of Toronto", $16,500.
1998-1999	National Water Research Institute, "Lake Erie LaMP Pollutant Modelling - Background Review", $20,000.
1995-1997	Ecology & Environment Inc., "Development of mercury mass balance model for the Lahontan Reservoir, Nevada", $US20,000
1993-94,95-96	Minnesota Pollution Control Agency, "Extension of the Minnesota fugacity/aquivalence model to treat multiple, interconverting species", US$11,950; US$5,000.
1991	City of Toronto, Environmental Protection Office, Assist with development of methodological for constructing historical landuse database, $3,000. Contract held with S. MacRitchie.
1990	City of Toronto, Environmental Protection Office, "Review of potential environmental and health effects of site remediation technologies", $5,000. Contract held with S. MacRitchie.
1989-90,90-91	Ontario Ministry of the Environment, "Development of a mass balance model for the Bay of Quinte", $37,000, $28,000. Contract held with D. Mackay, Institute for Environmental Studies, U of T.
1989,1990	Environment Canada, National Water Research Institute, "Review and modelling of sediment-water exchange processes", $6,000, $12,000.
1988	Environment Canada, Inland Waters Directorate "Assessing the feasibility of using evaluative models in the development of Canadian Sediment Quality Guidelines", $5,000. Contract held with T. Clark, MCM Consulting.

C. SCHOLARLY AND PROFESSIONAL WORK

H Index of 29, Total Citations 2707 (Web of Science,30 April, 2014 excluding self-citations).

7. REFEREED PUBLICATIONS

7. a. Articles

103. POSTUMA L, A BJØRN, MC ZIJP, M BIRKVED, **ML DIAMOND**, MZ HAUSCHILD, MAJ HUIJBREGTS, C MULDER, D VAN DE MEENT. 2014. Beyond safe operating space: Finding chemical footprinting feasible. *Environ Sci Technol* 48(11): 6057-6059. DOI: 10.1021/es501961k

102. NORTH ML, TK TAKARO, **ML DIAMOND**, AK ELLIS. 2014. Effects of phthalates on the development and expression of allergic disease and asthma. *Annals of Allergy, Asthma & Immunology.* 112(6): 496-502. DOI: 10.1016/j.anai.2014.03.013

101. BROMMER S, JANTUNEN L, BIDLEMAN TF, HARRAD S, **DIAMOND ML.** 2014. Determination of vapor pressures for organophosphate esters. *J Chem Eng Data.* 59(5): 1441-1447. DOI: 10.1021/je401026a10.1021/je401026a In press.

100. MELYMUK L, M ROBSON,SA CSISZAR, PA HELM, G KALTENECKER, B GILBERT, S BACKUS, L BRADLEY, P BLANDARD, L JANTUNEN, **ML DIAMOND**. 2014. From the city to the lake: loadings of PCBs, PBDEs, PAHs and PCMs from Toronto to Lake Ontario. *Environ Sci Technol* 48(7): 3732–3741.

99. GANDHI N, **ML DIAMOND**, R RAZAVI, SP BHAVSAR, EM HODGE, SB GEWURTZ, GB ARHONITSIS. 2014. A modeling assessment of contaminant fate in the Bay of Quinte, Lake Ontario: 2. Organic chemicals. *Aquatic Ecosys Health Management* 17(2): 137-150. DOI: 10.1080/14634988.2014.910442

98. CSISZAR SA, **ML DIAMOND**, SM DAGGUPATY. 2014. The magnitude and spatial range of current-use urban PCB and PBDE emissions estimated using a coupled multimedia and air transport model. *Environ Sci Technol* 48:1075-1083.

97. MELYMUK* L, M ROBSON+, PA HELM, **ML DIAMOND**. 2013 Application of land use regression to identify sources and assess spatial variation in urban SVOC concentrations. *Environ Sci Technol.* 47(4): 1887-1895. http://pubs.acs.org/doi/abs/10.1021/es3043609

96. PANTAZOPOULOS P, JM SAWYER*, ME TURYK, **M DIAMOND**, SP BHAVSAR, D MERGLER, S SCHANTZ, N RATYNAYAKE, DO CARPENTER. 2013. Fatty acids in Great Lakes trout and whitefish. *J Great Lakes Res* 39: 120-127.

95. RYAN MJ, KA KIDD, MV CROFT, S GEWURTZ*, **M DIAMOND**, L KINNEAR, P ROACH. 2013. Biotic interactions in temporal trends (1992-2010) of organochlorine contaminants in the aquatic food web of Lake Laberge, Yukon Territory. *Sci Total Environ* 44:80-92.

94. RAWN DFK, K BREAKELL, V. VERIGIN, S A TITTLEMIER, L DEL GOBBO*, **M DIAMOND**, L VANDERLINDEN, D. SIT. 2013. Impacts of cooking technique on polychlorinated biphenyl and polychlorinated dioxins/furan concentrations in fish and fish products with intake estimates. *J Agricu Food Chem* 61: 989-997. http://pubs.acs.org/doi/abs/10.1021/jf304010n

93. CSISZAR* SA, SM DAGGUPATY, **ML DIAMOND**. 2013. SO-MUM: a coupled atmospheric transport and multimedia model used to predict intraurban-scale PCB and PBDE emissions and fate. *Environ Sci Technol*..47: 436-445. http://pubs.acs.org/doi/ipdf/10.1021/es3033023

92. MELYMUK* L, M ROBSON+, PA HELM, **ML DIAMOND.** 2012. PCBs, PBDEs and PAHs in Toronto air: spatial and seasonal trends and implications for contaminant transport. *Science of the Total Environment* 429: 272-280. doi:10.1016/j.scitotenv.2012.04.022

91. CSISZAR* SA, **ML DIAMOND**, LJ THIBODEAUX. 2012. Modeling urban films using a dynamic multimedia fugacity model. *Chemosphere.* 87: 1024-1031.

90. TURYK ME, SP BHAVSAR, W BOWERMAN, E BOYSEN, M CLARK, **ML DIAMOND**, D MERGLER, P PANTAZOPOULOS, S SCHANTZ, DO CARPENTER.2012 Risks and benefits of consumption of Great Lakes fish. *Environ Health Persp* 120: 11-18. doi:10.1289/ehp.1003396

89. KLÁNOVÁ J, **M DIAMOND**, K JONES, G LAMMEL, R LOHMANN, N PIRRONE, M SCHERINGER, C BALDUCCI, T BIDLEMAN, KAREL BLÁHA, L BLÁHA, K BOOIJ et al. 2011. Identifying the research and infrastructure needs for the global assessment of hazardous chemicals ten years after establishing the Stockholm Convention. *Environ Sci Technol* 45(18): 7617-7619.

88. GANDHI* N, SP BHAVSAR*, **ML DIAMOND**. 2011. Critical load analysis in hazard assessment of metals using a unit lake model. *Environ Toxicol & Chem* 30(9): 2157–2166.

87. GANDHI* N, **ML DIAMOND**, MAJ HUIJBREGTS, J GUINEE, WJGM PEIJNENBURG, D VAN DE MEENT. 2011. Implications of considering metal bioavailability in estimates of freshwater ecotoxicity: Examination of two case studies. *Int J LCA* 16(8): 774-787. DOI:10.1007/s11367-011-0317-3.

86. ZHANG* X, M ROBSON+, **ML DIAMOND**, C IBARRA, SJ HARRAD. 2011. Polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) indoors in Toronto: concentrations, air/dust distribution, sources and emissions. *Environ Sci Technol* 45: 3268-3274.

85. MELYMUK* L, M ROBSON+, **ML DIAMOND**, L BRADLEY, S BACKUS. 2011. Wet deposition loadings of organic contaminants to Lake Ontario: assessing the influence of precipitation from urban and rural sites. *Atmos Environ.* 45(28): 5042-5049. DOI: 10.1016/j.atmosenv.2011.02.007

84. CSISZAR* S, N GANDHI*, R ALEXY, DT BENNIE, J STRUGER, C MARVIN, **ML DIAMOND**. 2011. Aquivalence revisited – an activity based model to assess environmental behaviour of ionic compounds and its application to pharmaceuticals in Hamilton Harbour. *Environment International* 37(5): 821-828.

83. GANDHI* N, **DIAMOND ML**, RAZAVI* R, BHAVSAR* SP, HODGE* EM. 2011. A modeling assessment of contaminant fate in the Bay of Quinte, Lake Ontario: 1. Metals. *Aquatic Ecosystem Health and Management*. 14(1):85-93.

82. MELYMUK* L., M. ROBSON+, P. HELM, **M.L. DIAMOND**. 2011. Evaluation of passive air sampler calibrations: selection of sampling rates and implications for the measurement of persistent organic pollutants in air. *Atmos Environ.* 45(10):1867-1875.

81. GANDHI* N, M HUIJBREGTS, D VAN DE MEENT, W PEIJNENBURG, J GUINEE, E WEBSTER, D MACKAY, **ML DIAMOND**. 2011. Implications of geographic variability on estimating comparative toxicity potentials of Cu, Ni and Zn in freshwaters of Canadian ecoregions. *Chemosphere* 82(2):268-77.

80. GANDHI* N, **ML DIAMOND**, D VAN DE MEENT, M HUIJBREGTS, A DE KONING J GUINEE, W PEIJNENBURG. 2010. A new method for calculating metals' comparative toxicity potentials for freshwater ecotoxicity: application to copper, nickel and zinc. *Environ Sci Technol.* 44(13):5195-5201.

79. ROBSON+ M, L MELYMUK*, S CSISZAR*, A GIANG*, **ML DIAMOND**, PA HELM. 2010. Continuing sources of PCBs: the significance of building sealants. *Environ Internat* 36:506-513.

78. HARRAD S, C DE WIT, M A-E ABDALLAH, C BERGH, JA BJ BJORKLUND, A COVACI, PO DARNERUD, J DE BOER, **M DIAMOND**, S HUBER, P LEONARDS, M MANDALAKIS, C OSTMAN, LS HAUG, C THOMSEN, TF WEBSTER. 2010. Indoor contamination with hexabromocyclodecanes, polybrominated diphenyl ethers, and perfluoroalkyl compounds: an important exposure pathway for people? *Environ Sci Technol.* 44(9):3221-3231.

77. **DIAMOND ML,** MELYMUK*, L., S. CSISZAR*, M. ROBSON+. 2010. Estimatino of PCB stocks,

emissions and urban fate: will our policies be effective? *Environ Sci Technol* 44(8):2777–2783.

76. SOMMERFREUND* J, **ML DIAMOND**, M FRIGNANI, G CAPODAGLIO, M GERINO, L BELLUCI, S GIULIANI, C MUGNAI+. 2010. Contaminant fate and transport in the Venice Lagoon: results from a multi-segment model. *Environ Ecotox Safety*. 73: 222-230. "Highlighted Arcticle"

75. SOMMERFREUND* J. GB ARHONDITSIS, **ML DIAMOND**, M FRIGNANI, G CAPODAGLIO, M GERINO, L BELLUCCI, S GIULIANI, C MUGNAI+. 2010. Examination of the uncertainty in contaminant fate and transport modeling: a case study in the Venice Lagoon. *Environ Ecotox Safety.*73:231-239. "Highlighted article"

74. **DIAMOND ML**, GANDHI* N, WJ ADAMS, SP BHAVSAR, C BULLE, P CAMPBELL, A DUBREIL, A FAIRBROTHER ET AL. 2010. The Clearwater Consensus: The estimation of metal hazard in fresh water. *Internat J LCA* 15(2): 143-147. DOI 10.1007/s11367-009-0140-2

73. DEL GOBBO* L, ARCHBOLD J. ECKLEY C, ROBSON+ M, **DIAMOND M,** VANDERLINDEN L. 2010. Mercury and Omega-3 fatty acid concentrations of fish sampled from markets in Toronto: consumption scenarios balancing risks and benefits for childbearing women. *Can J Dietetic Practice and Res.* 71(1): 41-46.

72. GEWURTZ SB, SP BHAVSAR, PW CROZIER, **ML DIAMOND**, PA HELM, CH MARVIN, EJ REINER. 2009. Perfluoroalkyl contaminants in window film from Toronto, Ontario, Canada, and an assessment of carpet as a possible source. *Environ Sci Technol.* 43:7317-7323.

71. HARRAD S, C IBARRA, M ROBSON+, L MELYMUK*, X ZHANG*, **M DIAMOND**, J DOUWES. 2009 Polychlorinated biphenyls in indoor dust from Canada, New Zealand, United Kingdom and United States: implications for human exposure. *Chemosphere.* 76(2):232-238.

70. ZHANG* X., **ML DIAMOND**, SJ HARRAD, C IBARRA. 2009. Multimedia modeling of PBDE emissions and fate indoors. *Environ Sci Technol* 43(8): 2845-2850.

69. WONG* F, ROBSON+ M, **ML DIAMOND**, S HARRAD, J TRUONG+. 2009. Concentrations and chiral signature of POPs in soils and sediments: a comparative urban vs. rural study in Canada and UK. *Chemosphere* 74: 404-111.

68. GEWURTZ* SB, N GANDHI*, GN CHRISTENSEN, A EVENSET, D GREGOR, **ML DIAMOND**. 2009. Application of a food web model to determine the relative influence of lake morphology, nutrients, and contaminant loadings on the dynamics of polychlorinated biphenyls in a high arctic food web. *Environ. Sci. Pollut. Res.* 16(2):176-190.

67. DEL GOBBO* L, TITTLEMIER S, PEPPER K, TAGUE B, VANDERLINDEN L. **DIAMOND, M.** 2008. Cooking reduces perfluorinated compound concentrations in fish. *J Agricult Food Chem.* 56(16):7551-7559.

66. ECKLEY CS, B BRANFIREUN, **M DIAMOND**, PC VAN METRE, F HEITMULLER. 2008. Atmospheric mercury accumulation and washoff processes on impervious urban surfaces. *Atmos Environ* 42:7429-7438.

65. WU* R, T HARNER, **ML DIAMOND.** 2008. Evolution rates and PCB content of surface films that develop on impervious urban surfaces. *Atmos. Environ.* 42(24):6131-6143.

64. WU* RW, T HARNER, **ML DIAMOND**, B WILFORD. 2008. Partitioning characteristics of PCBs in urban surface films. *Atmos. Environ.* 42(22):5696-5705.

63. BHAVSAR SP, N GANDHI, **ML DIAMOND**, AS LOCK, G SPIERS, MC ALFARO DE LA TORRE. 2008. Effects of estimates from different geochemical models on metal fate predicted by coupled speciation-fate models. *Environ. Toxicol. Chem.* 27(5):1020-1030.

62. HARRAD S, C IBARRA, **M DIAMOND**, L MELYMUK*, M ROBSON+, J DOUWES, L ROOSENS, AC DIRTU, A COVACI. 2008. Polybrominated diphenyl ethers in domestic indoor dust from Canada, New Zealand, United Kingdom and United States. *Environ Internat.* 34: 232-238.

61. ABDALLAH MA-E, S HARRAD, C IBARRA, **M DIAMOND**, L MELYMUK*, M ROBSON+, A COVACI. 2008. Hexabromocyclododecanes in indoor dust from Canada, the United Kingdom and the United States. *Environ. Sci. Technol.* 42(2):459-464.

60. BHAVSAR* SP, N GANDHI*, **ML DIAMOND.** 2008. Extension of coupled multispecies metal transport and speciation (TRANSPEC) model to soil. *Chemosphere* 70(5):914-924.

59. GANDHI* N, S BHAVSAR*, **ML DIAMOND,** JS KUWABARA, M MARVIN-DIPASQUALE. 2007. Development of mercury speciation, fate and bioaccumulation (BIOTRANSPEC) model: application to the Lahontan Reservoir. *Environ. Toxicol. Chem.* 26(11): 2260-2273.

58. MOREAU-GUIGON E, A MOTELAY-MASSEI, T HARNER, K POZO, **M DIAMOND**, M CHEVREUIL, H BLANCHOUD. 2007. Vertical and Temporal Distribution of Persistent Organic Pollutants in Toronto. 1. Organochlorine Pesticides. *Environ Sci Technol* 41(7):2172-2177.

57. ARCHBOLD* JA, R HULL, **ML DIAMOND**. 2007. Potential importance of inhalation exposures for wildlife using screening-level ecological risk assessment. *Human Ecol. Risk Assess.* 13(4):870-883.

56. **DIAMOND ML,** EM HODGE*. 2007. From source to effect: urban contaminant dynamics. *Environ. Sci Technol.* Feature article. 41(11): 3796-3805.

55. GALARNEAU* E, PA MAKAR, M SASSI, **ML DIAMOND**. 2007. Estimation of atmospheric emissions of six semivolatile PAHs in Canada and the U.S.A. by use of an emissions processing system. *Environ. Sci. Technol.* 41:4205-4213.

54. KWAMENA N-O, JP CLARKE*, TF KAHAN, **ML DIAMOND**, DJ DONALDSON. 2007. Assessing the importance of heterogeneous reactions of polycyclic aromatic hydrocarbons in the urban atmosphere using the Multimedia Urban Model. *Atmos. Environ.* 41(1):37-50.

53. GEWURTZ* SB, N GANDHI*, GA STERN, WG FRANZIN, B ROSENBERG, **ML DIAMOND.** 2006. Dynamics of PCBs in the food web of Lake Winnipeg. *J. Great Lakes Res.* 32:712-727.

52. GANDHI* N, S BHAVSAR*, SB GEWURTZ*, **ML DIAMOND**, A EVENSET, GN CHRISTENSEN, D GREGOR. 2006. Development of a multi-chemical food chain model: application to PBDE in Lake Ellasjoen, Bear Island, Norway. *Environ. Sci. Technol.* 40:4714-4721.

51. NABULO G, H ORYEM-ORIGA, **M DIAMOND**. 2006. Assessment of lead, cadmium and zinc contamination of roadside soils, surface films and vegetables in Kampala City, Uganda. *Environ. Res.* 101:42-52.

50. KLEIN G, EM HODGE*, **ML DIAMOND**, T DANN, G STERN, MS DENISON, P HARPER. 2006. Gas-phase ambient air contaminants exhibit significant dioxin- and estrogen-like activity in vitro. *Environ Health Perspec.* 114(5): 697-703.

49. HARNER T, M SHOEIB, **M DIAMOND**, M IKONOMOU, G STERN. 2006. Passive sampler derived air concentrations of PBDEs along an urban-rural transect: spatial and temporal trends. *Chemosphere* 64:262-267.

48. HARRAD SJ, **ML DIAMOND**. 2006. Exposure to polybrominated diphenyl ethers (PBDEs) and polychlorinated diphenyls (PCBs): Current and future scenarios. *Atmos. Environ.* 40:1187-1188.

47. GEWURTZ* SB, R LAPOSA*, **ML DIAMOND**, N GANDHI*, GN CHRISTENSEN, T SKOTVOLD. 2006. A comparison of contaminant dynamics in arctic and temperate fish: a modelling approach. *Chemosphere* 63:1328-1341.

46. SIMPSON AJ, B LAM*, **ML DIAMOND**, DJ DONALDSON, B LEFEBVRE, A MOSER, A WILLIAMS, N LARIN, M KVASHA. 2005. Assessing the molecular composition of urban surface films through a symbiotic array of nuclear magnetic resonance approaches. *Chemosphere.* 63(1):142-152.

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GOOSEY E, S CHAUDHURI, **M DIAMOND**, A SAINI. 2013. Flame retardant (FR) and phthalate spatial variability indoors. SETAC Europe, 23rd Annual Meeting, Glasgow UK. Oral Presentation.

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YACOOB S, ML DIAMOND, C GUEGEN. 2012. What's causing toxicity at a zinc-copper mine site? SETAC Europe 22nd Annual Meeting and SETAC World Congress. Poster Presentation. Berlin, May 20-24, 2012.

¢DIAMOND ML. 2011. The history of environmental chemistry – the Mackay era and beyond. SETAC North America 32st Annual Meeting, Boston, USA, November 13 - 17. Invited oral presentation.

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S, GIANG A. 2011. What we found in our backyard. SETAC North America 32st Annual Meeting, Boston, USA, November 13 - 17. Oral presentation.

MELYMUK L et al. PCBs, PBDEs, and PAHs in the urban atmosphere: spatial and seasonal trends and implications for contaminant transport. SETAC North America 32st Annual Meeting, Boston, USA, November 13 - 17. Poster presentation.

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HELM PA, GILBERT B, M ROBSON, L MELYMUK, DIAMOND ML. 2011. Transport of PCBs, PBDEs, PAHs, and Polycyclic musks via urban tributaries to Lake Ontario, Canada. SETAC North America 32st Annual Meeting, Boston, USA, November 13 - 17. Oral presentation.

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GANDHI N, SB GEWURTZ, PA HELM, SP BHAVSAR, **ML DIAMOND**. 2010 Application of a food web model to evaluate mechanisms controlling biomagnifications of polychlorinated naphthalenes in a Lake Ontario food web. SETAC North America 31st Annual Meeting, Portland, USA, November 7 - 11.

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Robson, M.E., Melymuk, L.E., Gilbert, B., Helm, P.A. Csiszar, S.A., **Diamond, M.L**. 2010. Polycyclic Musks in the urban environment: Sources trends and fate Poster, SETAC North America 31st Annual Meeting, Portland, USA, November 7 - 11.

Melymuk L, ME. Robson, **ML Diamond**, PA Helm. 2010. Atmospheric Fate and Transport of Selected Organic Pollutants in the Greater Toronto Area. SETAC North America 31st Annual Meeting, Portland, USA, November 7 - 11.

Melymuk, L.E., Robson, M., Csiszar, S.A., Diamond, M.L ., Daggupaty, S., Helm,P.A., Backus, S. Bradley, L. and Jantunen, L 2010. Urban Sources and Loadings of Toxics to Lake Ontario from an Integrated Measurements and Modeling Approach. SETAC North America 31st Annual Meeting, Portland, USA, November 7 - 11.

Csiszar, S.A., S. Daggupaty, **M.L. Diamond**, L. Melymuk, M. Robson 2010. BLFM-MUM: A coupled atmospheric transport and multimedia model used to study PCBs in Toronto. Platform presentation submitted to the SETAC North America 31st Annual Meeting, Portland, USA, November 7 - 11

Csiszar, S.A., S. Daggupaty, M.L. Diamond, L. Melymuk, M. Robson. 2010 BLFM-MUM: A coupled atmospheric transport and multimedia model used to study PCBs in Toronto: Modeling Urban Films.

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Melymuk, L.E., Robson, M.E., Csiszar, S.A., Diamond, M.L., Helm, P.A. 2010. Atmospheric fate and transport of selected organic pollutants in the Greater Toronto Area. Poster, Urban Environmental Pollution Conference, Boston, MA

Melymuk, L.E., Robson, M.E., Diamond, M.L., Bradley, L., Backus, S. 2010. Urban sources and loadings of organic contaminants to Lake Ontario: assessing the influence of precipitation from urban and rural sites. Poster, Urban Environmental Pollution Conference, Boston, MA

Robson, M., Melymuk, L.E., Csiszar, S.A., Diamond, M.L.*, Daggupaty, S., Helm, P.A., Backus, S, Jantunen, L. 2010. Urban Sources and Loadings of Toxics to Lake Ontario from an Integrated Measurements and Modeling Approach. Poster, SETAC, European Annual Meeting, Seville, Spain.

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Gandhi N. M Huijbregts, D van de Meent, W Peijnenburg[4], J Guinée, E Webster, D Mackay, ML Diamond. 2010. Implications of Geographic Variability on Estimating Comparative Toxicity Potentials of Metals in Freshwaters of Canadian Ecoregions. Platform presentation. Soc. Environ. Toxicol. Chem. (SETAC) Europe, Annual Meeting, Seville, Spain.

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Csiszar, S.A., S. Daggupaty, **M.L. Diamond**. 2010 BLFM-MUM: A coupled atmospheric transport and multimedia model used to study PCBs in Toronto: Modeling Urban Films. Poster IAGLR 53rd Annual Conference on Great Lakes Research, Toronto, May 17 - 21.

Melymuk, L.E., Robson, **M., Diamond,** M.L., Bradley, L., Backus, S, 2010. Urban Sources and Loadings of Organic Contaminants to Lake Ontario: assessing the influence of precipitation from urban and rural sites. Oral presentation, International Association for Great Lakes Research Annual Conference, Toronto, ON.

Robson, M., Melymuk, L.E., Helm, P.A., Gilbert, B., **Diamond, M.L.**, Backus, S, Jantunen, L. 2010. Urban Sources and Loadings of Toxics to Lake Ontario from the Greater Toronto Area. Poster, International Association for Great Lakes Research Annual Conference, Toronto, ON.

ROBSON M, L MELYMUK, **ML DIAMOND**, PA HELM, S BACKUS, P BLANCHARD. 2009. Polycyclic musks in Toronto rivers: the effects of urbanization and high flow events. International Association of Great Lakes Research, 52nd Annual Conference, Toledo, Ohio.

DEL GOBBO L, J SAWYER, C ECKLEY, **M DIAMOND**, J ARCHBOLD, L VANDERLINDEN, G TOMY. 2009. How much of which fish should we eat? Consumption guidance for Toronto market fish based on contaminants and omega-3 fatty acids. International Association of Great Lakes Research, 52nd Annual Conference, Toledo, Ohio.

MELYMUK L, M ROBSON, A GIANG, S CSISZAR, **M DIAMOND**, P HELM. 2009. Continuing sources of PCBs: the significance of building sealants. International Association of Great Lakes Research, 52nd Annual Conference, Toledo, Ohio.

Robson, M., Melymuk, L.E., Diamond, M. Helm, P., Gilbert, B. 2008. Comparison of Chemical Profiles in Urban Rivers during Base Flow and Storm Events". Oral presentation, International Association for Great Lakes Research Annual Conference, Peterborough, ON.

DIAMOND ML. 2009. Science meets policy – and politics! 44th Central Canadian Symposium on Water Quality Research.

DIAMOND ML. 2009. An overview of Bisphenol A. Special Symposium on Bisphenol A. 44th Central Canadian Symposium on Water Quality Research.

GANDHI*, N., M.L. DIAMOND, D. VAN DE MEENT, M. HUIJBREGTS, A. DE KONING, J. GUINEE, W. PEIJNENBERG. 2008. New method for calculating metal characterization factors in Life Cycle Impact Assessment. Soc. Environ. Toxicol. Chem. (SETAC) North America, Annual Meeting, Tampa, Florida. Platform.

DIAMOND, ML. 2008. A long range view of long range transport of POPs. Soc. Environ. Toxicol. Chem. (SETAC) North America, Annual Meeting, Tampa, Florida. Invited platform presentation to open session.

MUGNAI, C., SOMMERFREUND, J.K., G.B. ARHONDITSIS, **M.L. DIAMOND**, M. FRIGNANI, G. CAPADAGLIO, M. GERINO, L. BELLUCCI and S. GIULIANI. 2008. Modeling Venice Lagoon fate and transport of POPs and metals in two different wind regimes. Soc. Environ. Toxicol. Chem. (SETAC) North America, Annual Meeting, Tampa, Florida. Poster.

GANDHI*, N., M.L. DIAMOND, D. VAN DE MEENT, M. HUIJBREGTS, A. DE KONING, J. GUINEE, W. PEIJNENBERG. 2008. Influence of aquatic chemistry on fate and toxicity estimates of metals in hazard assessment. Soc. Environ. Toxicol. Chem. (SETAC) North America, Annual Meeting, Tampa, Florida. Platform.

DIAMOND, ML, CSISZAR S, ZHANG X. 2008. Where is my bisphenol A coming from? Soc. Environ. Toxicol. Chem. (SETAC) North America, Annual Meeting, Tampa, Florida. Platform.

ZHANG*, X., **M.L. DIAMOND**, S. HARRAD and C. IBARRA. 2008. Polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) in indoor environments in Toronto. Soc. Environ. Toxicol. Chem. (SETAC) North America, Annual Meeting, Tampa, Florida. Poster.

ROBSON, M, L MELYMUK, P HELM, A GIANG, ML DIAMOND. 2008. Continuing sources of PCBs: the significance of building sealants. Soc. Environ. Toxicol. Chem. (SETAC) North America, Annual Meeting, Tampa, Florida. Poster.

GANDHI, N., M.L. DIAMOND, D. VAN DE MEENT, M. HUIJBREGTS, A. DE KONING, J. GUINEE, W. PEIJNENBERG, B. KOELMANS. 2008. Improvements in estimating metal characterization factors in Life Cycle Impact Assessment – Incorporation of metal speciation into fate and effects calculations. Platform presentation. Soc. Environ. Toxicol. Chem. (SETAC) Europe, Annual Meeting, Warsaw, Poland.

GEWURTZ S., N. GANDHI*, S. BHAVSAR, G. TOMY, **M. DIAMOND**, K. LAW. 2008. Application of a multi-chemical food web model to assess the dynamics of PBDEs in the food web of Lake Winnipeg, Canada. Brominated Flame Retardants Workshop, Victoria, B.C.

ZHANG, X*, Z., ROBSON*, M., **M. DIAMOND**, S. HARRAD, C. IBARRA. 2008. What controls the emissions and fate of PBDEs indoors. Brominated Flame Retardants Workshop, Victoria, B.C.

GALARNEAU, E., P.A. MAKAR and **M.L. DIAMOND**. 2008. Atmospheric fate of semivolatile PAHs in North America. Abstract submitted to SETAC World Congress, Australia.

Robson, M. ,Melymuk, L., Diamond, M. Helm, P., Gilbert, B., 2007. Persistent organic pollutants in urban environments Invited Presentation, Urban Atmosphere Workshop, hosted by Baltimore Ecosystem Study, National Science Foundation. Baltimore, MA.

GANDHI*, N., **M.L. DIAMOND**, D. VAN DE MEENT, W. PEIJNENBURG, M. HUIJBREGTS, j. GUINEE, G. HUPPES and B. KOELMANS. 2007. Estimation of characterization factors for metals in Life-cycle Impact Assessment of ecotoxicity – analysis of metal speciation, fate and effects issues. Platform presentation. Soc. Environ. Toxicol. Chem. (SETAC), 28th Annual Meeting, Milwaukee.

DIAMOND*, M.L., S. HARRAD, X. ZHANG, L. MELYMUK, S. CSISZAR, J.P. CLARKE, N. GANDHI, S. GEWURTZ, H. JONES-OTAZO. 2007. Cities: from contaminant emissions to exposure. Symposium presentation. Soc. Environ. Toxicol. Chem. (SETAC), 28th Annual Meeting, Milwaukee.

ZHANG*, X., **M.L. DIAMOND**, S. HARRAD and C. IBARRA. 2007. PBDEs – Behaviour in indoor environment – a mass balance fugacity model approach. Symposium presentation. Soc. Environ. Toxicol. Chem. (SETAC), 28th Annual Meeting, Milwaukee.

MELYMUK*, L., M. ROBSON, **M.L. DIAMOND** and P. HELM. 2007. Concentrations and fluxes of persistent organic pollutants to Lake Ontario via the Greater Toronto Area. Symposium presentation. Soc. Environ. Toxicol. Chem. (SETAC), 28th Annual Meeting, Milwaukee.

GEWURTZ*, S., P. CROZIER, **M.L. DIAMOND**, et al. 2007. Perfluoroalkyl contaminants in window film before and after a carpet installation. Platform presentation. Soc. Environ. Toxicol. Chem. (SETAC), 28th Annual Meeting, Milwaukee.

CSISZAR*, S., N. GANDHI, **M.L. DIAMOND**, R. ALEXY, D. BENNIE, J. STRUGER and C. MARVIN. 2007. New model for pharmaceuticals: description and application to Hamilton Harbour.

Platform presentation. Soc. Environ. Toxicol. Chem. (SETAC), 28th Annual Meeting, Milwaukee.

GAHNDI*, N. S. BAHVSAR*, **M.L. DIAMOND**. 2007. Development of a generic method for hazard analysis of substances: Addressing metal speciation, fate and Ecotoxicity Issues. Mining and the Environment International Conference" held in Sudbury during October 19 - 26, 2007. Gandhi won second prize for the best student oral presentation.

MELYMUK, L., S. CSISZAR, J.P. CLARKE, **M.L. DIAMOND***, B. BRANFIREUN, P. HELM and T. HARNER. 2007. Are PCBs legacy POPs? Platform presentation. Soc. Environ. Toxicol. Chem. (SETAC) Europe, Annual Meeting, Porto, Portugal.

GANDHI*, N., **M.L. DIAMOND**, D. VAN DE MEENT, M. HUIJBREGTS, J. GUINEE, G. HUPPES, W. PEIJNENBERG and B. KOELMANS. 2007. Estimation of characterization factors for metals in Life Cycle Impact Assessment of ecotoxicity – addressing metal fate, exposure and effects. Poster presentation. Soc. Environ. Toxicol. Chem. (SETAC) Europe, Annual Meeting, Porto, Portugal.

CSISZAR*, S.A., **M.L. DIAMOND**, J.P. CLARKE, M.A. BELMONT, L.E. MELYMUK, S.J. HARRAD, P.C. VAN METRE, F.T. HEITMULLER, M. RAO, T. HARNER and B. BRANFIREUN. 2007. Estimating emissions and fate of PCBs and PBDEs from European and North American cities. Platform presentation. 50th Annual Conf Internat. Assoc. Great Lakes Res. Pittsburgh, Penn.

SOMMERFREUND, J.K., G.B. ARHONDITSIS, **M.L. DIAMOND***, M. FRIGNANI, G. CAPADAGLIO, M. GERINO, L. BELLUCCI and S. GIULIANI. 2007. Uncertainty, data limitations and modelling: case study of contaminant fate modelling in the Venice Lagoon. Platform presentation. 50th Annual Conf Internat. Assoc. Great Lakes Res. Pittsburgh, Penn.

MELYMUK*, L., S.A. CSISZAR, **M.L. DIAMOND,** P. HELM, T. HARNER and B. BRANFIREUN. 2007. Are PCBs legacy POPs? An assessment of current PCB use in urban areas. Platform presentation. 50th Annual Conf Internat. Assoc. Great Lakes Res. Pittsburgh, Penn.

GANDHI*, N., R. ALEXY, S. CSISZAR, M. BELMONT, **M.L. DIAMOND**, D. BENNIE, J. STRUGER, C. MARVIN. 2007. New Model for pharmaceuticals: description and application to Hamilton Harbour. 50th Annual Conf Internat. Assoc. Great Lakes Res. Pittsburgh, Penn.

GALARNEAU*, E., MAKAR, P.A., SASSI, M., **DIAMOND, M.L**. 2007. Atmospheric Emissions and Modelled Regional Fate of Semivolatile Polycyclic Aromatic Hydrocarbons (PAHs) in the Great Lakes Basin. Abstract submitted to 50th Annual Conf Internat. Assoc. Great Lakes Res. Pittsburgh, Penn.

MELYMUK, L., S. CSISZAR, J.P. CLARKE, **M.L. DIAMOND***, B. BRANFIREUN, P. HELM and T. HARNER. 2007. Are PCBs legacy POPs? Platform presentation. Soc. Environ. Toxicol. Chem. (SETAC) Europe, Annual Meeting, Porto, Portugal.

GANDHI*, N., **M.L. DIAMOND**, D. VAN DE MEENT, M. HUIJBREGTS, J. GUINEE, G. HUPPES, W. PEIJNENBERG and B. KOELMANS. 2007. Estimation of characterization factors for metals in Life Cycle Impact Assessment of ecotoxicity – addressing metal fate, exposure and effects. Poster presentation. Soc. Environ. Toxicol. Chem. (SETAC) Europe, Annual Meeting, Porto, Portugal.

CSISZAR*, S.A., R. ALEXY, N. GANDHI, M. BELMONT, **M.L. DIAMOND**, D.T. BENNIE, J. STRUGER and C. MARVIN. 2007. Pharmaceuticals as environmental contaminants: modelling, distribution and fate (Triclosan, Naproxen, Ibuprofen and Gemfibrozil in Hamilton Harbour). Poster presentation. Pharmaceuticals and personal care products in the Canadian Environment: Research policies and directions. Niagara-on-the-Lake, Canada.

SOMMERFREUND, J.A., ARHONDITSIS, G. and **DIAMOND*, M.L.** 2007. A probabilistic approach for contaminate fate and transport modelling. Canadian Assoc. Water Quality, Burlington, Ont. Platform.

GEWURTZ, S.B., N. GANDHI, S.P. BHAVSAR*, **M.L. DIAMOND**, G.T. TOMY and K. LAW. 2006. Application of a multi-chemical food web model to assess the dynamics of PBDEs in the food web of Lake Winnipeg, Canada. Soc. Environ. Toxicol. Chem. (SETAC), 27th Annual Meeting, Montreal.

DIAMOND, M.L., L. MELYMUK, S. CSISZAR, M. BELMONT, P. HELM and J.P. CLARKE. 2006. Are PCBs legacy POPs? Assessment of current use in an urban area. Poster presentation. Soc. Environ. Toxicol. Chem. (SETAC), 27th Annual Meeting, Montreal.

ROBSON*, M., L. MELYMUK, **M. DIAMOND**, B. GILBERT, P. HELM and T. CHEN. 2006. Concentrations of Polycyclic Aromatic Hydrocarbons in River Sediments in the Greater Toronto Area. Poster presentation. Soc. Environ. Toxicol. Chem. (SETAC), 27th Annual Meeting, Montreal.

DIAMOND*, M.L., M.A. BELMONT, L.E. MELYMUK*, J.P. CLARKE*, S.J. HARRAD, P.C. VAN METRE, F.T. HEITMULLER, M. RAO and T. HARNER. 2006. More on the fate of PBDEs in cities — a Tale of 3 cities. Oral presentation. Soc. Environ. Toxicol. Chem. (SETAC), 27th Annual Meeting, Montreal.

DIAMOND, M.L., S.P. BHAVSAR and N. GANDHI. 2006. Advances in coupled fate and speciation modeling of metals. Oral presentation. Soc. Environ. Toxicol. Chem. (SETAC), 27th Annual Meeting, Montreal.

GANDHI*, N., S. BHAVSAR, J.P. CLARKE, L. MELYMUK, S. CSISZAR and **M.L. DIAMOND**. 2006. Assessing the long-term cycling of PCBs in Hamilton Harbour. Oral Presentation. Soc. Environ. Toxicol. Chem. (SETAC), 27th Annual Meeting, Montreal.

GANDHI, N., S.P. BHAVSAR, **M.L. DIAMOND**, D. VAN DE MEENT, M. HUIJBREGTS, J. GUINEE, H. HUPPES, W. PIJNENBERG and B. KOELMANS. 2006. Estimation of Characterization Factors for Metal Fate, Exposure and Effects Issues. Oral presentation. Soc. Environ. Toxicol. Chem. (SETAC), 27th Annual Meeting, Montreal.

DIAMOND, M.L., N. GANHDI, S.P. BHAVSAR, R. RAZAVI, E. HOGDE, J.P. CLARKE, H. LING. 2006. Modelling toxics in Areas of Concern: Lessons learned from Bay of Quinte, Hamilton Harbour. 49th Annual Conf. Internat. Assoc. Great Lakes Res. Windsor, Ont. Platform presentation.

CLARKE, J.P. and **M.L. DIAMOND***. 2006. PCB Dynamics in a city: Application of Multi-media Urban Model. 49th Annual Conf. Internat. Assoc. Great Lakes Res. Windsor, Ont. Platform presentation.

RAZAVI, R., E. HODGE, **M.L. DIAMOND***, G. ARHONDITSIS. 2006. Contaminant fate in Bay of Quinte: A modelling assessment. 49th Annual Conf. Internat. Assoc. Great Lakes Res. Windsor, Ont. Platform presentation.

SOMMERFREUND*, J., **M.L. DIAMOND**, S. GUILANI, M. FRIGNANI, G. CAPODAGLIA. 2006. Modelling contaminants in the Venice Lagoon. 49th Annual Conf. Internat. Assoc. Great Lakes Res. Windsor, Ont. Platform presentation.

THIBODEAUX*, L. and **M. DIAMOND**. 2006. An air-to-surface film chemodynamic model for PAH partitioning to urban surfaces. SETAC Europe, Den Haag, Netherlands. Platform presentation.

BHAVSAR, S.P., **M.L. DIAMOND***, N. GANHDI. 2006. A coupled multispecies metal transport and speciation (TRANSPEC II) model for soil and water. SETAC Europe, Den Haag, Netherlands. Platform presentation.

J.P. CLARKE, **M.L. DIAMOND***. 2006. PCB dynamics in a city: Application of the Multi-media Urban Model (MUM-Fate). SETAC Europe, Den Haag, Netherlands. Poster presentation.

SOMMERFREUND*, J., **M.L. DIAMOND**, S. GUILANI, M. FRIGNANI, G. CAPODAGLIA. 2006. Modelling contaminants in the Venice Lagoon. SETAC Europe, Den Haag, Netherlands. Poster presentation.

Bhavsar, S, Gandhi, N, ***Diamond, M**. 2005. Estimating Critical Loads of metals to surface aquatic systems using a coupled metal TRANsport-SPECiation-TOXicity (TRANSPEC-TOX) model. Oral presentation. Soc. Environ. Toxicol. Chem. (SETAC), 26th Annual Meeting, Baltimore, Maryland.

*Gewurtz, S., Helm, P., Gandhi, N., Bhavsar, S., **Diamond, M.**, Marvin, C., Whittle, D. 2005. Application of a food web model to evaluate the mechanisms controlling polychlorinated naphthalene concentrations in a Lake Ontario food web. Oral presentation. Soc. Environ. Toxicol. Chem. (SETAC), Baltimore, Maryland.

Gandhi, N., Bhavsar, S., Gewurtz , S., ***Diamond, M.**, Evenset , A., Christensen , G., Gregor, D. 2005. Development of a multi-chemical food chain model: Application to study debromination and bioformation of PBDEs. Oral presentation. Soc. Environ. Toxicol. Chem. (SETAC), 26th Annual Meeting, Baltimore, Maryland.

*Sommerfreund, J., Gandhi, N., Bhavsar, S., Gewurtz, S., **Diamond, M.**, Guiliani, S. and M. Frignani. 2005. A fugacity based assessment of fate and transport of organic contaminants in the Venice Lagoon, Italy. Poster presentation. Soc. Environ. Toxicol. Chem. (SETAC), 26th Annual Meeting, Baltimore, Maryland.

Hernandez-Martinez, N., J. Truong and **M.L. Diamond**. 2005. Variability in surface films on impervious surfaces. Poster presentation. Soc. Environ. Toxicol. Chem. (SETAC), 26th Annual Meeting, Baltimore, Maryland.

DIAMOND, M.L., J. ARCHBOLD, S. BHAVSAR, J. CLARKE, E. HODGE, H. JONES-OTAZO, T. LABENCKI, J. TRUONG, F. WONG and M. MONABBTI 2005. Contaminants in cities: fate, exposure and potential health effects. 4th Annual Urban Health Conference, Toronto. Poster presentation.

*KENNEDY, C. and **M.L. DIAMOND** 2005. Sources and fate of chemical in the urban metabolism. 55th Annual Canadian Chemical Engineering Conference. Toronto, Oct. Oral presentation.

*SOMMERFREUND J., N. GANDHI, S. BHAVSAR, S. GEWURTZ, S. GUILANI, M. FRIGNANI and **M.L. DIAMOND**. 2005 A fugacity/aquivalence-gased assessment of contaminant fate and transport I the Venice Lagoon, Italy. 55th Annual Canadian Chemical Engineering Conference. Toronto, Oct. Poster presentation.

***DIAMOND, M.L.**, J.P. CLARKE, N. HERNANDEZ-MARTINEZ, T. LABENCKI, B. LAM, E. HODGE, H. JONES-OTAZO. 2005. Contaminants in the city: sources and fate. 55th Annual Canadian Chemical Engineering Conference. Toronto, Oct. Oral presentation.

BHAVSAR, S., N. GANDHI and **M.L. DIAMOND***. 2005. Connecting metal loadings with ecotoxicity in lakes using a coupled modelling approach. 55th Annual Canadian Chemical Engineering Conference. Toronto, Oct. Oral presentation.

***DIAMOND, M.L.**, C. BUTT, B. LAM, J. TRUONG, N. HERNANDEZ-MARTINEZ, T. LABENCKI, R. WU, A. SIMPSON. 2005. The Composition and implications of atmospherically-derived films on impervious surfaces. Israel Society of Ecology and Environmental Quality and Science, Annual Meeting, Rehovot, Israel.

*RAZAVI, R., N. GANDHI, S.P. BHAVSAR, S.B. GEWURTZ, B. JONES and **M.L. DIAMOND**. 2005. Chemical dynamics in the Bay of Quinte, Lake Ontario: a comparative modelling approach. 48th Annual Conf. Internat. Assoc. Great Lakes Res. Chicago, Il. Poster presentation.

*BHAVSAR, S.P., **DIAMOND, M.L.**, and GANDHI, N. 2005. Extension of coupled multispecies metal TRANsport and SPECiation (TRANSPEC) model to soil compartment. 48th Annual Conf. Internat. Assoc. Great Lakes Res. Chicago, Il. Oral presentation.

GEWURTZ, S.B., GANDHI, N., CHRISTENSEN, G.N., EVENSET, A., GREGOR, D., STERN, G.A., FRANZIN, W.G., RYAN, M., and **DIAMOND, M.L.** 2005. A Comparison of the mechanisms controlling PCB bioaccumulation in lakes of different latitudes: a modeling approach. 48th Annual Conf. Internat. Assoc. Great Lakes Res. Chicago, Il. Oral presentation.

*GANDHI, N., BHAVSAR, S.P., GEWURTZ, S.B., **DIAMOND, M.L.**, RUSMIR-WOODS, C., and BOYD, D. 2005. Assessing long-term PCB cycling in Hamilton Harbour - An application of integrated fate-transport and food web model. 48th Annual Conf. Internat. Assoc. Great Lakes Res. Chicago, Il. Oral presentation.

*GANDHI, N., BHAVSAR, S.P., **DIAMOND, M.L.**, MORASH, P., and ANDERSON, J. 2005. Impacts of metal dissolution kinetics on recovery of metal contaminated sediments – an application of extended TRANSPEC model to Spanish Harbour. 48th Annual Conf. Internat. Assoc. Great Lakes Res. Chicago, Il. Oral presentation.

HERNANDEZ-MARINTEZ, N., J. TRUONG, M.L. DIAMOND. 2005. Variability and temporal trends in urban film composition. 48th Annual Conf. Internat. Assoc. Great Lakes Res. Chicago, Il. Poster presentation.

*WU, R.W., T. HARNER, **M.L. DIAMOND**, A. MOTELAY-MASSEI, C.M. BUTT. 2005. Surface organic films: growth dynamics and response to meteorology. Oral presentation. SETAC Europe. Lille France.

*MOTELAY-MASSIE, A. T. HARNER, P. VAN METRE, C. ECKLEY, B.J. MAHLER, **M. DIAMOND**, B. BRANFIREUN. 2005. Diurnal variations of air-surface exchange for organic pollutants in urban areas. Abstract submitted for oral presentation. SETAC Europe. Lille France.

*GEWURTZ, S.B., N. GANDHI, G.N. CHRISTENSEN, A. EVENSET, D. GREGOR, G.A. STERN, W. FRANZIN, M. RYAN. **M.L. DIAMOND**. 2004. A comparison of the mechanisms controlling POP bioaccumulation in lakes of different latitudes: a modelling approach. Oral presentation. Soc. Environ. Toxicol. Chem. (SETAC), 25th Annual Meeting, Portland, Oregon.

*BHAVSAR, S.P., N. GANHDI, J. ARCHOLD, M.L. DIAMOND, R. GOULET. 2004. BIOTRANSPEC-ERA: A model to estimate metal speciation-fate-bioaccumulation and toxicological hazard for LCIA. Oral presentation. Soc. Environ. Toxicol. Chem. (SETAC), 25th Annual Meeting, Portland, Oregon.

*BHAVSAR, S.P., **M.L. DIAMOND**, N. GANDHI. 2004. Extension of coupled multispecies metal TRANsport and SPECiation (TRANSPEC) model to soil compartment. Oral presentation. Soc. Environ. Toxicol. Chem. (SETAC), 25th Annual Meeting, Portland, Oregon.

*GEWURTZ, S.B., R. LAPOSA, N. GANDHI, G. CHRISTENSEN, A. EVENSET, D. GREGOR, **M.L. DIAMOND**. 2004. Accumulation of POPs in a high arctic food web: influence of temperature, nutrients, and loadings. Poster presentation. Soc. Environ. Toxicol. Chem. (SETAC), 25th Annual Meeting, Portland, Oregon.

*LAM, B., *M.L. DIAMOND, A.J. SIMPSON, J. TRUONG, N.A. HERNANDEZ, J.D. DONALDSON. 2004. Chemical composition of surface films and their related implications to atmospheric chemistry. Poster presentation. Soc. Environ. Toxicol. Chem. (SETAC), 25th Annual Meeting, Portland, Oregon.

*HERNANDEZ, N.A., M.L. DIAMOND, J. TRUONG, J. DONALDSON. 2004. Variability and reproducibility of surface films on impervious urban surfaces. Poster presentation. Soc. Environ. Toxicol. Chem. (SETAC), 25th Annual Meeting, Portland, Oregon.

WONG, F., **M.L. DIAMOND***, M. ROBSON, S.J. HARRAD, T.F. BIDLEMAN, J. TRUONG. 2004. Chiral signature of PCBs and organochlorine pesticides along an urban-rural transect. Oral presentation. Soc. Environ. Toxicol. Chem. (SETAC), 25th Annual Meeting, Portland, Oregon.

*GANDHI, N., S.B. *GEWURTZ, S.P. BHAVSAR, G.N. CHRISTENSEN, A. EVENSET, D. GREGOR, T. SKOTVOLD, **M.L. DIAMOND.** 2004. A coupled fate-transport and food chain model for PBDEs in the High Arctic: application to Lake Ellasjoen, Bear Island, Norway. 3rd International Workshop on Brominated Flame Retardants. Toronto, Canada. Poster.

JONES-OTAZO, H., J.P. CLARKE, J. ARCHBOLD, **M.L. DIAMOND**, J.J. RYAN, G. FERGUSON. 2004. A preliminary comparison of Canadian PBDE exposures from oral and inhalation routes. 3rd International Workshop on Brominated Flame Retardants. Toronto, Canada. Poster.

ARCHBOLD, J.A., R.N. HULL, M.L. DIAMOND. 2004. Take a deep breath – its time to reconsider wildlife inhalation risk. SETAC Laurentian, Ottawa, Canada. Poster.

*GEWURTZ, S.B., N. GANDHI, G.A. STERN, W. FRANZIN, **M.L. DIAMOND**. 2004 Dynaimcs of POPs in the biota of Lake Winnipeg: a modeling approach. 47th Annual Conf. Internat. Assoc. Great Lakes Res. Waterloo, Ont. Oral presentation.

*GEWURTZ, S.B., R. LAPOSA, N. GANDHI, G.N. CHRISTENSEN, A. EVENSET, D. GREGOR, T. SKOTVOLD, **M.L. DIAMOND.** 2004. A comparison of contaminant dynamics in arctic and temperate fish.47th Annual Conf. Internat. Assoc. Great Lakes Res. Waterloo, Ont. Poster presentation.

*HERNANDEZ, N. **M.L. DIAMOND**, J. TRUONG, D.M. LAPIERRE, B.L. FRYER. 2004.

Contaminant fate in organic films on impervious urban surfaces. 47^{th} Annual Conf. Internat. Assoc. Great Lakes Res. Waterloo, Ont. Poster presentation.

*LABENCKI, T.L., **M.L. DIAMOND**, J. TURONG, D.M. LAPIERRE, B.A. BRANFIREUN. 2004. Characterization of wash-off from urban impervious surfaces. 47^{th} Annual Conf. Internat. Assoc. Great Lakes Res. Waterloo, Ont. Oral presentation.

*GANDHI, N. S.P. BHAVSAR, **M.L. DIAMOND**, D. GREGOR, A. EVENSET, G.N. CHRISTENSEN. 2004. Concentrations in the aquatic food chain of Lake Ellasjoen, Bear Island, Norway. 47^{th} Annual Conf. Internat. Assoc. Great Lakes Res. Waterloo, Ont. Poster presentation.

JONES-OTAZO, H., J.P. CLARKE, ***M.L. DIAMOND**, J. ARCHBOLD, J. RYAN, E.M. HODGE, Q.-T. LIU, J. TRUONG, C.M. BUTT, M. IKONOMOU. 2004. Predicted urban loadings and risk of human health effects from multimedia exposure to semi-volatile organic contaminants. 47^{th} Annual Conf. Internat. Assoc. Great Lakes Res. Waterloo, Ont. Oral presentation.

BUTT, C.M., R.W. *WU, T. HARNER, **M.L. DIAMOND**, B.A. BRANFIREUN. 2004. Characterization of surface organic films in urban centers. 47^{th} Annual Conf. Internat. Assoc. Great Lakes Res. Waterloo, Ont. Poster presentation.

*CAMPBELL, L.M., D.G. DIXON, M. EVANS, **M.L. DIAMOND**, S.B. GEWURTZ, R.E. HECKY, K.A. KIDD, L. LOCKHART, D.C.G. MUIR, G.A. STERN. 2004. Mercury trophodynamics across latitudes.47^{th} Annual Conf. Internat. Assoc. Great Lakes Res. Waterloo, Ont. Oral presentation.

*BHAVSAR, S.P., J. TRUONG, **M.L. DIAMOND**, B.J. FRYER. 2004. Spatial and temporal variations of metals in film on exterior surfaces of glass windows: a promising passive air sampler. 47^{th} Annual Conf. Internat. Assoc. Great Lakes Res. Waterloo, Ont. Oral presentation.

MAKAR, P.A., **M. DIAMOND**, D.J. DONALDSON, J. TRUONG, A. ASAD, N.H. MARTINEZ, E. DEMOU and H. VISRAM. 2004. Organic absorptive partitioning: theoretical predictions and comparisons to measurements. European Geophysical Union Annual Meeting, Nice, France.

WONG, F., **M. DIAMOND***, J. TRUONG, M. ROBSON, S. HARRAD, T. BIDLEMAN. 2003. Accumulation and chiral analysis of organic chemicals in forest soils along an urban-rural gradient. Soc. Environ. Toxicol. Chem. (SETAC) 24th Annual Meeting in North America, Austin, TX. Oral presentation.

* **DIAMOND, M.L.**, J.A. ARCHBOLD, S.P. BHAVSAR, M. MONABBATI. 2003. Fugacity in the city: MUM-Fate and MUM-Risk. Soc. Environ. Toxicol. Chem. (SETAC), 24th Annual Meeting, SETAC in North America, Austin, TX. Oral presentation.

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MACKAY*, D. and **M. DIAMOND.** 1991. The role of mass balancing in Great Lakes management of toxic chemicals. Paper presented at 34th Conf. of Internat. Assoc. for Great Lakes Research, Buffalo, NY.

DIAMOND*, M.L. and D. MACKAY. 1990. Quantifying chemical sources and fate in the Bay of Quinte: An application of mass balance models. Paper presented at Soc. Environ. Toxicol. Chem., 11th Annual Meeting, Arlington, Virginia.

DIAMOND*, M.L., M. COQUERY and P.M. STOKES. 1990. Development of a regional model of mercury accumulation in sport fish. Paper presented at Internat. Conf. Mercury as an Environmental Pollutant, Gavle, Sweden.

DIAMOND*, M.L. and D. MACKAY. 1990. Modelling seasonal variations in contaminant dynamics in a small lake. Paper presented at 33nd Conf. of Internat. Assoc. for Great Lakes Research, Windsor, Ontario.

DIAMOND*, M.L. and D. MACKAY. 1990. Modelling arsenic dynamics in a small lake: An examination of seasonal influences. Paper presented at 10th Annual SLANT/TRESLA Conference, Quebec City, Quebec.

MACKAY*, D., **M.L. DIAMOND** and W. STIVER. 1990. Modelling sediment-water interactions. Paper presented at Symp. on Organic Substances in Sediments and Water, Amer. Chem. Soc. Meeting, Boston, Mass.

DIAMOND*, M.L., W. STIVER and D. MACKAY. 1989. The Linear Additivity Principle and its use for assessing chemical contributions from contaminated sediments. Paper presented at Soc. Environ. Toxicol. Chem., 10th Annual Meeting, Toronto.

MACKAY*, D., W.Y. SHIU and **M.L. DIAMOND.** 1989. Characteristics of contaminant condensation in cold climates. Paper presented at Soc. Environ. Toxicol. Chem., 10th Annual Meeting, Toronto.

DIAMOND*, M.L. and D. MACKAY. 1989. Extending the fugacity approach to inorganic chemical behaviour in lakes: estimating contributions from contaminated sediments. Paper presented at 40th Amer. Inst. Biol. Sci. Meeting, Toronto.

DIAMOND*, M.L. and D. MACKAY. 1989. Modelling chemicals in the Great Lakes: Applying a novel equilibrium criterion, "aquivalence". Paper presented at 32nd Conf. of Internat. Assoc. for Great Lakes Research, Madison, Wisconsin.

MACKAY*, D., **M.L. DIAMOND** and W. STIVER. 1989. A simple method for estimating chemical profiles in sediments. Paper presented at 32nd Conference of Internat. Assoc. for Great Lakes Research, Madison, Wisconsin.

MACKAY*, D. and **M.L. DIAMOND**. 1988. Aquivalence: A "new improved" substitute for fugacity in environmental modeling and interpretation. Paper presented at Soc. Environ. Toxicol. Chem., 9th Annual Meeting, Arlington, Virginia.

DIAMOND*, M.L., D. MACKAY, S. LANDSBERGER, and A.G. CHENG. 1988. Modelling arsenic dynamics in a contaminated lake. Paper presented at Internat. Conf. Trace Metals in Lakes, Hamilton.

DIAMOND*, M.L. and D. MACKAY. 1988. Modelling the movement of inorganic chemicals in lakes. Paper presented at 31st Conf. of Internat. Assoc. for Great Lakes Research, Hamilton, Ontario.

DIAMOND*, M.L., D. MACKAY, D. PHALP and S. LANDSBERGER. 1988. First a sink, then a source: arsenic dynamics in Moira Lake sediments. Paper presented at Conf. Can. Soc. Limnol., Ottawa.

DIAMOND*, M.L., R.J. CORNETT and D. MACKAY. 1986. Modelling the fate of arsenic in lakes. Poster presented at Technology Transfer Conf., Ontario Ministry of the Environment, Toronto.

* author presenting the paper

¢ invited presentation

11. INVITED LECTURES

2014	"What have we learned (or not learned) from PBDEs?", Institute for Chemical and Bioengineering, ETH (Swiss Federal Institute of Technology) Zurich. May 8, 2014. 1 hour.
2014	"What have we learned (or not learned) from PBDEs?", Swedish University of Agriculture, Stockholm. May 6, 2014. 1 hour.
2013	"Following the paths travelled by halogenated flame retardants", University of Manitoba, March 15, 2013. 1 hour.
2013	"Following the paths travelled by halogenated flame retardants", Brace Centre for Water Resources Management, McGill University, January 31, 2013. 1 hour.
2013	"The Flame Retardant Story", McMaster University, McMaster Institute for Environment and Health. January 19, 2013 1 hour.
2013	"The Flame Retardant Story", Environment Canada, Air Quality Research Division. 1 hour.
2012	"Recent advances in metal characterization", co-sponsored by University of Copenhagen (Faculty of Sciences) and Danish Technical University (Dept of Environ Engineering)
2012	"The flame retardant story". Stockholm University. In the series "Lectures in Contaminant Science", and a 2nd lecture at IVL Swedish Environmental Research Institute, Stockholm.
2011	"Tracing chemicals from source to exposure". Lecture & webinar at Ontario Agency for Health Protection and Promotion. May 2011.
2011	"Stockholm Convention in the context of preventative engineering, alternatives assessment, and sustainability re: POPs". Plenary address at "RECETOX Workshop. Identifying the research needs in the global assessment of toxic compounds ten years after the signature of the Stockholm Convention". Brno, Czech Republic, 22-24 May 2011.
2011	Emerging pollutants. Innolec Lectures. Masarykova Univerzita, Czech Republic.
2010	Where are chemicals in the lakes coming from and what does it mean? Toronto and Region Conservation Authority, Great Lakes Evening,
2010	Sources of brominated flame retardants: BFRs - from source to lake. Webinar organized

by the Great Lakes Commission.

2010 Tracing the pathways of polybrominated diphenyl ethers. CML Leiden University, The Netherlands.

2010 Connecting metal emissions with ecotoxicology through modelling. Departments of Chemistry and Physics, Trent University.

2010 Where the water hits the road – urban water pollution issues. University of Maryland at Baltimore.

2009 Contaminants in Us -- Much Ado about Nothing or Serious Stuff? Dept of Chemistry, University of Winnipeg. Departmental seminar.

2009 The Science, Art and Politics of Chemical Management. SETAC Laurentian Annual Meeting, Plenary Talk.

2009 Source to sink to management and beyond: the story of PCBs. Dept. of Chemistry, UmeΔ University, Sweden.

2009 Can we manage our toxics? From science to policy to politics. Duke University, North Carolina.

2008 The Simpsons, Toxic Chemicals and the Future. Centre for Environment, University of Toronto.

2008 The Simpsons, the Chemical Management and the Future of the World. Ontario Ministry of Environment.

2008 Bisphenol A and Ontario's Toxic Reduction Strategy", Ontario Ministry of Environment, Drinking Water Division, Drinking Water Symposium, Toronto, June 17, 2008,

2008 How did that chemical that was inside my computer get inside me? Royal Canadian Institute seminar series.

2008 Urban Thin Films. AirUCI* Annual Workshop, Invited opening talk, University of California at Irvine. *Atmospheric Integrated Research: Understanding Chemistry at Interfaces.

2007 Approaching sustainability: cities, contaminants and health. University of Saskatchewan

2007 Tress and People in Cities: How do we best achieve health benefits? International Congress "A Global Vision of Forestry in the 21st Century", Faculty of Forestry, University of Toronto.

2007 Connecting the dots between contaminant emissions and exposure in cities. CEAS Seminar Series. Dept. of Chemical Engineering. University of Manchester.

2007 Connecting the dots between contaminant emissions and exposure. Division of Environmental Health and Risk Management. University of Birmingham.

2006 POPs in the City. Plenary lecture, 1st Network Conference on Persistent Organic Pollutants: human exposure and impacts, University of Birmingham.

2006 Chemical contaminants in Toronto: Concentrations to potential effects. Health Canada Workshop, Place Matters: Health Difference in Ontario Cities and Neighbourhoods.

2006 Brominated flame retardants – from source to exposure. Environmental Physician's Group of Ontario Medical Association, seminar series "Clinical Reviews".

2005 Brominated flame retardants: environmental pathways and human exposure. Dept. of Environmental Chemistry and Energy, Weizmann Institute, Israel.

2005 Tracing contaminant sources and potential health effects: the Toronto experience. Environment & Health seminar series, Institute for Environmental Studies, University of Toronto.

2004 9/11: The chemical signature. University of Birmingham.

2004 The fate, exposure & potential risks of persistent organic pollutants in urban areas. Makerere University.

2004 Air pollution-health connections: complexity at its best. Guest speaker, Symposium on Windsor Air Quality, sponsored by Windsor Essex County Environment Committee,

	Windsor, Ontario.
2003	Surface films on impervious surfaces: implications for contaminant fate and effects. PPG Industries (Pittsburgh Plate and Glass), Glass Technology Center, Pittsburgh, PA.
2003	Cities: The Good, the Bad and the Ugly. Invited seminar, Great Lakes Institute for Environmental Research, University of Windsor.
2003	Multimedia Movement and Risk of Contaminants in Urban Areas. SETAC, Laurentian Chapter. Keynote address.
2002	Contaminant Fate and Effects in Urban Areas. Invited seminar, Meteorological Service of Canada, Environment Canada.
2002	Cities: Contaminant Fate and Effects. Invited seminar, Health Canada.
2002	Urban Toxics Monitoring in Toronto. Binational Toxics Strategy Integration Workgroup Meeting, co-sponsored by Environment Canada and the United States Environmental Protection Service. Windsor.
2002	Estimating the fate, bioavailability and potential toxicological risk posed by metals in the environment. Keynote address, International Workshop on Life Cycle Assessment and Metals. Co-sponsored by UNEP, SETAC, APEC-GEMEED, ICMM and NRCan. Montreal.
2002	Methods of Model Validation: Priniciples and Examples. Invited presentation at International Workshop on "Design of exposure multi-media models and conditions for application to soil pollutants: an international workshop." Organized by Institut de Veille Sanitaire, France.
2001	Urbanization: Effects on Contaminant Fate. Dept. of Environmental Engineering, Ryerson University.
2000	Current issues in urban air pollution. Presentation to the Environmental Assessment and Appeal Board of the Ontario Ministry of the Environment.
2000	Multimedia models: description and assessment for air quality modelling. Workshop on Combining Environmental Fate and Air Quality Modeling, Sponsored by the Reactivity Research Working Group Subgroup 3 on Atmospheric Availability and Environmental Fate, Research Triangle Park, NC.
2000	Chemical contaminants in urban areas and their potential impacts on human and ecosystem health. Issues in Urban Health. 22nd University College Symposium. Jan 31 to Feb 4, 2000.
1999	Fate and transport of toxics in urban ecosystems. Department of Geography, University of Maryland, Baltimore County and Baltimore Ecosystem Study.
1999	Behaviour of arsenic in Moira Lake. "How Healthy is the Moira" workshop, Trent University.
1999	Contaminants in urban areas: movement and effects. Environment and Health Seminar Series, Institute for Environmental Studies and Gage Occupational and Environmental Health Unit, University of Toronto.
1998	The multi-media movement of contaminants in urban areas and their accumulation on impervious surfaces. York University, Department of Geography Graduate Programme.
1997	Multi-media chemical distribution in urban areas: the role of organic films. State University of New York at Albany, Department of Environmental Health and Toxicology, School of Public Health.
1997	An overview of multi-media modelling and its use as a decision-making tool. Minnesota Department of Transportation.
1997	Mercury in aquatic systems. Invited presentation at "Mercury elimination and reduction symposium", Organized by Pollution Probe. Toronto, Ontario.
1997	Mercury cycling in the environment and its toxicological implications. Environment and Health Seminar Series, Institute for Environmental Studies and Gage Occupational and Environmental Health Unit, University of Toronto.

1996 Can we build habitable cities without damaging the environment? Public forum on "Mitigation of Environmental Impacts of Urban Development". Co-sponsored by the York Chapter, Professional Engineers Organization and the Rotary Club of Richmond Hill.

1996 Mercury: what models can tell us. Seminar sponsored by: Sevenson Environmental Services, Inc., Dept. of Civil Engineering, Great Lakes Program and NYS Center for Hazardous Waste Management, University of Buffalo.

1994 Contaminants in Arctic Lakes: Behaviour and Fate. Ecology Seminar Series, Co-sponsored by Departments of Botany and Zoology, University of Toronto.

1992 A simple model of mercury dynamics in a lake. Ontario Hydro, Research Division, Toronto.

D. LIST OF COURSES

12. a. UNDERGRADUATE COURSES TAUGHT

2014-present ESS 299Y. UNDERGRADUATE RESEARCH OPPORTUNITY. Clara Thaysen. Contaminant-Fabric Dynamics: Experiments assessing sorption and release.

2013-present BIG 102Y. THE INTERNET: SAVING CIVILIZATION OR TRASHING THE PLANET? One of three instructors for this high profile 1st year course.

2010-2013, 2015 GGR 308. PHYSICAL ASPECTS OF THE CANADIAN ARCTIC AND SUBARCTIC. Chief cook and bottle washer.

2009-2013 JGE 236Y. HUMAN INTERACTIONS WITH THE ENVIRONMENT. Course coordinator, co-taught. 2012 offered as a ½ course.

2006-2008 JEG 221Y ENVIRONMENTAL AND SUSTAINABLE DEVELOPMENT. Course coordinator (with S. Scharper in 2006-07). Delivery of 1/3 of lectures plus participation in 3 panel discussions, review, etc. Jointly offered by Geography and Centre for Environment.

2001-02, 04 GGR 307S SOIL AND WATER: LANDSCAPE PROCESSES. Responsible for course that includes lectures, group research projects, problem set and exam.

2000-07 SCI 199Y1 ENVIRONMENTAL CHANGE. Co-taught with Tony Davis or Danny Harvey. IMAGES AND INDICATORS: MEASURING ENVIRONMENTAL PERFORMANCE. Co-taught with Virginia Maclaren.

1997-98 GGR 299Y RESEARCH OPPORTUNITY PROGRAM. Diane Leal and John Roppa.

1994-2006 GGR 233Y ENVIRONMENTAL MANAGEMENT FOR SUSTAINABLE DEVELOPMENT. Spring term. Co-lectured with J. Newton in 1994. Enrolment starts at 200, with about 150 finishing. Enrolment in 2003 is 180. Responsible for lectures, supervising T.A.s, assignments and final exam (marked part thereof). The course introduces students in the Environment and Resource Management Program with the scientific (basic and applied) basis of environmental issues.

1994-95 GGR 491Y INDEPENDENT RESEARCH I. Lisa Sumi (co-supervised with J. Gerits and M. Alaee, National Water Research Institute).

1997-98	Katina Kominos.
1992-93	Andrew Rodie (co-supervised with J. Gerits);
2003	Alison Bodurtha.
2013	Brielle Carriero (half credit)

1993-2002 ENV 221Y APPROACHES TO ENVIRONMENTAL ISSUES I. Team taught with Prof. J. Grant, Prof. S. Scharper and Dr. M. Winfield. My component is 6 weeks. Enrolment 60 to 85. Provides students with the approaches taken to environmental issues by various disciplines, using a case study as a unifying theme. I teach the environmental science/physical geography component, discussing the scientific concepts and approaches specific to the case study.

1993-97 ENV 200Y ASSESSING GLOBAL CHANGE: SCIENCE AND THE ENVIRONMENT. Prof. A. Zimmerman coordinates and lectures for most of the course, with my component being 2 to 3 weeks. Enrolment about 300. Science breadth course. Goal is to expose non-science students with the science behind environmental issues.

2008-09	ENV 498Y INDEPENDENT RESEARCH IN ENVIRONMENT. David Berliner
2000	Christina Lee (co-supervised with D. MacDonald).
1995-96	Jean-Guy Pageau
1997-98	Kirsten Fertuck

1993-94	INI 491Y INDEPENDENT STUDY. Tulio Bugada, Steve Dresher, Steven Ogilvie.
1992-93	Neil Banerjee (co-supervised with S.D. Scott, Geology, Geotechnical Engineering); Maria Terra (co-supervised with L. Grima).
1991-92	Leslie Megson (co-supervised with R. Shimizu, Institute for Environmental Studies), Michelle Perera.

	CHE 499Y THESIS (CHEMICAL ENGINEERING)
2010-11	Evelyn Mukwedeya "Spatial and temporal variations of phthalate concentrations in Vancouver homes"
2009-10	Vivian Cheung
2005-06	Jennifer Sears
2004-05	Queenie Cheung
2003-04	Bushra Drir
2001-02	Ian Collins
1999-00	Liam Moore, Trinh Tieu
1993-94	Alan Teare

1992-2012 GGR 409F CONTAMINANTS IN THE ENVIRONMENT. Enrolment up to 30. From 1993 to present, physical science course. Responsible for all components of course. Lectures are supplemented with tutorials to provide students with a scientific understanding of the processes and factors controlling contaminant behaviour and effects in the environment. Problem sets introduce quantitative methods to estimate chemical fate, including simple mathematical modelling.

1992 (spring), 1992-93 INI 220Y ENVIRONMENTAL FACTORS AND DECISION MAKING. Enrolment 100. Responsible for lectures, supervising T.A.s, assignments and final exam (marked the latter). Provided students with tools for environmental assessment and sectoral impacts. Included guest lectures.

1992, 1993 INI 320Y CANADIAN ENVIRONMENTAL ISSUES. Spring term. Enrolment 80. Responsible for lectures, course organization, supervising T.A.s and marking portion of student reports. Co-taught with Dr. Beth Savan in 1992-93. Using principles of adult education, students were guided through two research projects in the term.

12. b. GRADUATE COURSES TAUGHT

1992-2013 JGE 1212H CONTAMINANTS IN THE ENVIRONMENT. Offered in conjunction with GGR 409 in 1992-93 and 1994-95, 1995-onwards (science version), offered as stand-alone social science course in 1993-94 and 1995-96. Enrolment varies from 5 to 13. Course has shifted from first catered to all graduate students, next for social science and planning students, and finally for science and health students. Course introduces scientific concepts behind environmental concerns and discusses policy and scientific aspects of selected environmental topics. Now offered as JGE 1212H, jointly listed with Centre for Environment.

2010 GGR 1200F PHYSICAL GEOGRAPHY CORE COURSE. Co-taught with W. Gough.

1996-1997 GGR 1213S FATE OF CONTAMINANTS IN LAND AND WATER. Co-taught with K. Bolton in 1996. Physical science course covering contaminant-soil interactions (Bolton) and multimedia contaminant dynamics (Diamond).

1995-1997 GGR 1400H CURRENT RESEARCH APPROACHES IN ENVIRONMENTAL GEOGRAPHY. Introduction to research methods, and development and vetting of research proposal. Directly supervise my graduate students and contribute to lectures.

1995-96, 01, 03 GGR 1149H READINGS IN SELECTED TOPICS. Judy Fedorowick, Sherry Eaton, Sarah Gewurtz, Lise Sabatier

1994-95 GGR 1400H CURRENT RESEARCH APPROACHES IN ENVIRONMENTAL GEOGRAPHY. Co-coordinator (with R. Jaakson), enrolment about 10.

1993-94 GGR 1400H CURRENT RESEARCH APPROACHES IN ENVIRONMENTAL GEOGRAPHY. Course coordinator.

2000 MSC 4000 SEMINARS IN ENVIRONMENT AND HEALTH. Team taught with F. Silverman and D. Cole. Seminar course designed to expose students to current topics and researchers in the multidisciplinary field.

1990-91 ESE 1008S ENVIRONMENTAL MANAGEMENT II: REMEDIAL ACTION PLANS IN THE GREAT LAKES. Course coordinator and lecturer, co-designed course (with G. Krantzberg).

1989 ESE 1014F AQUATIC CHEMISTRY. Developed and coordinated course, lectured and evaluated students.

1989 ESE 1006S MAN-ENVIRONMENT THEORY II. Co-coordinator. Lectured and provided project supervision.

Short Courses:

2000-2002 "Fundamentals of Risk Assessment", Short course offered by Professional Development

Centre, Faculty of Applied Science and Engineering. Co-taught with M. Monabbati and J. Archbold.

Guest Lectures in University Courses:

2012 Guest lecture in Faculty of Medicine, Determinants of Community Health (DOCH) course, Year 1, Semester 2. 1 hour lecture with 2 ours prep. " health promotion, including individual and community-level health promotion strategies, as well as health protection, including a focus on environmental and occupational health." Developed lecture in 2011-2012, delivered lecture in May 2, 2012-2013.

2013 Guest lecture, ENV 100, Oct 11, 2012, 2 hours

2013 Guest lecture, ENV 221, late October & early November. 2, 1 hour lectures = 2 hours total

2008-2013 JEH 445 (Assisted with design of course curriculum)

2004-2012 ES 9030 Environmental Applied Science and Management Program, Ryerson University

1987-2013 PCL 473/JNP 1014Y Interdisciplinary Toxicology.

1999 MSC4000 Seminars on Environment and Health.

1990,92,94,97,00,01 JNP 1016S Graduate Seminar in Toxicology.

1992-1993 GGR 1200H Physical Geography Core Course.

1992 ESE 1014S Aquatic Chemistry.

1990 POL 102 Introduction to Issues in Canadian Politics.

1990 CHE 201F Physico-Chemical Principles I.

12. c. THESES SUPERVISION

Department of Earth Sciences, M.Sc., Theses:

2012-present Daniela Serodio. Physical-chemical properties and persistence of organic flame retardants.

Department of Geography, Ph.D. Theses:

2011-present Golnoush Abbasi. Material flow analysis of PBDEs as a result of changes in policies from 1970-2020.

2007-2014 Jennifer Sawyer. Evaluating the transfer and accumulation of polyunsaturated fatty acids in freshwater food webs: a modeling approach Winner of 2010 International Assoc Great Lakes Res Graduate Student Award, .2011 Winner of J.E.R. Ross Scholarship from Dept of Geography UofT. Maternity leave spring 2012-current.

2000-2005 Sarah Gewurtz. An evaluation of factors controlling the dynamics of persistent organic pollutants in aquatic food webs: a modeling approach. Winner of Canadian Water Quality Association Graduate Fellowship. NSERC Scholar.

1996-1998 Neely Law. Transferred Ph.D. to University of North Carolina.

Department of Geography, M.Sc., Theses:

2006-2008 Xianming Zhang. Measurement and modelling of indoor concentrations of PCBs and PBDEs.

2005-2007 Lisa Melymuk. The multi-media movement of trace organic contaminants in an urban and urbanizing watershed. NSERC Scholar.

2005-2007 Liana del Gobbo. Risks and benefits: Contaminant and omega 3 fatty acid concentrations in fish and seafood consumed by the South-East Asian community.

2003-2005 Rosa Wu. Films on impervious surfaces: accumulation properties, contaminant concentrations and partitioning characteristics. Co-supervised with T. Harner, Environment Canada.

2002-2004 Tanya Labencki. Film-water exchange from impervious surfaces.

2001-2005 John Clarke. Applying the Multimedia Urban Model to measured PCBs, PAH and PBDEs in urban areas. Part-time student.

2001-2004 Heather Jones-Otazo. Development of MUM-FamRisk to estimate potential health effects of contaminant exposure in urban areas. Winner of 2003 Gordon Cressy Student Leadership Award, Labatt Fellowship, John Brown Award and Goerge Burwash Langford Prize, Univ of Toronto. NSERC Scholar.

2000-2003 Josephine Archbold. The Multimedia Urban Model: development and application of a screening-level ecological risk assessment model. Winner of 2002 Gordon Cressy Student Leadership Award, Sperrin Chant Masonic Award in Toxicology.

2000-2003 Craig Butt. Chemical and physical characterization of organic films on an impervious surface. Winner of 2002 Gordon Cressy Student Leadership Award, Labatt Fellowship.

1999-2002 Fiona Wong. Investigating persistent organic pollutants in soils along an urban-rural gradient. 1999-2002.

2001 Erin Hodge. Aryl hydrocarbon receptor mediated toxicity of the complex mixture of organic film from urban impervious surfaces. Co-supervised with P. Harper, Dept. of Pharmacology.

2000 Sheryl Law. Factors affecting the occurrence, isomer ratio and enantioselective degradation of hexachlorocyclohexane in arctic and temperate aquatic systems. 1998-00.

1999 Shannon Vickers. Metal accumulation and sediment-water exchange in an urban wet detention pond. Co-supervised with K. Bolton. 1997-99.

1999 Yau-Fei Chan. The effect of arsenic speciation on sorption and desorption to and from natural sediment. Co-supervised with K. Bolton. 1997-99. NSERC Scholar

1999 Sarah Gingrich. Chemical characterization of an organic film on impervious surfaces.

1996 Neely Law. Developing a simple model of chemical distribution in an urban watershed. 1994-96.

1993 Helen Wen Ling. Application of the QWASI fugacity/aquivalence model to assessing the fate of contaminants in the water and sediments of Hamilton Harbour. D. Mackay, co-supervisor. 1991-93.

Department of Geography, M.Sc., Research Papers:

1999 Marcy Burchfield. Characterizing scale dependent changes in spatial pattern of an urban land cover classification and the effects on a chemical fate and transport model. Co-supervised with F. Csillag. 1998-99.

1996 Glynn Gomes. The fate of organic contaminants in wet water detention ponds. 1995-96.

1996 Sherry Eaton. Application of the QWASI fugacity model to selected PAHs in Mohawk Lake, Brantford: An assessment of contaminant dynamics and system recovery. 1993-96, part time; 1994-96*.

1996 Judy Fedorowick. A multi-media inventory of pollutant loadings to the Don River watershed. 1992-96, part time; 1994-96*.

1996 Virginia Heffernan. Estimating *in situ* degradation rates for petroleum products in the Lower Don Lands, Toronto, Ontario. 1993-96. Leave of absence 6/94-1/95; 1/95-1/96, part time.

1995 Peter Jackson. Weekday-weekend variations of tropospheric ozone in the Metropolitan Toronto Region. 1993-95. 5/94-1/95, part time.

1994 James Helfield. Evaluating the use of wetlands in the Lower Don Lands. 1993-94.

1994 Margaret Faye. The role of primary production in the removal of arsenic from the waters of Moira Lake. 1992-94.

Department of Geography, M.A., Research Papers:

1993 Fredrick Bernard. Regulatory framework pertaining to toxics in Canada -- Southern Ontario in-service PCB case study. 1989-93, part time; 1992-93*.

Department of Geography, M.Sc.Pl.:

1997	Mark James. Analysis of the PCB destruction program at the contaminated site of General Electric in City of Toronto.
1993	Yvette Ali. A strategy for integrated pollution prevention and planning for Ontario.
1993	Rita Mezei. Site remediation planning process in Ontario: the need for reform. J. Whitney, co-supervisor.

Department of Chemical Engineering and Applied Chemistry, Ph.D. Theses:

2010-2013	Sri Chaudhuri. Measuring and understanding the indoor fate of, and exposure to phthalate esters. Withdrew April 2013.
2007-2012	Susan Csiszar. Estimating urban scale semi-volatile organic compound emissions and fate using a coupled multimedia and atmospheric transport model. OGS
2007-2012	Lisa Melymuk. Semi-volatile organic contaminants in the urban atmosphere: spatial and seasonal distributions and implications for contaminant transport. Winner of Eco-Tech Founders Award, 2007-08, Winner Sperrin Chant Masonic Award 2008, NSERC Scholar, Winner of Edward Jarvis Tyrrell Fellowship of 2011.
2006-2011	Nilima Gandhi. Improvements in hazard and Life Cycle Impact Assessment method for metal in freshwaters: addressing issues of metal speciation, fate, exposure and ecotoxicity. 2 NSERC Centennial Scholarship. Winner John R. Brown Prize 2008, Winner of Chris Lee Award from the Society of Environmental Toxicology & Chemistry and the International Copper Institute, 2010, Winner of Ray Langford Prize, Centre for Environment 2011.
2002-2007	Elisabeth Galarneau. Particle-gas partitioning of PAH: analysis and modelling.
2002-2005	Satyendra Bhavsar. Development of a coupled metal transport-speciation model for surface aquatic systems and its extension to soil.
1999	Mehran Monabbati. Effect of salinity and organic matter content of sediments on the sediment-water exchange of arsenic. 1994-99.

Department of Chemical Engineering and Applied Chemistry, M.A.Sc. Theses:

2013-present	Jimmy Truong. Organophosphosphate flame retardants and plasticizers in the Greater Toronto Area.
2012-present	Anna Krol. Development and evaluation of the Indoor Multimedia Assessment Model.
2010-2013	Sumera Yacoob. Examining Model Predictions of Zinc and Copper Aqueous Speciation and Freshwater Ecotoxicity: Case Study of Ross Lake, Flin Flon, Manitoba, Canada.
2006-2007	Susan Csiszar. The fate of PCBs and PBDEs in urban areas: application of the Multimedia Urban Model. By-pass to PhD.
2004-2007	Julie Sommerfreund. Evaluation of contaminant fate in the Venice Lagoon using a multi-segment fugacity/aquivlaence model and a probabilistic uncertainty analysis.
2004-2006	Roshanak Razavi. Contaminant fate in the Bay of Quinte: a modeling assessment.
2003-2004	Harshan Radhakrishnan. Optical imaging and investigation of the development of organic films. Co-supervised with S.Liss, Ryerson University. Changed supervisors.
2003-2005	Nadia Martinez Hernandez. Chemical characterization of organic films.
2001-2003	Nilima Gandhi. Modelling mercury in the Lahontan Reservoir and food web, Nevada.
2000-2002	David Schryer. Multimedia Urban Model: refinement and application. Withdrew.
1999-2002	Satyendrakumar Bhavsar. Coupling chemical speciation and fate models: estimating the fate of metals in Ross Lake, Manitoba. By-pass to Ph.D.
2000	David Priemer. The multimedia urban model: assessing the fate and transport of semivolatile organic compounds in urban areas. 1998-00. NSERC Scholar.
1999	Ayan Chakraborty. Modelling organic contaminants in lakes of the Upper Yukon River basin. Withdrew.
1999	Paul Helm. Degradation of α-Hexachlorocyclohexane and organochlorine contaminant

fate in high arctic lakes. 1996-99. NSERC Scholar.

1997 Murali Ganapathy. Modelling mercury dynamics in the Lahontan Reservoir, Nevada. 1995-97.

1994 Hilary Freitas. Modelling organic and inorganic chemicals in Arctic lakes. 1992-94.

Department of Chemical Engineering and Applied Chemistry, M. Eng. Papers:

1995 Makoto Kawai. A preliminary model to estimate chemical behaviour in lakes of the Upper Yukon River Basin. 1993-95; 1994-95*.

1994 Lennox Gibbs. A seasonal model for arsenic dynamics in Moira Lake. 1993-94; 1994*.

1994 Rochmi Widjajanti. Developing environmentally sound technology for the palm oil industry. 1991-94; 1993-94*.

* Time under my supervision.

Dalla Lana School of Public Health, M.Sc. Theses or research projects:

2013 Caryn Thompson. Analysis of phthalate concentrations indoors (withdrew from project)

2012-present Fe de Leon. Flammability standard setting in Canada.

2003-2005 Shelby Yamamoto. The status and potential health risks of PAH in Kampala, Uganda. Co-supervisor with Donald Cole. Winner of Eric Krause Award.

Department of Physical and Environmental Sciences, Ph.D. Theses:

2012-present Joseph Okeme. Indoor passive air sampling of semi-volatile organic compounds.

2011-present Aman Sanai. The role of clothing in human exposure to semi-volatile organic compounds.

Additional Graduate Related Activities:

Ph.D. Supervisory Committees University of Toronto

2012-present Matt Binington, PhD committee member, (Dept Physical & Environ Sci, UTSC).

2012 John Westgate, Final PhD defense committee member (Dept of Chemistry)

2011-2012 Serguei Stremilov,UTSC Physical and Environmental Sciences, Member of reading & comprehensive examination committee. (Dept Physical & Environ Sci, UTSC).

2010-present Alex Gudinov., Member of reading committee. (Dept Physical & Environ Sci, UTSC).

2010 Fiona Wong. Dept of Chemistry, University of Toronto. Member of Senate oral committee. (Dept of Chemistry)

2010-2012 Christina Quinn. Dept of Chemistry, University of Toronto. Member of Senate oral committee. (Dept of Chemistry)

2010-2011 Xianming Zhang, Dept of Chemistry, University of Toronto. Member of reading and PhD committees. (Dept of Chemistry)

2007-2014 Kelly Sabaliauskas, Dept of Chemical Engineering. Member of reading committee.

2008-2013 Maryam Ramin, Dept. of Physical and Environmental Science, UTSC. Member of reading committee.

2008 Fiona Wong, Dept. of Chemisty, Member of qualifying oral committee

2007 Gillian Daly, Dept. of Chemical Engineering. Member of final PhD examination committee.

2007 Sarah Hershorn. Dept. of Geology. Member of final PhD examination committee.

2006-2010 Julian Cleary, Dept. of Geography, Member of comprehensive examination committee.

2003-2007 Chris Eckley, Dept. of Geography. Member of reading committee and defense committees.

2000-2007 Adam Cornwell. Dept. of Geography. Member of reading committee and department defence committee.

2007 Chris Warren, Trent University. External Examiner on Ph.D. oral defense.

1999-2004 Levi Waldron. Faculty of Forestry. Member of reading and final examination committee.

1999-2002 Paul Helm. Dept. of Chemical Engineering. Member of reading committee.

1999–2009	Liisa Jantunen. Dept. of Chemical Engineering. Member of reading committee.
1997	Tom Harner. Dept. of Chemical Engineering. Member of examination committee.
1997-2001	Jonathan Schwartz. Dept. of Political Science. Member of reading committee.
1997-1999	Chris Desousa, Dept. of Geography. Member of reading, comprehensive exam, departmental defense and final defense committees.
1996-2000	James Smith, Dept. of Geography. Member of reading and comprehensive exam comm.
1996	Steven Young, Dept. of Material Science and Metallurgy. Member of reading and examination committee, Internal examiner for Senate oral.
1994-1998	Annameiki Farenhorst, Dept. of Geography. Member of reading and exam. committee.
1995-2000	Cathy Cottrell. Dept. of Chemical Engineering. Member of reading, departmental defense and final defense committees.
1995-1998	Edwin Tam. Dept. of Civil Engineering. Member of reading, comprehensive exam, departmental and final defense committees.
1994	Frank Wania, Dept. of Chemical Engineering. Member of Dept. and Senate oral committees.
1993	Kathleen Jagger. Dept. of Geography. Member of oral comprehensive examination committee.

Master's Committees, Dept. of Geography

2010	Nyssa Clubine, M.Sc.
2008	Tony Zhang, M.Sc.
2004	Yvonne Feng, M.Sc.
2003	Angelika Bayer, M.Sc.
2002	Carl Mitchell, M.Sc.
2001	Maggie Young, M.Sc.
	Frank Donnelly, M.A.
	Kyle Hodder, M.Sc.
	Carrie Lillyman, M.Sc.
1999	Andrew Cornwell, M.Sc.
	Vivian Campbell, M.Sc.
1997	James Sterling, M.Sc.
	Anastasia Svirejava, M.Sc.
	Dan Fitzgerald, M.Sc.
	Eric Krause, M.A.
	Sue Asprey, M.Sc.Pl.
1996	Heather Alexander, M.A.
	Keilly Griffiths. M.Sc.Pl.
	Neil Mallen. M.Sc.Pl.
	Andrew Rodie, M.Sc.
1994	Sue Dickson. M.Sc.
	Claire Woolveridge. M.A.
	Larry Dufay. M.A.
	Val Aloe. M.Sc.Pl.
1993	Sarah Cowell. M.Sc.
	Simon Benger. M.Sc.
	Sean Ledgerwood. M.A.
1992	Huang Zhen. M.Sc.
	Kerry Lakatos-Hayward. M.Sc.Pl.

Master's Committees, Dept. of Chemical Engineering and Applied Chemistry

2010	Bernadaette Assamoi. M.Sc.Eng. project defense

2007	Kelly Sabaliauskas, M.A.Sc. bypass oral.
2002	Elizabeth Gilmore, M.A.Sc.
2000	Yan Liang, M.Eng.
1994	Penny Vlahos. M.A.Sc.
1993	Shirley Thompson. M.Eng.
1991	Robert Caron. M.A.Sc.

Master's Committees, other departments and universities

2006	Christopher Warren. Trent University. External examiner.
2002	David Wasserstein. Institute of Medical Sciences. Internal examiner.
2002	Gail Klein, Dept. of Pharmacology. External examiner.
2002	Charlotte Corda, Dept. of Pharmacology. External examiner.
1999	Matt McLeod. Trent University. External examiner.
1992	Fereshteh Hashemi, Dept. of Botany. M.Sc.

External PhD Examiner

2013	Michael Owsianiak, Danish Technical University
2013	Paul Messing, University of Manitoba
2012	Karen Søgaard Christiansen, University of Copenhagen
2011	Karen Lavin, University of Otago, New Zealand
2010	Anneke Sleeswijk, Leiden University, The Netherlands
2010	Emma Goosey, University of Birmingham
2009-10	Nadia Abdelouahab, Universite de Quebec a Montreal. External reviewer.
2009	Kristina Sundqvist, University of Umeå, Sweden
2007	Cecile Bulle, Dept of Chemical Engineering, Ecole Polytechnique, Montreal, Quebec. External examiner for PhD

Additional Supervisory Activities:

Post-Doctoral Fellows

2014-present	Congqiao Yang, PhD.
2010-2013	Emma Goosey, Ph.D.
2007-2009	Cristian Mugnai, PhD. (visiting from Italy)
2006-2010	Matthew Robson, Ph.D.
2005-2006	Marco Belmont, Ph.D.
1999-2002	Qintao Liu, Ph.D.
1999-2001	Bagher Bahavar, Ph.D.
1999-2002	Mehran Monabbati, Ph.D.
1998-1999	Nisheeth Bahadur, Ph.D.

Visiting Scholars

2011-2012	Anping Zhang, Assoc. Prof, Zhejiang University, Hangzhou, China. Spending most of his time at Environment Canada.
2011-2012	Qi Hong, Assoc. Prof, Harbin Inst Technology, Nanjing, China
2010	Deqi Xiong, Ph.D., Dalian Maritime University, China
2006	Radka Alexy, Ph.D.

Visiting Students

2013	Sandra Brommer, University of Birmingham, U.K. PhD candidate. 3 month visit.
2012	Maria Bialo, National School for Water and Environmental Engineering of Strasbourg (ENGEES)

Research Associates

2013	Jimmy Truong
2012	Daniela Serodio
2011	Clayton Catching
2010-2011	Stefanie Verkoyoen
2008-2009	Catherine Abreu
2007-2008	Liana del Gobbo, M.Sc.
2003-2005	Nilima Gandhi, M.Sc.
2004	Julie Sommerfreund, B.Sc.
2003-2004	Buuan Lam. B.Sc.
2001-04, 06	Dianne Lapierre
2001-2004	Erin Hodge, M.Sc.
2001-2006	Jennifer Truong, B.Sc.
2000-2001	Trinh Tieu, B.A.Sc.
2000-2001	Marcy Burchfield, M.Sc.
1999-2000	Sarah Gingrich, M.Sc.
1998-1999	Edwin Tam, Ph.D.
1995-97	Cynthia Page, M.A.Sc.
1994	Lennox Gibbs, M.Eng.
1994	Hilary Freitas, M.A.Sc.
1993-1994	Helen Ling, M.Sc.

NSERC Undergraduate Research Award Recipients

2001	Kim Tsoi, Department of Chemical Engineering and Applied Chemistry.
2000	Jennifer Truong, Department of Geography.
1994	Ilan Kelman, Department of Chemical Engineering and Applied Chemistry.
1993	Rebecca Laposa, Department of Geography.

Undergraduate Summer Assistants

2013	Angela Huang
2012	Kevan Saba
2008 & 2009	Amanda Giang
2008	Kristina Dean
2007-2008	Catherine Abreu
2006	Kate Liss, Jennifer Cheung
2005	Kate Liss
2004	Veronica Lo, Rina Goldberg
2003	Bushra Drir, Talya Manoim
2002	Dianne Lapierre, Azadeh Zarashkian, Ylva Olsson
2001	Dianne Lapierre, Jennifer Truong
2000	Trinh Tieu, Dianne Lapierre.
1999	Asif Jalil, Julia Tsai.
1998	Sheryl Law*.
1997	Julie Phillips*
1996	Wilfred Tan, Judy Josefowicz (part-time)
1995	Judy Josefowicz (part-time)
1994	Martha Scroggie (part-time)
1993	David Tu*, Martha Scroggie, Melissa Fotiadis
1992	Andrew Rodie*, Hilary Freitas, Rebecca Laposa, Michelle Perera

* Environmental Youth Corps

Ontario Work-Study Plan Students

2014	Clara Thaysen
2013	Grant de Jeong
2013	Patrick Feghali
2012	Esmaeil Mansouri
2011-12	Vanessa Ymele
2006-07	Calvin Au
2005-06	Amy Leung
1999-00	Amelia Du
1995-1996	Laura Alionte
1992-1993	Andrew Rodie

12. d. OTHER TEACHING AND LECTURES

Annual	Guest lecture at Ryerson University, Environmental program.
2012	Mathematical modeling approaches to understanding environmental fate and behaviour of flame retardants. IVL Swedish Environmental Research Institute, Stockholm. Part of the INFLAME research project of the European Union. April 23,24, 2012.
2012	Interdisciplinary research. Held at University of Birmingham. Part of the INFLAME research project of the European Union. January 18-19, 2012.
2007	"Brominated flame retardants: from release to exposure", UTSC, Dept of Physical & Environmental Sciences and Centre for Environment, Master of Environmental Science.
2007	"Connecting the dots between contaminant emissions and exposure", University of Toronto, Moving Canada towards Sustainability. A forum to discuss global environmental issues.
2007	"Urban Contributions of Contaminant Load to Lake Ontario". Lake Ontario Lake-wide Management Plan (LaMP) annual meeting, Niagara, N.Y. Organized by Environment Canada and U.S. EPA.
2007	"Loadings and fate of PCBs in Hamilton Harbour from a mass balance perspective". Hamilton Harbour Remedial Action Plan (RAP) meeting.
2007	"What if the chemicals are toxic or persistent?" Urban Metabolism workshop held at University of Toronto. Organized by Prof. Chris Kennedy, Dept of Civil Engineering. Sponsored by Toronto & Region Conservation Authority.
2007	"Computer models in Great Lakes Decision-making". A panel discussion held at 49th Annual Conf. Internat. Assoc. Great Lakes Res. Windsor, Ont.
2006	"Brominated flame retardants: from release to exposure", Ryerson University, Environmental Applied Science & Management Program.
2006	"What's the burning issue with brominated flame retardants?" Physical Geography Research Day. Fall 2006.
2006	Polybromianted Diphenyl Ethers: Exposure pathways and human exposure. SENES Consultants.
2006	Brominated flame retardants – from source to exposure. Environmental Physician's Group of Ontario Medical Association, seminar series "Clinical Reviews".
2004	"Contaminants around us: the Toronto experience", Centre for Urban Health Initiatives. University of Toronto.
2004	"Polybrominated diphenyl ethers: connecting sources and exposure", Environmental Chemistry Seminar Series, Dept. of Chemistry, University of Toronto.
2004	"Chemical contaminants in the environment: from release to effects", Gartner Lee Ltd.
2003	"Cities: contaminant fate and effects", Toronto & Region Conservation Authority.
2002	"Water Quality", "Women in Science". Later Life Learning, Innis College.
2000	"Toxins in the Environment – Sources, Movement and Control Measures". Public lecture

in Green Waves Eco Talks organized by the Festive Earth Society.

1999	"Persistent Organic Pollutants: Fate in an Urban Environment and Potential Health Effects". Presentation to Toronto Public Health Department, Health Promotion and Environmental Protection, City of Toronto.
1999	Arsenic cycling in Moira Lake. Presentation in workshop organized by "How Healthy is the Moira?" committee.
1996	Science Outreach. Lecture for girls 9 to 14 on research and career opportunities.
1992	Saturday Morning Seminar Series for Secondary School Students. Lecture on Great Lakes water quality.
1988	Tutorial Assistant, University of Toronto, Dept. of Chemical Engineering
1980-1981	Tutorial Assistant, McGill University, Dept. of Biology
1976-1979	Tutorial Assistant, University of Alberta, Dept. of Zoology

E. ADMINISTRATIVE POSITIONS

13. a. SERVICE ON COMMITTEES AND ORGANIZATIONS

Initiatives:

1998-2004	Initiation, organization and Vice-chair of "Women in Arts and Science Committee", advisory to Dean of Arts and Science.
1997	Organized and chaired "Research Day" of Institute for Environmental Studies.
1997	Organized "The Great Debate" with Ruth Grier and Michael Bliss.
1996, 2000, 10	Organized or co-organized "Physical Geography Research Day" series to be held twice yearly as a forum for faculty and graduate students.
1994-1996	Involved with initiative to develop analytical facilities at University of Toronto. Member of ad hoc committee for ANALEST (Analytical Laboratory for Environmental Teaching).
1994	Developed M.Sc. Thesis option for Dept. of Geography and IES Collaborative Program.
1993	Initiated change of undergraduate program from "Physical Geography" to "Physical and Environmental Geography"

Major:

2011-2012	Dean's working group on Environment and Resources, also curriculum committee for Environmental Science program
2011-2014	Provostial Assessor, Faculty of Nursing, search committees, promotions committee
2010-2012	Member, University Tribunal Committee
2010-2012	Vice-Chair, Planning and Budget Committee of Academic Board
2009-2012	Member, Honourary Degree Committee of Academic Board
2009-2010	Member, Academic Policy and Planning Committee of Academic Board
2007-present	Coordinator, Physical Geography Building
2007-2009	Chair, Council of the Faculty of Arts and Sciences
2007-2010	School of Graduate Studies, Tenure Assessor
2007	Dean's ad hoc committee on Earth & Planetary Sciences
2007	Dean's representative, Dept. of Geology, search committee, Radiogenic Isotope Geochemistry
2004-05	Member, Search committee, Chair of Department of Geology
2004-05	Member, Search committee, Dept. of Geography, physical geography search
2004-05	Member, Search committee, Department of Physical Sciences, UTSC
2004-2008	Vice-Chair, Planning and Budget Committee of Academic Board, University of Toronto
2004-05	Governance Committee, Department of Geography
2003-04	Academic Planning Committee, Department of Geography.

2003-04	Search Committee, Department of Physics (Condensed Matter, CRC).
2003-2008	Member, Planning & Budget Committee of Academic Board, University of Toronto.
2003	Ad hoc Committee on Governance, advisory to Dean of Arts & Science.
2002	Search Committee, Physical Geography, St. George campus.
2001-2012	Member of Academic Board of Governing Council, University of Toronto.
2001	Search Committee, Technician, Physical Geography.
2001	Search Committee, Soil Science position, Scarborough College.
2000, 01	Search Committee, Physical Geography position, St. George campus.
2000	Graduate Admissions Committee, Member.
2000	Search Committee, Senior Hydrology position, Geography, St. George campus.
1999	Search Committee, Soil Science position, Scarborough College.
1999	Search Committee, Environment and Resource Management position in Geography, St. George campus.
1998	Search Committee, Hydrology position in Geography, St. George campus.
1998-99	5 Year Review Committee for Institute for Environmental Studies.
1998	Search Committee, Hydrology position at Erindale College.
1997	Chair of the Weigand Lecture committee. Organized and hosted seminars for two invited speakers.
1996	Physical Geography Research Day. Organized and chaired first of on-going series.
1994	Discover Science. Organized volunteers for demonstration in Physical Geography.
1994	Search Committee, Hydrology position at Erindale College.
1994	Science Options. Organized Dept. of Geography Information Booth. Rewrote information sheet on "Programs in Physical Geography"
1994	Member of Environmental Protection Subcommittee on Grounds/Water Use/Biodiversity.
1993-1996	Women in Science Committee, Faculty of Arts and Science Related activities: • Women in Science Faculty Advisor, Dept. of Geography; • Panelist, "Challenges and Solutions: Balancing an academic career and family responsibilities", Workshop for Women Faculty and Librarians, April 15, 1997. • "Women in Science" luncheons. Co-organized and moderated discussions. Co-sponsored by Dept. of Geography and Faculty of Arts and Science. 1996, 1994; • Forum on Women in Science, "Graduate School and Beyond". Moderated panel discussion. April, 1993.
1992-1993	Division of the Environment, Science Subcommittee.
1992	WHMIS and laboratory safety seminar. Co-organizer of seminar for Dept. of Geography.
1991-1993	Innis College Environmental Programme Committee.

Minor:

2010-2011	Provostial Assessor, Search Committee, Faculty of Physical Education and Health
2009	Member, Search Committee, Graduate Chair of Dept. of Geography
2006	Centre for the Environment: Member of advisory committee of Collaborative Program on Environment & Health.
2003-2008	Life Sciences Awards Committee, University of Toronto
2004-05	Search Committee, Paleoclimatographer Dept. of Geology (half of search)
2004-2005	Member, Ontario Graduate Student Scholarship Panel.
2004-05	Promotion Committee, tenure committee, Department of Geography
2003-04	Senior Committee, Department of Geography.
2003	Research Advisory Committee, Institute for Environmental Studies
2001	Member of Advisory Committee for Environmental Management Certificate Program, Professional Development Centre.
2000, 2003	Innis College Curriculum Review

1999-present	Collaborative Graduate Program in Environment and Health. Member of Advisory Committee.
1997-2004	Arctic Working Group. Member.
1996-2000	Environmental Engineering Faculty Council. Member.
1995-2001	Collaborative Graduate Program in Toxicology. Member of Program Committee.
1994-1997	Graduate Committee, Dept. of Geography.
1994	Ranking NSERC and OGS applications.
1994	Mathematics Sciences Review Committee.
1994	Ranking NSERC Undergraduate Student Research Awards from "non-NSERC" departments.
1992-1993	Undergraduate Committee, Dept. of Geography.

F. OTHER

Co-organizer of the following Conferences, Workshops and Conference Sessions:

2013	Co-chair, session at Dioxin 2013 Conference, Daegu, Korea
2012	Co-organizer, Discussion of a Chemical Planetary Boundary, Chalmers University, Gotenburg, Sweden, April 18-20, 2012
2008-2010	Co-chair of the annual conference of the International Association of Great Lakes Research, held at the University of Toronto, May 2010.
2009	Canadian Association for Water Quality, Central Region. 44th Annual conference. Co-chair of special symposium on Bisphenol A.
2008	Life Cycle Impact Assessment: The Clearwater Meeting on Developing Characterization Factors for Aquatic Ecotoxicity of Metals.
2007	Diversity in POPs, Co-organizer of Special Symposium at Society of Environmental Toxicology & Chemistry annual meeting, Milwaukee.
2003	SETAC, Laurentian Chapter Annual Meeting, Toronto.
1999	Lake Ontario Research and Management Workshop. Held at University of Toronto. Co-chaired by D. Mackay, Trent University, and J. DePinto, SUNY Buffalo.
1996	Life Cycle Assessment of Site Remediation Options - A Review of the Generic Approach and Case Study. Funded by Ministry of Environment and Energy. Held at Dept. of Geography, Toronto.
1992	Lake Superior Mass Balance Workshop. Funded by the International Joint Commission and Atmospheric Environment Service of Environment Canada, Toronto.
1991	Great Lakes Research Day. Sponsored by the Institute for Environmental Studies, Toronto.
1991	Great Lakes Mass Balance Workshop. Funded by the International Joint Commission, Niagara-on-the-Lake.
1990	Workshop to develop a regional model of mercury accumulation in sport fish. Held at the Institute for Environmental Studies, Toronto.

Workshop Participant:

2013	Blue Mountain Retreat. Assembled 21 experts and industry representatives to advance the agenda of toxic chemical control. June 2013.
2011	Advancing exposure science to improve chemical safety. Co-sponsored by American Chemistry Council and Health Canada, Quebec City, June 2011. Rapporteur for poster session.
2009 & 2010	SVOCs in Indoor Air, Indoor Air Institute.
2009	ScorePP: Workshop on Urban pollution sources and water treatment, Universite de Quebec

2009	Canadian Environmental Modelling Centre, Partners' Meeting, "Advances in modelling the aquatic fate and toxicity of metals", Trent University.
2009	Indoor contaminants. Workshop sponsored by US EPA, Raleigh, NC.
2009	Exposure science in the 21st century. National Research Council, 8th Workshop of the Standing Committee on Risk Analysis Issues and Reviews. Speaker "Predictive Model Frameworks: Physical Models". Washington, DC.
2008	Health and indoor environments, sponsored by National Research Council.
2008	Health-Environment Linkages, sponsored by Statistics Canada.
2007	National Policy Consultation on Children's Health and Environment. Workshop #5, Toxic Substances in Consumer Products. Respondent in discussion.
2007	Lake Ontario Lake-wide Management Plan. Annual meeting. Environment Canada and U.S. EPA.
2007	Hamilton Harbour Remedial Action Plan. Summary of Results 2007.
2007	Roundtable Discussion, Ontario Ministry of Environment, Air Pollution & Climate Change. Opportunity to discuss with Minister Laurel Brotten.
2007	City of Toronto Workshop on "Community Right to Know", developing a toxic release inventory.
2007	"Health and Environmental Tracking and Surveillance in Canada". Health Canada workshop.
2007	"Air Pollution and Children's Health" Co-sponsored by Pollution Probe, Children's Health Coalition, Health Canada. Participant.
2003	"Hazard Identification Approach for Metals and Inorganic Metal Substances", Pellston Workshop sponsored by SETAC.
2003	"Metal Unit World" workshop. Organized by Center for the Study of Metals in the Environment, University of Delaware.
2002	Retreat on science in the Meteorologic Service of Canada, Environment Canada. Organized by the Senior Scientists Committee of MSC, Environment Canada.
2001	Framework for Modelling Ecological Change in the Detroit River - Lake Erie Corridor. Panelist in a workshop sponsored by the International Joint Commission - Council of Great Lakes Research Managers'.
2000	"Northern Contaminants Workshop". Sponsored by Dept. of Indian Affairs and Northern Development.
1999	"Lake Ontario Mass Balance Workshop". Sponsored by University of Toronto, Trent University, SUNY Buffalo, Toronto.
1999	"Environmental Resource Group Meeting for the PSL2 Assessment of releases from copper and zinc smelters and refineries". Sponsored by Environment Canada, Ottawa.
1999	"How Healthy is the Moira?", Sponsored by Trent University and "How Healthy is the Moira" Committee, Peterborough, Ontario.
1999	Canadian Network of Toxicology Centres (CNTC), Annual Research Symposium, Ottawa.
1998	"Wolf Creek Research Workshop". Sponsored by Environment Canada, Whitehorse.
1997	"Environmental Resource Group Meeting for the PSL2 Assessment of releases from copper and zinc smelters and refineries". Sponsored by Environment Canada, Ottawa.
1997	"Arctic Archipelago Project Planning Meeting". Sponsored by Dept. Sponsored by Dept. of Indian Affairs and Northern Development, Iqaluit, Nunavik.
1997	"Nunavik and Northern Labrador Contaminants Action Plan Meeting". Sponsored by Dept. of Indian Affairs and Northern Development, Kuujjuaq, Nunavit.
1997	"Northern Contaminants Research Results Workshop". Sponsored by Dept. of Indian Affairs and Northern Development, Victoria 1997, Calgary 1996, Winnipeg 1994, Burlington 1993.
1994	Yukon Contaminants Workshop. Organized by Yukon Contaminants Committee.

Whitehorse, Yukon.

1993 "Evaluating the Benefits of Water Quality Improvements". Sponsored by the Ontario Ministry of Environment and Energy.

1990 & 1991 "Bay of Quinte Remedial Action Plan Workshop". Two workshops sponsored by the Ontario Ministry of Environment.

Referee for Reports:

2003 "Lake Ontario Mass Balance". Member of Scientific Review Panel, U.S. EPA.

1998 "Lake Michigan Mass Balance Program". Member of Scientific Review Panel, U.S.EPA.

1998 "Hudson River PCB Mass Balance Study". Member of Peer Review Panel, U.S. EPA.

1994 "Lower Don Lands Site Characterization and Remedial Options Study". Review for the Waterfront Regeneration Trust.

1993 "Niagara River (Ontario) Stage I RAP Report". Review for the Great Lakes Regional Office, International Joint Commission. Review included oral presentation at public information meeting in Niagara Falls, Ontario.

1991 "Arsenic and its Compounds, Priority Substances List Assessment Report". Review for Government of Canada, Health and Welfare Canada and Environment Canada under the Canadian Environmental Protection Act (CEPA).

Referee for Journals and Monographs:

Environmental Science and Technology
Environmental Pollution
Atmospheric Environment
Environmental Management
Science of the Total Environment
Journal of Great Lakes Research
Water Environment Federation
Mercury as a Global Pollutant: Towards Integration and Synthesis.

Referee for Grant Proposals:

2013 NSERC Discover Grants
2012 Israeli Environmental Health Fund
2010 NSERC, Swiss Federation of Science
2007 NSERC.CRD
2006 Large Pelagics Research Centre.
2003 NSERC Discovery Grants Program, Canada Foundation for Innovation, Canadian Foundation for Climate and Atmospheric Sciences
2001, 2002 NSERC Collaborative Research and Development Grants Program
2000 Hudson River Foundation
1998 NSERC Strategic Grant.
1997 Minnesota Sea Grant College Program
1997 Hudson River Foundation
1996 National Science Foundation.
1993 Great Lakes Research Fund.

Miscellaneous:

Numerous others that I've stopped recording.

2011 "Tracking toxins in the city: where are chemicals coming from and what does it mean?" Presentation to UTSS.

2008 "What's in the air we breathe?" Presentation at Women's Health conference.

2007 "How to stop climate change." Presentation at forum organized by MP Olivia Chow,

	Trinity-Spadina riding.
2006	Later Life Learning. "All you want to know about contaminants!"
2001	Presentation to the Walkerton Inquiry, Public Hearing 5: Regulatory and Technical Issues for Specific Sources of Contaminants; Water Quality, "Urban development and water quality protection". Toronto, Ontario.
1997, 2000	Judge for Chandler-Misener Award, International Association for Great Lakes Research.
1997	Co-chair, "Modeling chemicals in the Great Lakes: What have we learned? Where do we go from here?" International Association for Great Lakes Research 1997 Conference, Buffalo, N.Y.

Selected Media interviews*:

2014	March 20, 2014. David Fraser, CBC. Discussion about flame retardants. 30 minutes.
2013	CTV Newsworld, July 10, 2013. Live to air TV comment on environmental impact of train disaster in Lac Magantic.
-	Al Jazeera English, August 14, 2013. Video interview for posting on pay TV channel and website. About stockpile of refinery coking residue in Detroit blowing over to Windsor and broader issue of society's waste.
-	Weather Network. Microplastics. Kasia Bodurka. Phone interview Sept 17, shoot Oct 3. 2013.
-	Toronto Star, Raveena Aulakh. The environmental cost of cheap clothing. Phone interview Oct 8, 2013.
-	CBC Marketplace, Friday Oct 11, 2013. Comment on the finding in tea leaves levels of some pesticides above Health Canada guidelines. About 1.5 hours spent on research and the phone call.
	Press release from Environmental Defense. "Pre-polluted, A report on toxic substances in the umbilical cord blood of Canadian newborns", June 26, 2013.
	SRC, Radio Canada. Flame retardants. Jan 24, 2012, 30 min interview.
2012	Global TV. Telephone interview re: health risks to fire fighters. I asked not to be quoted directly since this isn't my area of expertise but I did provide background information. May 8, 2012.
	CBC Market Place, May 11, 2012
	Press release from Canadian Environmental Law Association regarding flammability standards requiring use of flame retardants. May 11, 2012.
	Global News. For on-line news. Interview regarding news of anticipation of extremely hot summer, May 16, 2012
	Global Toronto.com Interview with James Armstrong. The annual "smog" interview. June 11, 2012.
	CBC French. Comment on Peter Kent's announcement of $16 million to fight algae blooms in Great Lakes (a re-announcement of money already being spent!) Oct 9, 2012
	CBC National News, discussion about a potential story, Thurs November 29, 2012
	Toronto Star, article on flame retardants, Thurs November 29, 2012, for Monday's paper
	CFAX radio in Victoria, ½ live to air interview re: flame retardants, Thurs November 29, 2012
	Interview for magazine, Canadian Chemical News, from Chemical Institute of Canada. Tyler Irving. Monday December 3, 2012. Re: flame retardants.
	CBC TV Marketplace. November 30, 2012. Advice and guidance on program, on camera interviews in lab and on location, experimental work on location and in our lab.
	May 11, 2012. Press release from Canadian Environmental Law Association regarding flammability standards requiring use of flame retardants
	May 8, 2012. Global TV. Telephone interview re: health risks to fire fighters.
	May 11, 2012 CBC Market Place
2011	Post Canada Magazine. June 23, 2011

November 22, 2011. CBC News. Removing BPA from canned soup.
Flame retardants: are the benefits worth the risk". Participated in film clip to be used as a trailer to get funding for film with that title. Producer – James Redford), March 28, 2012
November 2011. "A consumer's guide to buying the right mattress: personal health; environmental concerns; comfort". Provided information to free-lance author of this story that was published in ....
A few Q&A with CBC researchers
March 2012. Interview with Stephen Scharper regarding deep cuts to Environment Canada, which he profiled in his column in Toronto Star

2010 CBC's Market Place (feature interview & TV shoot)
http://www.cbc.ca/marketplace/2011/lousylabels/miriamdiamond.html

2009 Interview, Zoe Cormier, for New Internationalist
CBC Radio, Here and Now. Interview on Toronto's garbage strike (July 8)
CBC Radio, The Current. Interview on "Slow Death by Rubber Duck" (June 18)
Toronto Sun, beaches water quality (July 24)
CBC TV special on the future (July 24), 20 minute hour interview
CBC.ca on-line news article on "back to school" shopping. Phthalates in kids school supplies (August 26), 1/4 hour interview
Toronto International Film Festival, article connecting "Green Porno" at TIFF with scientific perspective, 1.5 days
Toronto Sun, phone interview. Sept 18, 15 minutes. Comment on nearshore Lake Ontario water quality
Green Living magazine, interview (March 2009 appeared in April 2009) (interview)

2008 Toronto Star, Feature article, October 23, 2008.
Global TV, water pollution. Extended interview broadcast on 19X6 (interview on camera, ~1 hour)
University of Toronto magazine, short & extended interviews on toxic chemicals

2007 BC Metro Morning. June 7. Live interview, Environ Sci of the Year.
Toronto Star, June 7. Lead in drinking water.
Toronto Star, June 7. Smog and health effects (annual interview on the subject that fails to go away).
Toronto Star, July 9. Air pollution trends.
Toronto Star, July 11. Release of Stats Can report on Canadian's going "shades" of green.
Globe & Mail, July 12. Biomagnification of persistent organic pollutants.
CBC, The Nature of Things, July 16-19. Health effects of climate change and air pollution in cities. Aired November 2007.
Hamilton Spectator, July 30. Fire at pesticide plant resulting in effluents entering Spencer Creek.
CTV, Night news. July 31. Ultra fine particles from laser printers. TV shoot.
Global TV. Consultation on series on pollution. TV interview re: Toronto's major polluters, aired Wed March 7, 2007.
Radio interview, The Green Majority, CIUT. March 2.
CBC Radio, Edmonton and Calgary. April 17.
Canadian Geographic Magazine, 2 weeks, January.

* List starts in 2007

Exhibit C

Statement of David A. Eastmond

RIVERSIDE

DEPARTMENT OF CELL BIOLOGY & NEUROSCIENCE
RIVERSIDE, CALIFORNIA 92521 USA
VOICE: (951) 827-4497
FAX: (951) 827-3087

Sept. 15, 2014

To whom it may concern:

I, David A. Eastmond, am writing this statement in support of the Petition to the CPSC to ban or significantly restrict the availability of certain household products containing additive non-polymeric organohalogen flame retardants.

1. I am Professor and Chair of the Department of Cell Biology and Neuroscience, and a Research Toxicologist at the University of California, Riverside. I received B.S. and M.S. degrees from Brigham Young University, in Provo, Utah, and a Ph.D. from the University of California, Berkeley. My research focuses on the mechanisms involved in the toxicity and carcinogenicity of environmental and agricultural chemicals, with a goal to more accurately identify the potential adverse health effects associated with chemical exposures. I was a Jefferson Science Fellow at the US Department of State, and have served as President of the Environmental Mutagen Society and as Chair of the Board of Scientific Counselors for the National Toxicology Program, NIEHS. I have also participated on numerous review panels related to chemical mutagenesis, carcinogenesis and risk assessment, including panels for the US EPA, the US Food and Drug Administration, the International Programme for Chemical Safety, the International Agency for Research on Cancer, the Organisation for Economic Cooperation and Development, Health Canada, and the International Working Group for Genotoxicity Testing. In 2011, I was elected a Fellow of the Collegium Ramazzini, an organization of international scholars working towards solutions to occupational and environmental health problems occurring internationally. I am currently a member of the Carcinogen Identification Committee for the California Environmental Protection Agency and of the Chemical Assessment Advisory Committee of the US EPA. I have attached my CV and list of publications.

2. Organohalogens are often used as flame retardants in consumer products, without adequate toxicological information to assess whether or not they may be harmful to human or environmental health. To address this lack of knowledge on health effects, two of my graduate students, Virunya Bhat and Kristi Capsel, performed, under my supervision, a hazard screen of approximately 90 brominated and chlorinated flame retardants, ~85 of which are non-polymeric compounds. The list of studied chemicals includes a large number of organohalogen flame retardants (OFRs) in use or available for potential use in consumer products. The objective of the hazard screen was to determine which of these OFRs should be considered toxic, and therefore used with caution, or not used at all. The results of this study have been presented at several scientific meetings, and we are in the process of preparing a peer-reviewed journal article describing our results.

3. Using the Chemical Abstract Services (CAS) registry numbers as primary identifiers, we performed an extensive search for toxicity information on these 85 non-polymeric OFRs. Whenever possible, we searched for and used, if found, the results of existing hazard screens or

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toxicity reviews, such as those from the U.S. EPA Design for the Environment program, the Office of Environmental Health Hazard Assessment of the California Environmental Protection Agency, the World Health Organization/International Programme on Chemical Safety, the Agency for Toxic Substances and Disease Registry, the International Agency for Research on Cancer, Health Canada/Canadian Environmental Protection Agency and/or Clean Production Action. Additionally, we searched for peer-reviewed toxicity data in public databases such as Pubmed and Toxnet. Because often we could not identify peer-reviewed data in these databases, we also used other information sources, which included non-peer reviewed information or unpublished data, such as the U.S. EPA Toxic Substance Control Act Test Submissions, the Registry of Toxic Effects of Chemical Substances, the European Chemicals Agency database, and the U.S. EPA High Production Volume data submissions. We gave preference to *in vivo* data via any exposure route, rather than *in vitro* data, due to the lack of guidelines or current consensus on appropriate method(s) to determine human relevance or to extrapolate the results of *in vitro* assays when characterizing *in vivo* hazard potential. In the cases in which we could not identify any empirical data, we used Structure-Activity Relationship (SAR) models.

4. We used three related hazard screening tools: the U.S. EPA's Design for the Environment (DfE) program, the Clean Production Action's GreenScreen™, and the Washington State Department of Ecology's Quick Chemical Assessment Tool (QCAT®). All three provide a framework for identifying problematic characteristics of chemicals and then grading the chemicals according to the level of concern. Because most OFRs lacked sufficient information to use the DfE tool or run a GreenScreen™, our hazard screening was based mainly on the QCAT® methodology (Stone, 2010, 2012), with some modifications to account for the overall lack of publicly available toxicity information for the majority of chemicals.

5. The QCAT® prioritizes 9 out of the 18 hazard categories included in the more comprehensive GreenScreen™ and US EPA DfE approaches: acute mammalian toxicity, five human health hazards (carcinogenicity, reproductive toxicity, developmental toxicity, mutagenicity/genotoxicity and endocrine disruption) and three environmental hazards (acute aquatic toxicity, persistence, and bioaccumulation). These hazard endpoints are considered to pose significant threats to sensitive populations such as children, and provide a good indication of the risks associated with exposure to chemicals (Stone, 2010). The QCAT® grading process is similar to that established for the GreenScreen™. The main difference is that assigning a QCAT® score requires less information than for a GreenScreen™, meaning that the QCAT® can be performed even on chemicals for which not enough data are available to conduct a GreenScreen™, but it is not as thorough an evaluation of potential hazards posed by chemical alternatives as the GreenScreen™. However, if a chemical is found to be a poor alternative using the QCAT methodology, it will also be a poor candidate using the GreenScreen™ methodology. There remains a chance that a chemical not rejected by QCAT® could still prove to be unsatisfactory if a more complete review is done using methods like the GreenScreen™.

6. To perform our hazard assessment, we assigned concern levels for each hazard category, such as Low, Moderate, or High, based on the available information. Examples are provided below.

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a. Acute Mammalian Toxicity: We assigned the hazard scores based preferentially on the most potent empirical oral, inhalation, and/or dermal LD_{50} (the dose that is lethal to 50% of a population of test animals) values. When empirical LD_{50} data were not identified, SAR predictions (rat oral LD_{50}) were used to assign the score.
b. Carcinogenicity: Cancer bioassays were found for 8 of the studied OFRs, resulting in all of these OFRs being listed as carcinogens by authoritative bodies (i.e. "High" concern). Since most of the screened OFRs did not have empirical carcinogenicity data, the ISS and Oncologic QSAR models (OECD Toolbox, 2012) were used to identify a structural alert for carcinogenicity. If a structural alert was identified, we assigned a hazard score of "Moderate".
c. Reproductive toxicity: Two chemicals listed by an authoritative source as reproductive toxicants were rated as "High" concern. For a limited number of OFRs for which a two-generation reproduction study was identified, we assigned concern levels based on NOAEL values identified from these studies. Less than one-third of the OFRs screened had data to assess reproductive toxicity. We did not conduct SAR modeling of reproductive toxicity, due to the lack of guidelines for the use of SAR modeling tools for this hazard category.
d. Developmental toxicity: The same two chemicals listed by an authoritative source as reproductive toxicants were also listed as developmental toxicants, and thus rated as "High" concern. When developmental toxicity studies were identified, we assigned concern levels based on NOAEL values from these studies. For most of the OFR, we used VEGA Caesar (2012) and/or U.S. EPA (2011) Toxicity Estimation Software Tool (T.E.S.T.) software to predict developmental toxicity potential due to the lack of empirical data. If predicted positive, we assigned a hazard score of "Moderate".
e. Mutagenicity/Genetic Toxicity: One OFR, TCEP (tris(2-carboxyethyl) phosphine, CAS#115-96-8), was listed by an authoritative source as a Global Harmonization System (GHS) category 1B germ cell mutagen (i.e. "High" concern). For the other OFRs, the scores were based, when possible, on empirical data, most commonly *Salmonella* reverse mutation assays. A few chemicals were negative in *Salmonella* assays but positive in other assays of genetic toxicity. In this case, we applied a hazard score of "Moderate". When mutagenicity data were not identified, we used the ISS Quantitative Structure-Activity Relationship (QSAR) model (OECD Toolbox, 2012) to identify molecular functional groups or substructures considered to be structural alerts for *in vivo* or *in vitro* mutagenicity.
f. Endocrine disruption: A few OFRs were listed as known or suspected endocrine disruptors by authoritative sources. Most of the other OFRs lacked empirical data specifically assessing endocrine disruption. Due to the current lack of SAR models to

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predict endocrine disruption, no further modeling was done. This hazard category was the most prevalent one for data gaps.

g. Acute aquatic toxicity: Those chemicals classified as toxic to aquatic organisms by an authoritative source were designated as "High" concern. For the others, the score was based on empirical LC_{50} (the lethal concentration to 50% of the organisms tested) or EC_{50} (the concentration that affects 50% of the organisms) values when identified. When empirical data were not identified, we used the U.S. EPA (2011) ECOSAR software to predict acute aquatic toxicity.
h. Persistence: OFRs that have been classified as POP (Persistent Organic Pollutants) or PBT (Persistent, Bioaccumulative and Toxic) were designated as "High" concern. Most screened OFRs did not have empirical data available for these parameters. For these, the hazard score for persistence was based on the most conservative EPISuite model estimates for half-life in soil, water and sediment.
i. Bioaccumulation: For the OFRs that were not listed or classified as a POP or PBT, the hazard score for bioaccumulation was based on octanol-water partition coefficients (K_{ow}) and bioaccumulation or bioconcentration factors, which were predicted using U.S. EPA (2011) EPISuite software when empirical data could not be identified.

7. Data gaps posed the greatest challenge in this study, and as indicated above, we often had to rely on QSAR modeling. It should be noted that QSAR models are often based on SMILES structures, which are sometimes not unique for every chemical, and the models are likely not calibrated specifically for OFRs. Therefore, we interpreted the modeling results with caution and did not rely solely upon them to denote chemicals of "High" concern. I would like to emphasize that the QCAT® methodology we used is generally health-protective. While it may not find all substances of concern, when it does, that result is defined according to independently established criteria and would be sufficient to warrant concern prompting further investigation or a search for a suitable alternative with a lower degree of concern.

8. On the basis of these data and model results, we assigned each chemical both an initial and a final grade based on QCAT® criteria, where:

"A" means few concerns / preferable,
"B" means the chemical raises slight concerns / improvement possible,
"C" means the chemical raises moderate concern / use but search for safer alternatives,
"D" means the chemical is of high concern / avoid
"F" means the chemical is toxic/do not use.

Chemicals received an automatic F if they were assigned a "High" score for any of the 5 priority human health endpoints. The initial grade considers only the concern levels based on empirical data and model results. The final grade assigned by the QCAT® model includes penalties for excessive data gaps.

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9. The results of our on-going hazard screen are presented in draft form in the attached summary table. Italicized hazard scores denote that QSAR model results and/or low confidence empirical data served as the basis of the score. As the table shows, the initial grades for all of the evaluated organohalogen flame retardants were C or worse: 9 OFRs received C grades, 26 received D grades, and the remaining 48 received F grades. In the final grading step, 5 OFRs received D grades, and the remaining 78 received F grades. Five polymers and 3 OFRs with inadequate chemical information to allow for scoring were excluded from these tallies. These low grades were due to empirical data suggesting high hazard, SAR model predictions, and/or excessive data gaps. Carcinogenicity was the most prominent potential health hazard identified based on empirical data. Endocrine disruption exhibited the most prevalent data gaps.

10. In conclusion, all of the non-polymeric OFRs that we have screened using the QCAT® and related methodologies were found to be either of high concern or toxic based on the criteria described above. The results of our screening show that critical toxicological data are lacking for many OFRs, and that those for which data are available have the potential to pose significant hazards for human or environmental health.

Sincerely,

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Chemical Name	Abbrev. (Bergman 2012)	CAS #	Initial Grade	Final Predicted Grade (SAR included)	Acute toxicity	Carcinogenicity	Reproduction	Development	Mutagenicity/ Genotoxicity	Endocrine Disruption	Acute Aquatic	Persistence	Bioaccumulation
1H-Indene, 4,5,6,7-tetrabromo-2,3-dihydro-1,1,3-trimethyl-3-(2,3,4,5-	OBTMPI	1084889-51-9, 893843-07-7,	F	F		M	dg	M	L	dg	L	vH	L
Benzene, 1,1'-oxybis [2,3,4,5,6-pentabromo- or Decabromodiphenyl ether	DecaBDE	1163-19-5	F	F	L	M			L	dg	L		H
Phenol, 2,4,6-tribromo-	TBP	118-79-6	F	F	H	M	H	M	L	M	vH	vH	M
Phenol, 2,4,6-tribromo-3-	TBPD-TBP	168434-45-5	C	F	M	L	dg	dg	L	dg	L	vH	L
Benzene, 1,2,4,5-tetrabromo-3,6-dimethyl-	TBX	23488-38-2	D	F	L	M	dg	dg	L	dg	M	vH	vH
1,3,5-Triazine, 2,4,6-tris(2,4,6-	TBP-TAZ	25713-60-4	F	F	L	L	L	L	L	dg		vH	H
Benzene, dibromoethenyl-	DBS	31780-26-4	D	F	M	M	dg	M	L	dg	M	vH	L
1,4,-Bis(2,4,6-tribromophenoxy)-2,3-dibromobutene	OBPB	31977-87-4	D	F	M	L	dg	M	L	dg	L	vH	L
Pentabromodiphenyl ether	Penta BDE	32534-81-9	F	F	L	M	M		L				vH
Octabromodiphenyl ether	Octa BDE	32536-52-0	F	F	L	M			L	M			M
N-N-Ethylene-bis(tetrabromophthalimide	EBTEBPI	32588-76-4	D	F	L	M	L	L	L	dg	L		H
Benzene, 1,3,5-tribromo-2-(2-propen-1-	TBP-AE	3278-89-5	D	F	L	L	dg	M	L	dg	L	vH	H
Phenol, 4,4'-(1-methylethylidene)bis[2,6-dibromo-, 1,1'-diacetate	TBBPA-BOAc	33798-02-6	F	F	M	M	dg	M	M	dg	L	vH	vH
Bicyclo[2.2.1]hept-2-ene, 1,2,3,4,7,7-hexachloro-5-(2,3,4,5-tetrabromophenyl)-	HCTBPH	34571-16-9	C	D	M	M	dg	dg	L	dg	L	vH	L
Benzene, 1,3,5-tribromo-2-(2,3-	TBP-DBPE	35109-60-5	F	F	M	M	dg	M	M	dg	L	vH	vH
Benzene, 1,2,3,4,5-pentabromo-6-(2-propen-1-yloxy)-	PBP-AE	3555-11-1	F	F	M	L	dg	M	L	dg	L	vH	vH
1,2-Bis(2,4,6-tribromophenoxy)ethane	BTBPE	37853-59-1	F	F	L	M	dg	L	L	dg		vH	H
Benzene, 1,2,3,4,5-pentabromo-6-	PBBB	38521-51-6	F	F	L	M	dg	M	M	dg		vH	vH
Benzene, 1,2,3,4-tetrabromo-5-chloro-6-	TBCT	39569-21-6	D	F	M	M	dg	M	L	dg	M	vH	vH
Phenol, 4,4'-sulfonylbis[2,6-dibromo-	TBBPS	39635-79-5	D	F	L	L	dg	M	L	dg	L	vH	H
Benzene, 1,1'-sulfonylbis[3,5-dibromo-4-(2,3-dibromopropoxy)- AKA	TBBPS-BDBPE	42757-55-1	C	F	M	M	dg	M	M	dg	L	vH	M
Benzene, 1,1'-[oxybis(methylene)]bis[2,3,4,5,6-	DBDBE	497107-13-8	C	F	M	L	dg	M	L	dg	L	vH	L

Chemical Name	Abbrev. (Bergman 2012)	CAS #	Initial Grade	Final Predicted Grade (SAR included)	Acute toxicity	Carcinogenicity	Reproduction	Development	Mutagenicity/ Genotoxicity	Endocrine Disruption	Acute Aquatic	Persistence	Bioaccumulation
1,3,5-Triazine-2,4,6(1H,3H,5H)-trione, 1,3,5-tris(2,3-dibromopropyl)-	TDBP-TAZTO	52434-90-9	F	F	M	M	dg	M	M	dg	L	vH	vH
1,3,5-Triazine-2,4,6(1H,3H,5H)-trione, 1-(2,3-dibromopropyl)-3,5-di-2-propen-1-yl-	DBP-TAZTO	57829-89-7	D	F	L	M	dg	M	L	dg	M	vH	H
Benzene, 1,2,3,4,5-pentabromo-6-	PBBC	58495-09-3	F	F	H	M	dg	M	M	dg	L	vH	vH
Benzene, 1,2,4,5-tetrabromo-3,6-bis(2,3,4,5,6-pentabromophenoxy)-	4'-PeBPOBDE208	58965-66-5	D	F	L	L	dg	M	M	dg	L	vH	L
2-Propenoic acid, (2,3,4,5,6-pentabromophenyl)methyl ester	PBB-Acr	59447-55-1	F	F	H	M	dg	M	M	M	L	vH	vH
Phenol,2,3,4,5,6-pentabromo-	PBP	608-71-9	F	F		M	dg	dg	L			vH	M
Phenol, 2,4-dibromo-	DBP	615-58-7	F	F		M		M	L		M	vH	L
Phenol, 4,4'-(1-methylethylidene)bis[2,6-dibromo-, polymer with 2,2'-[(1-		68928-70-1	C	F	L	M	L	L	M	dg	L	vH	L
Benzene, 1,1'-sulfonylbis[3,5-dibromo-4-	TBBPS-BME	70156-79-5	F	F	M	L	dg	M	L	dg	L	vH	vH
Tetrabromophthalic anhydride or 4,5,6,7-tetrabromo-2-benzofuran-1,3-dione		72625-95-7	F	F	H	L	dg	dg	M	dg	L	vH	H
Decabromodiphenylethane	DBDPE	84852-53-9	F	F	L	M	dg	L	L	dg	L	vH	H
Benzene, 1,2,3,4,5-pentabromo-6-ethyl-	PBEB	85-22-3	F	F	L	M	dg	M	L	M	L	vH	vH
1,2,3,9-Tetrabromo-1,2,3,4-tetrahydro-1,4-methanonaphthalene	TTMN	855992-98-2			dg		dg	dg	dg	dg			
1,2,3,9-Tetrabromo-1,2,3,4-tetrahydro-1,4-methanonaphthalene	TTMN	855993-01-0	D	F	M	L	dg	M	L	dg	L	vH	M
Benzene, 1,2,3,4,5,6-hexabromo-	HBB	87-82-1	F	F	M	M	dg	L	L	dg		vH	H
Benzene, 1,2,3,4,5-pentabromo-6-methyl-	PBT	87-83-2	F	F	H	M	dg	L	L	M	L	vH	vH
Brominated epoxy resin end-capped with tribromophenol		135229-48-0	C	F	L	L	L	L	L	dg	L	vH	L
Poly(dibromostyrene): Benzene, ethenyl-, ar-bromo derivs., homopolymers	FIREMASTER CP44-HF & PBS-64HW	148993-99-1			dg		dg	dg	dg	dg		dg	dg
Polypentabromobenzyl acrylate PBB-MA Brominated polyacrylate or 2-Propenoic		59447-57-3	C	F	L	M	L	L	M	dg	L	vH	L

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Benzene, ethenyl-, homopolymer, brominated or Brominated polystryene	na	88497-56-7	C	F	L	L	L	L	L	dg	L	vH	L
1-Propanol, 2,3-dibromo-, 1,1',1"-	TDBPP	126-72-7	F	F	M					dg		M	L
1-Propanol, 3-bromo-2,2-bis(bromomethyl)-, 1,1',1"-phosphate	TTBNPP	19186-97-1	D	F	L	M	H	H	M	dg	L	H	M
Tetrabromophthalic anhydride	TEBP-Anh	632-79-1	D	F	M	L	dg	dg	L	dg	M	vH	H
Bis(pentabromobenzyl)	BPBTB	82001-21-6	D	F	M	M	dg	M	M	dg	L	vH	L
Bis(pentabromobenzyl) terephthalate	BPBTerP	90075-91-5	D	F	H	L	dg	M	M	dg	L	vH	L
Benzoic acid, 2,3,4,5-tetrabromo-, 2-ethylhexyl ester	EH-TBB	183658-27-7	D	D	L	M	M	M	L	dg	L	vH	L
1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, 1-[2-(2-hydroxyethoxy)ethyl] 2-	HEEHP-TEBP	20566-35-2	D	F	L	M	dg	M	L	dg	M	H	L
1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, 1,2-bis(2-ethylhexyl) ester	BEH-TEBP	26040-51-7	F	F	L	M	dg	L	M	dg		vH	L
1,3,5-Triazine-2,4,6(1H,3H,5H)-trione, 1,3-bis(2,3-dibromopropyl)-5-(2-propen-1-yl)-	BDBP-TAZ	75795-16-3	F	F	M	M	dg	M	M	dg	L	vH	vH
1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, mixed esters with diethylene		77098-07-8	C	F	M	M	dg	M	M	dg	L	vH	L
Ethanol, 2-chloro-, phosphate (3:1)	TCEP	115-96-8	F	F	M					dg		vH	L
Tris(1-chloro-2-propyl)phosphate	TCIPP	13674-84-5	C	D	M	M	L	L	L	dg	M	vH	L
2-Propanol, 1,3-dichloro-, phosphate (3:1)	TDCIPP	13674-87-8 (see isomer 78-43-3)	F	F	L		M	M	M	dg	M	vH	L
Tetrakis(2-chloroethyl)dichloroisopentyldiphosphate	BCMP-BBCP	38051-10-4	C	F	L	M	M	M	L	dg	M	vH	L
Tris(2,3-dichloro-1-propyl)phosphate		66108-37-0	D	F	M	L	dg	M	M	dg	M	vH	L
2,3-dichloro-, 1,1,1-phosphate propanol	TDCPP	78-43-3 (see isomer 13674-87-8)	F	F		M	dg	M		dg	M	vH	L
Cyclodecane, hexabromo-	HBCYD	25495-98-1	F	F	L	M	dg	M	M	dg	L		
1,2,5,9,10-Hexabromocyclodecane	unspecified HBCD	25637-99-4	F	F	L	M	H	H	L	H	H		
1,2,5,9,10-Hexabromocyclodecane	HBCDD	3194-55-6	F	F	L	M	H	L	L	M			
Cyclooctane, 1,2,5,6-tetrabromo-	TBCO	3194-57-8	F	F	L	M	dg	dg	L	dg	vH	vH	H
Cyclohexane, 1,2-dibromo-4-(1,2-	DBE-DBCH	3322-93-8	F	F	L	M	dg	M	H		L	vH	L

Chemical Name	Abbrev. (Bergman 2012)	CAS #	Initial Grade	Final Predicted Grade (SAR included)	Acute toxicity	Carcinogenicity	Reproduction	Development	Mutagenicity/ Genotoxicity	Endocrine Disruption	Acute Aquatic	Persistence	Bioaccumulation
Chlorendic anhydride aka 4,7-Methanoisobenzofuran-1,3-dione, 4,5,6,7,8,8-hexachloro-3a,4,7,7a-	HCBCH-DCAnh	115-27-5	C	D	L	H	M	L	L	dg	M	vH	L
Chlorendic acid	HCBCH-DCA	115-28-6	F	F	M		M	M	M	dg	M	vH	vL
1,4:7,10-Dimethanodibenzo[a,e]cyclooctene, 1,2,3,4,7,8,9,10,13,13,14,14-dodecachloro-	DDC-CO	13560-89-9	D	F	L	M	L	L	L	dg	L	vH	H
1,3,4-Metheno-1H-cyclobuta[cd]pentalene, 1,1a,2,2,3,3a,4,5,5,5a,5b,6-dodecachlorooctahydro-	MIREX	2385-85-5	F	F	vH				L		M		
1,4:6,9-Dimethanodibenzofuran, 1,2,3,4,6,7,8,9,10,10,11,11-dodecachloro-1,4,4a,5a,6,9,9a,9b-octahydro-	DDC-DBF	31107-44-5	F	F		M	dg	dg	M	H	vH		
hexachlorocyclopentadienyl-	DBHCTD	51936-55-1	F	F	L	M	dg	M	L	dg	L	vH	H
1-Propanol, 3-bromo-2,2-bis(bromomethyl)-	TBNPA	1522-92-5	F	F	L	M	dg	dg		dg	M	vH	L
1,3-Propanediol, 2,2-bis(bromomethyl) OR 2,2-Bis(bromomethyl)-1,3-propanediol	DBNPG	3296-90-0	F	F	M		M	M		dg	M	H	L
1-Propanol, 2,2-dimethyl-, tribromo derive. (Tribromoneopentylalcohol)		36483-57-5	D	F	L	M	dg	dg	M	dg	vH	vH	L
Flamestab Nor 116 or 1,3-Propanediamine, N,N'-1,2-ethanediylbis-,		191680-81-6			L	dg	dg	dg	dg	dg	dg	dg	dg
Alkanes, C10-13, chloro	SCCP	85535-84-8; 71011-	F	F	L		dg	M	L	M		vH	
Medium chain chlorinated paraffins (more DATA in ECHA)	MCCP	85535-85-9	F	F	L				M	M		vH	H
1,3-Isobenzofurandione, 4,5,6,7-tetrachloro- (TETRACHLOROPHTHALIC	TCP-Anh	117-08-8	C	D	L	M	L	L	L	dg	L	vH	M
1,4:5,8:9,10-Trimethanoanthracene, 1,2,3,4,5,6,7,8,12,12,13,13-dodecachloro-1,4,4a,5,8,8a,9,9a,10,10a-decahydro-	DDC-Ant	13560-92-4	D	F	M	M	dg	dg	L	dg	L	vH	L
Benzene, 1,1'-(1-methylethylidene)bis[3,5-dibromo-4-(2,3-dibromopropoxy)-	TBBPA-BDBPE	21850-44-2	F	F	L	M	M	M	M	dg	L	vH	H
Benzene, 1,1'-(1-methylethylidene)bis[3,5-dibromo-4-(2-propen-1-yloxy)-	TBBPA-BAE	25327-89-3	D	F	L	L	dg	M	L	dg		vH	vH

Chemical Name	Abbrev. (Bergman 2012)	CAS #	Initial Grade	Final Predicted Grade (SAR included)	Acute toxicity	Carcinogenicity	Reproduction	Development	Mutagenicity/ Genotoxicity	Endocrine Disruption	Acute Aquatic	Persistence	Bioaccumulation
Oxirane, 2,2'-[(1-methylethylidene)bis[(2,6-dibromo-4,1-phenylene)oxymethylene]]bis-	TBBPA-BGE	3072-84-2	D	F	*H*	*M*	dg	*M*	*M*	dg	*L*	*vH*	*M*
Phenol, 4,4'-(1-methylethylidene)bis[2,6-dibromo-, dipropanoate (9Cl)	TBBPA-BP	37419-42-4	D	F	*M*	*M*	dg	*M*	*M*	dg	*L*	*vH*	*H*
Benzene, 1,1'-(1-methylethylidene)bis[3,5-dibromo-4-methoxy- AKA TETRABROMOBISPHENOL A BME	TBBPA-BME	37853-61-5	D	F	*L*	*M*	dg	*H*	*L*	dg	*M*	*vH*	*H*
Ethanol, 2,2'-[(1-methylethylidene)bis[(2,6-dibromo-4,1-phenylene)oxy]]bis-	TBBPA-BHEE	4162-45-2	F	F	*H*	*L*	dg	*M*	*M*	dg		*vH*	*vH*
2-Propenoic acid, 1,1'-[(1-methylethylidene)bis(2,6-dibromo-4,1-	TBBPA-BA	55205-38-4	D	F	*M*	*L*	dg	dg	*M*	dg	*L*	*vH*	*H*
2-Propenoic acid, 1,1'-[(1-methylethylidene)bis[(2,6-dibromo-4,1-	TBBPA-BHEEBA	66710-97-2	D	F	*M*	*L*	dg	*M*	*M*	dg	*L*	*vH*	*H*
Phenol, 4,4'-(-methylethylidene)bis[2,6-	TBBPA	79-94-7	F	F	L	*M*		*H*	L			*vH*	
1,2,5,9,10-Hexabromocyclodecane	γ-HBCD	134237-52-8	F	F	*L*	*M*	*H*	*M*	*L*	*H*	*H*		
1,2,5,9,10-Hexabromocyclodecane	α-HBCD	34237-50-6	F	F	*L*	*M*	*H*	*M*	*L*	*H*	*H*		
1,2,5,9,10-Hexabromocyclodecane	β-HBCD	34237-51-7	F	F	*L*	*M*	*H*	*M*	*L*	*H*	*H*		
2,2',4,4'-Tetrabromodiphenyl ether	BDE-47	5436-43-1	F	F	*M*	*M*			*M*	*H*	*M*	*vH*	*vH*

CURRICULUM VITAE

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EDUCATION: University of California, Berkeley, California, Ph.D., Environmental Health Sciences (Toxicology), 1987.

Brigham Young University, Provo, Utah, M.S., Entomology, 1983.

Brigham Young University, Provo, Utah, B.S., Zoology, 1980.

PROFESSIONAL EXPERIENCE:

Professor, Environmental Toxicology Graduate Program and Department of Cell Biology & Neuroscience, University of California, Riverside, California; Assistant professor 1990-1996, Associate professor 1996-2000, Professor 2000-present, Graduate Program Chair, 1999-2004, 2005-08, Interim Director, UC Washington Center and UC Sacramento programs at UCR, 2007-08; Department Chair, 2008-present.

Assistant Research Toxicologist, Department of Biomedical and Environmental Health Sciences, University of California, Berkeley, California, 1989.

Alexander Hollaender Distinguished Postdoctoral Fellow in Genetic and Molecular Toxicology, Biomedical Sciences Division, Lawrence Livermore National Laboratory, University of California, Livermore, California, 1987-1989.

Research assistant in biochemical toxicology, University of California, Berkeley, California, 1983-1987.

Intern with the Environmental Effects Branch, Office of Toxic Substances, Environmental Protection Agency, Washington, D.C., 1983.

Research assistant in environmental toxicology, Brigham Young University, Provo, Utah. 1979-1983.

Field supervisor for a seed alfalfa integrated pest management project directed by Utah State University, Delta, Utah, summer 1979.

Field technician conducting environmental impact-related studies directed by BYU for the Department of Energy, Raft River, Idaho, summer 1978.

TEACHING EXPERIENCE:

Instructor for a graduate-level Principles of Toxicology course (ENTX 201) at UC Riverside

Instructor for a graduate-level and an undergraduate level Risk Assessment courses (ENTX 154 & 220) at UC Riverside.

Lead instructor for a graduate-level seminar course (ENTX 270) at UC Riverside

Lead instructor and co-instructor for a graduate-level Mechanisms of Toxicity course (ENTX 202) at UC Riverside

Co-instructor for an undergraduate-level Cancer Biology course (ENTX 150) at UC Riverside

Instructor for freshman-advising seminars (NASC 91 and 93) at UC Riverside

Instructor for an Environmental Toxicology course (Env. Sci. X100) taught through the UC Riverside Extension.

Teaching assistant in the General Biology, Introductory Entomology, Human Physiology, and Comparative Toxicology classes at Brigham Young University.

OTHER PROFESSIONAL EXPERIENCE:

Member, Chemical Assessment Advisory Committee, Science Advisory Board, U.S. Environmental Protection Agency, Nov. 4, 2013 - Sept. 30, 2016

Member, Carcinogen Identification Committee, Science Advisory Board, Office of Environmental Health and Hazard Assessment, State of California, 1999 - 2003, 2005 to present.

Associate Director, NIEHS Training Program in Environmental Toxicology at University of California, Riverside, July 1, 2010 - present.

Member, Genotoxicity Test Guidelines Working Group, Organisation for Economic Cooperation and Development Sept. 2010 - present.

Member, Genetic Toxicology Technical Committee Steering Team, Health and Environmental Sciences Institute, International Life Sciences Institute, Jan. 2013 - present.

Member, Working Group on Quantitative Approaches and Non-Linear Dose-Response Relationships in Genotoxicity Assessment, International Working Group on Genotoxicity Testing, Jan. 2013 - present.

Chair, Board of Scientific Counselors, National Toxicology Program, NIEHS, Member, Jan. 2009 – Dec. 2012, Chair, Feb. 2011 – Dec. 2012.

Participant, Research Participation Program, National Center for Environmental Assessment, Environmental Protection Agency, 2008 – 2011.

Co-chair, Expert Panel on Genotoxicity Testing of Pharmaceuticals, Center for Drug Evaluation and Research, Food and Drug Administration, Jan. 2010.

Member, Risk and Technology Review Panel, Science Advisory Board, Environmental Protection Agency, July 2009 - Jan. 2010.

Council Member, National Council on Radiation Protection and Measurements, 2004 to 2010; consociate member, 2010 - present.

Editorial board member for the journals *Toxicological Sciences* (2007 – present), *Mutation Research, Genetic Toxicology and Environmental Mutagenesis* (1994 - present), and *Chemico-Biological Interactions* (1998 - 2001).

Member, Working group, International Agency for Research on Cancer, Working group meeting on pharmaceuticals, Oct. 2008.

Chair, WHO/IPCS international expert meetings to conduct an update of the "IPCS harmonization of methods for the prediction and quantification of human carcinogenic/mutagenic hazard", April 2007 and June 2008.

Working group member, International Agency for Research on Cancer, Working group meeting on ethylene oxide, 1,3-butadiene, vinyl chloride, vinyl bromide, and vinyl fluoride, June 2007.

Advisor to the US Environmental Protection Agency and conducted detailed reviews of the following topics: Chemical and radiation-induced leukemogenesis in humans and rodents and the value of rodent models for assessing risks of lymphohematopoietic cancers, 1995-96; The use of genetically modified animals in the cancer risk assessment process, 2001; Genotoxicity of carbon tetrachloride and its implications for mode-of-action and dose response decisions, 2006; Conducted a review of the literature on “Childhood leukemia: origins and biomarkers” 2005-2006; Conduced a review of the genotoxicity and mode-of-action sections of the draft toxicological review of 1,2,3-trichloropropane (NCEA-S-1669), 2007; Lymphohematopoietic Cancers Induced by Chemicals and Other Agents: Overview and Implications for Risk Assessment, 2012.

Invited expert for the USEPA “Peer Consultation Workshop on Research Needs Related to the IRIS Draft Toxicological Review of Naphthalene”, April 2005

Invited specialist, International Agency for Research on Cancer, Working Group meeting on Formaldehyde, 2-butoxyethanol, and propylene glycol mono-t-butyl ether, June 2004.

Program chair, 34th Annual meeting of the Environmental Mutagen Society, Miami Beach, Florida, May 10-14, 2003.

Member, ILSI Risk Science Institute Steering Committee for Screening Tests for Toxic Chemicals, 2002-05.

Reviewer of Public Health Goal Documents, Risk Assessment Documents or Proposed Guidelines for the US Environmental Protection Agency (EPA), 1999, 2004 and the California EPA, Office of Environmental Health Hazard Assessment, 1998, 2001, 2002, 2004, 2005, 2006, 2008.

Invited participant to the ILSI/Health Canada peer consultation panel on "Genotoxicity for Categorisation of "Inherent Toxicity" to Humans under CEPA '99", 2002.

Council member, Environmental Mutagen Society, April 1997-2000.

Panel member, US Environmental Protection Agency's Expert Panel Peer Review of Benzene Risk Assessment Update, June-July 1997.

Research associate, Statewide Air Pollution Research Center, Riverside, California.

Invited participant in the World Health Organization's International Programme on Chemical Safety Task Group to finalize the Environmental Health Criteria for Hydroquinone. Carshalton Surrey, United Kingdom May 1993.

Reviewer of manuscripts for *American Journal of Human Genetics; Archives of Biochemistry and Biophysics; Archives of Environmental Contamination and Toxicology*; *Biochemie*; *British Journal of Cancer; Bulletin of Environmental Contamination and Toxicology; Cancer Epidemiology, Biomarkers and Prevention*; *Cancer Letters: Cancer Research*; *Chemico-Biological Interactions*; *Critical Reviews in Toxicology; Cytometry; Environmental and Molecular Mutagenesis*; *Environmental Health Perspectives*; *Environmental Pollution; Environmental Science & Technology; Environmental Toxicology & Pharmacology; Genes, Chromosomes and Cancer*; *Genetics and Molecular Biology*; *Human Genetics; International Journal of Environmental Research and Public Health; International Journal of Environmental Research and Public Health; International Journal of Radiation Biology; Journal of Agriculture and Food Chemistry; Journal of Toxicology and Environmental Health; Leukemia; Mutagenesis*; *Mutation Research; Oncology Research; Pediatrics; Proceedings of the National Academy of Sciences; Toxicological Sciences; Radiation Research; Toxicology Letters; Toxicology and Applied Pharmacology; Vaccine.* 1987-present.

Member of the Society of Toxicology's ad hoc Tox 90s Educational Issues Task Force 1991-1993.

Reviewer of Grant Proposals, Pre-proposals/Fellowship Applications, or Cooperative Research Agreements for the U.S. Environmental Protection Agency (1989), the Air Force Office of Scientific Research (1990), Center for Indoor Air Research (1995), NIEHS Small Business Grants (1995, 96, 97, 03), Flanders (Belgium) Fund for Scientific Research (1998), UC MEXUS (2003), Health Effects Institute (1994, 2005), University of California Biotechnology Research and Education Program (2005 and 2006), University of California Toxic Substances Research and Teaching Program (1992, 2007 and 2008).

Invited Participant in a peer review session to recommend acceptable levels of polycyclic aromatic hydrocarbons in the Great Lakes for the International Joint Commission, 1982.

Selected Participant in a tropical biology research project on the function of buttressing in tropical trees, Barro Colorado Island, Panama, 1982.

Participant in a marine biology field experience, focusing primarily on intertidal ecology, Friday Harbor, Washington, 1980.

AWARDS AND RECOGNITIONS:

Article by Bhat, Hester, Nesnow and Eastmond was selected as "One of the Best Papers Advancing the Science of Risk Assessment" by the Risk Assessment Specialty Section of the Society of Toxicology at its 2014 annual meeting, March 2014.

Recipient of the Perry J. Gehring Best Graduate Student Abstract Mentor Award by the Risk Assessment Specialty Section of the Society of Toxicology at its 2013 annual meeting, March 2013.

Elected Fellow of the Collegium Ramazzini, Nov. 2011

Jefferson Science Fellow, US Department of State (administered by the National Academy of Sciences), Washington DC, 2004-2005.

President, Environmental Mutagen Society, May 2003-Oct. 2004.

Outstanding Environmental Toxicology Faculty/Mentor award presented by the students of the Environmental Toxicology Graduate Program, University of California, Riverside, 2001, 2007 and 2011.

Alexander Hollaender Distinguished Postdoctoral Fellow, U.S. Dept. of Energy, 1987-1989.

Outstanding Postdoctoral Research Presentation, Genetic and Environmental Toxicology Association of Northern California, 1988.

Selected New Investigator, Society of Toxicology, 1987.

Recipient of the Margaret Beattie Award for Excellence in the Laboratory Sciences, School of Public Health, U.C. Berkeley, 1987.

Honorable Mention, Society of Toxicology Mechanisms Award, 1987.

Outstanding Graduate Student Research Presentation, Genetic and Environmental Toxicology Association of Northern California, 1986.

Thesis selected as the Outstanding Thesis of the College of Biological and Agricultural Sciences at BYU, 1983.

Various Fellowships and Traineeships, U.C. Berkeley, 1983-1987.

Sigma Xi Research Society, 1982.

Phi Kappa Phi Honor Society, 1980.

Alvin S. Barrett Scholarship, Brigham Young Univ., 1974-75, 1977-80.

SOCIETY MEMBERSHIPS:

Environmental Mutagenesis and Genomics Society

Society of Toxicology (National and Southern California Chapters)

Collegium Ramazzini

American Association for the Advancement of Science

BIBLIOGRAPHY

David A. Eastmond, Ph.D.

PUBLICATIONS

1. Vassilaros, D.L., Eastmond, D.A., West, W.R., Booth, G.M., and Lee, M.L. (1982). Determination and Bioaccumulation of Polycyclic Aromatic Sulfur Heterocycles in Aquatic Biota. In: Polynuclear Aromatic Hydrocarbons: Physical and Biological Chemistry, M. Cooke, A.J. Dennis, and G.L. Fisher (Eds.), Battelle Press, Columbus, pp. 845-857.

2. Porter, S., and Eastmond, D.A. (1982). *Euryopsis coki* (Therididae), A Spider that Preys on *Pogonomyrmex* Ants. J. Arachnology 10, 275-277.

3. Eastmond, D.A., Meuhle, C.M., Price, R.L., Hutchens, C.A., Booth, G.M., and Lee, M.L. (1983). Acute Toxicity, Bioconcentration, and Elimination of a Coal Liquid in Freshwater Organisms. In: Polynuclear Aromatic Hydrocarbons: Formation, Metabolism, and Measurement, M. Cooke and A.J. Dennis, (Eds.), Battelle Press, Columbus, pp. 451-469.

4. Eastmond, D.A. (1983). Toxicity, Accumulation, and Elimination of Polycyclic Aromatic Sulfur Heterocycles in *Daphnia magna*. Master's Thesis, Brigham Young University.

5. Fluck, D.S., Rappaport, S.M., Eastmond, D.A., and Smith, M.T. (1984). Conversion of 1-Naphthol to Naphthoquinone Metabolites by Rat Liver Microsomes: Demonstration by HPLC with Reductive Electrochemical Detection. Arch. Biochem. Biophys. 235, 351-358.

6. Eastmond, D.A., Booth, G.M., and Lee, M.L. (1984). Toxicity, Accumulation, and Elimination of Polycyclic Aromatic Sulfur Heterocycles in *Daphnia magna*. Arch. Environ. Contam. Toxicol. 13, 105-111.

7. Smith, M.T., Fluck, D.S., Eastmond, D.A., and Rappaport, S.M. (1985). Detection of Quinone Metabolites by HPLC with Reductive Electrochemical Detection. Life Chemistry Reports 3, 250-258.

8. Lipnick, R.L., Bickings, C.K., Johnson, D.E., and Eastmond, D.A. (1985). Comparison of QSAR Predictions with Fish Toxicity Screening Data for 110 Phenols. In: Aquatic Toxicology and Hazard Assessment, Eighth Symposium, ASTM STP 891, R.C. Bahner and D. J. Hensen, (Eds.), American Society for Testing and Materials, Philadelphia, pp. 153-176.

9. Eastmond, D.A., Smith, M.T., Ruzo, L.O., and Ross, D. (1986). Metabolic Activation of Phenol by Human Myeloperoxidase and Horseradish Peroxidase. Molecular Pharmacology 30, 674-679.

10. Eastmond, D.A., French, R.C., Ross, D., and Smith, M.T. (1987). Metabolic Activation of Diethylstilbestrol by Human Leukocytes. Cancer Letters 35, 79-86.

11. Eastmond, D.A. (1987). Free Radical Mechanisms in Benzene Toxicity. Doctoral Dissertation, University of California, Berkeley.

12. Eastmond, D.A., French, R.C., Ross, D., and Smith, M.T. (1987). Metabolic Activation of Phenol and 1-Naphthol by Human Leukocytes and a Xanthine Oxidase System. Chemico-Biological Interactions, 63, 47-62.

13. Smith, M.T., Eastmond, D.A., and Di Monte, D. (1987). The Activation and Detoxication of Quinones by DT-Diaphorase. Chemica Scripta, 27A, 105-107.

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15. Warren, S.D., Black, H.L., Eastmond, D.A., and Whaley, W.H. (1988). Structural Function of Buttresses of *Tachigalia versicolor.* Ecology 69, 532-536.

16. Eastmond, D.A. and Tucker, J.D. (1989). Identification of Aneuploidy-inducing Agents Using Cytokinesis-blocked Human Lymphocytes and an Antikinetochore Antibody. Environmental and Molecular Mutagenesis 13, 34-43.

17. Smith, M.T., Yager, J.W., Steinmetz, K.L., and Eastmond, D.A. (1989). Peroxidase-dependent Metabolism of Benzene's Phenolic Metabolites and its Potential Role in Benzene Toxicity and Carcinogenicity. Environmental Health Perspectives, 82, 23-29.

18. Eastmond, D.A. and Pinkel, D. (1989). Aneuploidy Detection by Analysis of Interphase Nuclei Using Fluorescence *In Situ* Hybridization with Chromosome-Specific Probes. In: Mechanisms of Chromosome Distribution and Aneuploidy, M.A. Resnick and B.K. Vig (Eds.), Alan R. Liss, New York, pp. 277-284.

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22. Tucker, J.D. and Eastmond, D.A. (1990). Use of an Antikinetochore Antibody to Discriminate Between Micronuclei Induced by Aneuploidogens and Clastogens. In: Mutation and the Environment, Part B: Metabolism, Testing Methods, and Chromosomes, ML Mendelsohn and RJ Albertini, Wiley-Liss, Inc. pp. 275-284.

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24. Eastmond, D.A. and Smith, M.T. (1990). Xenobiotic Activation by Stimulated Human Polymorphonuclear Leukocytes and Myeloperoxidase. Methods in Enzymology 186:579-585.

25. Eastmond, D.A. and Pinkel, D. (1990). Detection of Aneuploidy and Aneuploidy-inducing Agents in Human Lymphocytes using Fluorescence *In Situ* Hybridization with Chromosome-specific DNA Probes. Mutation Res. 234, 303-318.

26. Kolachana, P., Subrahmanyam, V.V., Eastmond, D.A., and Smith, M.T. (1991). Metabolism of Phenylhydroquinone by Prostaglandin (H) Synthase: Possible Implications in o-Phenylphenol-induced Bladder and Kidney Carcinogenesis. Carcinogenesis 12, 145-149.

27. Robertson, M.L., Eastmond, D.A., and Smith, M.T. (1991). Two Benzene Metabolites, Catechol and Hydroquinone, Produce a Synergistic Genotoxic Response in Cultured Human Lymphocytes. Mutation Research 249, 201-209.

28. Subrahmanyam, V.V., Ross, D., Eastmond, D.A., and Smith, M.T. (1991). Potential Role of Free Radicals in Benzene-induced Myelotoxicity and Leukemia. Free Radical Biology & Medicine 11, 495-515.

29. Eastmond, D.A. (1993). Induction of Micronuclei and Aneuploidy by the Quinone-forming Agents Benzene and *o*-Phenylphenol. Toxicology Lett. 67, 105-118.

30. Eastmond, D.A., Rupa, D.S., Chen, H.W. and Hasegawa, L. (1993). Multicolor Fluorescence *In Situ* Hybridization with Centromeric DNA Probes as a New Approach to Distinguish Chromosome Breakage from Aneuploidy in Interphase Cells and Micronuclei, In: Chromosome Segregation and Aneuploidy, BK Vig (Ed.), Springer-Verlag, Berlin, pp. 377-390.

31. Eastmond, D.A., Rupa, D.S., and L.S. Hasegawa (1994). Detection of Hyperdiploidy and Chromosome Breakage in Interphase Human Lymphocytes Following Exposure to the Benzene Metabolite Hydroquinone Using Multicolor Fluorescence *In Situ* Hybridization with DNA Probes. Mutation Res. 322, 9-20.

32. Chen, H.W., Rupa, D.S., Tomar, R., and D.A. Eastmond (1994). Chromosomal Loss and Breakage in Mouse Bone Marrow and Spleen Cells Exposed to Benzene *In Vivo*. Cancer Res. 54, 3533-3539.

33. Lambert, A.C. and Eastmond, D.A. (1994). Genotoxic Effects of the *o*-Phenylphenol Metabolites Phenylhydroquinone and Phenylbenzoquinone in V79 Cells. Mutation Res. 322, 243-256.

34. Chen, H.W., Tomar, R., and D.A. Eastmond (1994). Detection of Hydroquinone-induced Nonrandom Breakage in the Centromeric Heterochromatin of Mouse Bone Marrow Cells Using Multicolor Fluorescence *In Situ* Hybridization with the Mouse Major and Minor Satellite Probes. Mutagenesis 9, 563-569.

35. Dobo, K.E. and Eastmond, D.A. (1994). The Role of Oxygen Radicals in the Chromosomal Loss and Breakage Induced by the Quinone-Forming Compounds Hydroquinone and *tert*-Butylhydroquinone. Environ. Molecul. Mutagen. 24, 293-300.

36. Dobo, K.L., Giver, C.R., Eastmond, D.A., Rumbos, H.S. and A.J. Grosovsky (1995). Extensive Loss of Heterozygosity Accounts for Differential Mutation Rate on Chromosome 17q in Human Lymphoblasts. Mutagenesis 10, 53-58.

37. Rupa, D.S., Hasegawa, L. and D.A. Eastmond (1995). Detection of chromosomal breakage in the 1cen - 1q12 region of interphase human lymphocytes using multicolor fluorescence *in situ* hybridization with tandem DNA probes. Cancer Res. 55, 640-645.

38. MacGregor, J.T., Tucker, J.D., Eastmond, D.A. and Wyrobek, A.J. (1995). Integration of Cytogenetic Assays with Toxicology Studies. Environ. Molecul. Mutagen. 25, 328-337.

39. Eastmond, D.A. and Rupa, D.S. (1995). Fluorescence *In Situ* Hybridization: Application to Environmental Mutagenesis. In: *Environmental Mutagenesis*, (D.H. Phillips and S. Venitt, eds.), Bios Scientific Publishers, Oxford, United Kingdom. pp. 261-290.

40. Chen, H. and Eastmond, D.A. (1995). Synergistic Increase in Chromosomal Breakage Within the Euchromatin Induced by an Interaction of the Benzene Metabolites Phenol and Hydroquinone in Mice. Carcinogenesis 16, 1963-1969.

41. Hasegawa, L.S., Rupa, D.S. and Eastmond, D.A (1995) A Method for the Rapid Generation Of *Alpha*- And Classical Satellite Probes for Human Chromosome 9 by Polymerase Chain Reaction Using Genomic DNA And their Application To Detect Chromosomal Alterations In Interphase Cells Mutagenesis 10, 471-476.

42. Chen, H. and Eastmond, D.A. (1995) Topoisomerase Inhibition By Phenolic Metabolites: A Potential Mechanism For Benzene's Clastogenic Effects. Carcinogenesis 16: 2301-2307.

43. Eastmond, D.A., Schuler, M. and Rupa, D.S. (1995) Advantages and Limitations of Interphase Analysis using Fluorescence *in situ* Hybridization for the Detection of Aneuploidy in Human Cells. Mutation Res. 348, 153-162.

44. Arey, J., Atkinson, R., Sasaki, J., Gupta, P., Eastmond, D.A. and Grosovsky, A.J. (1995) Atmospheric Transformation Reactions of 2-4 Ring Polycyclic Aromatic Hydrocarbons and the Formation of Mutagenic Products. In: "Ecotoxicology of Air Compartment", Communications of the International Symposium in Rouen, Society of Fundamental and Applied Ecotoxicology Congress, pp. 15-22.

45. Frantz, C.E., Chen, H. and Eastmond, D.A. (1996) "Inhibition of Human Topoisomerase II *in vitro* by Bioactive Benzene Metabolites" Environ. Health Perspect. Vol. 104, Suppl. 6, 1319-1323.

46. Cranor, C.F., Fischer, J.G. and Eastmond, D.A. (1996) "Judicial boundary drawing and the need for context-sensitive science in toxic torts after *Daubert v. Merrell-Dow Pharmaceutical*" Virginia Environmental Law Journal 16:1-77.

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49. Rupa, D.S., Schuler, M. and Eastmond, D.A. (1997) "Detection of hyperdiploidy and breakage affecting the 1cen-1q12 region of cultured interphase human lymphocytes treated with various genotoxic agents" Environ. Mol. Mutagen. 29:161-167.

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Exhibit D

Statement of David Epel

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JANE AND MARSHALL STEEL, JR.
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November 17, 2014

I, David Epel, am writing this statement in support of the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. I, David Epel, am a Jane and Marshall Steel Jr. Professor Emeritus of Biological and Marine Sciences at the Hopkins Marine Station of Stanford University. I have a Ph.D. from the University of California, Berkeley. I have been a Guggenheim Fellow, and am a Fellow of the American Association for the Advancement of Science, a Fellow of the California Academy of Sciences, and a Life Fellow of Clare Hall of the University of Cambridge in the UK. I was awarded the Ed Ricketts Memorial Award for Lifetime Achievement in the Marine Sciences. Please see my CV and list of publications accompanying this statement.

2. One of my areas of research deals with the cellular and molecular mechanisms that allow embryos to resist the effects of environmental stresses such as ultraviolet radiation, pathogens and natural and man-made toxins. My expert opinion below is based on my work on the primary line of defense against toxic substances provided by a large family of efflux transporters known as ABC (**ATP**-**b**inding **c**assette) transporters.

3. These ABC transporters are proteins in the plasma membrane of cells that act as "bouncers" to keep toxic substances out of cells, and also as "garbage collectors", removing chemicals that evaded the original bouncer action. All organisms, from bacteria to plants to humans, employ this defense system. If the transporters can recognize a chemical, they can then prevent its entry into the cell. A well-studied example of this mechanism is resistance to cancer chemotherapy, which can develop during the course of cancer treatment. When cells are exposed to anti-cancer drugs, they often respond by elevating the number of ABC transporters. This keeps the anti-cancer drugs out of the cell and makes the cells resistant to chemotherapy.

4. Some chemicals seem to evade this bouncer defense, for example teratogen thalidomide, neurochemical methyl mercury, and organohalogen compounds such as DDT, PCBs and chlordane. These chemicals are not recognized by the ABC transporters. The cell also has little capacity to metabolize or convert these chemicals to less toxic forms. As a result, these chemicals accumulate in the cell, where they remain for the lifetime of the cell – a legacy of prior exposure.

5. A large group of organohalogen flame-retardants are similar to DDT, PCBs and chlordane in that they have very low water solubility and have carbon-halogen bonds. These chemicals:
(1) Are not transported out of the cell by the ABC transporters.
(2) Are fat soluble, so they can permeate the cell membrane and enter the cell.

(3) Are not metabolized by the cell or converted to forms that can be eliminated. Consequently, the organohalogen flame-retardants with low water solubility persist in many organisms including in humans, fish, and marine mammals.

6. A colleague has recently studied the interactions between some PBDE congeners (which are also organohalogen flame retardants with very low water solubility) and the ABC transporters. He found that the studied PBDEs inhibited the ABC transporters, which could explain the inability to transport these chemicals out of the cell. This inhibition would also impair the cell's defenses, altering its ability to keep other toxic compounds out. My colleague is continuing to study other organohalogen flame retardants, but these preliminary results are of concern, as they suggest that organohalogen flame-retardants can not only cause biological harm on their own, but also potentially exacerbate the harmful effects of other chemicals.

7. All organohalogen flame-retardants form a structurally similar chemical class, characterized by one or more halogens (chlorine or bromine) bound to carbon. Those that have very low water solubility can bioaccumulate and have the potential to produce the adverse biological effects described above, as my research on their interactions with the ABC transporters has shown. The more water-soluble organohalogen flame retardants do not tend to bioaccumulate. However, as a result of their carbon-halogen bonds, they are also not natural to mammalian biochemistry and may not be recognized by the ABC transporters. Animal and epidemiological studies have linked exposure to the more water-soluble organohalogen flame retardants (most of which are organophosphates) to adverse health effects. Thus, sufficient evidence from scientific studies shows a substantial potential of harm from the entire class of organohalogen flame-retardants (i.e. both water-soluble and water-insoluble).

8. To conclude, my research, as well as the research of many other colleagues, has shown that properties shared by all organohalogen flame-retardants as a class can lead to adverse effects for human health. This class of chemicals easily enters the cells, may decrease the cells' ability to keep out other toxic compounds, and can cause adverse health effects. Because of these findings, my professional opinion is that consumer products containing non-polymeric organohalogen flame-retardants in additive form (which results in exposure) should be banned, as explained in the accompanying petition.

Yours sincerely,

David Epel, PhD

Jane and Marshall Steel Jr. Professor Emeritus of Biological and Marine Sciences
Hopkins Marine Station, Stanford University

CURRICULUM VITAE

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Date of Birth:March 26, 1937; Detroit, Michigan
Marital Status: Married 1960 to Lois S. Ambush; 3 children

Education:A.B., Wayne University, 1958
Ph.D., University of California, Berkeley, 1963

PRESENT POSITION
The Jane and Marshall Steel Jr. Professor Emeritus of Marine Sciences (2009-present)
The Jane and Marshall Steel Jr. Professor of Marine Sciences (1999-2009) and Professor of Biological Sciences (1977-present); Interim Director, 1984-1988; Associate Director (1988-2007).

PREVIOUS POSITIONS
Post-doctoral fellow, Johnson Research Foundation, Department of Biophysics and Biophysical Chemistry, University of Pennsylvania Medical School, 1963-1965
Assistant Professor of Biology, Hopkins Marine Station, Department of Biological Sciences, Stanford University, 1965-1970
Associate Professor of Biology, 1970-1974; then Professor, 1974-1977 - Department of Scripps Institution of Oceanography, University of California, San Diego

NATIONAL AND INTERNATIONAL TEACHING POSITIONS:
Faculty Member, Fertilization & Gamete Physiology Training Program, Marine Biological Laboratory, Woods Hole, MA; summer, 1974
Co-Director, Embryology Course, Marine Biological Laboratory, Woods Hole, MA; summers, 1975-1977; adjunct faculty, summer 1992.
Faculty, International Cell Research Organization/UNESCO Course on Developmental Biology, Palermo Italy, 1987.
Visiting Professor, Toho University, Japan 1989.
Faculty, NSF Antarctic Biology Course, McMurdo Sound, Antarctica, January 1996.
Faculty, International Cell Research Organization/UNESCO course on Early Embryonic Development, International Marine Research Centre, Sardinia Italy ,October 1997.
Faculty, European Molecular Biology Organization Course on "Reproduction and Early Development: Marine Molecular Biology Aspects", Bergen Norway, October 1998.
Visiting Professor of Developmental Biology, Plymouth Environmental Research Center and the University of Plymouth, United Kingdom, 1998-2004.

HONORS

Guggenheim Fellow, 1976-1977
Overseas Fellow of Churchill College, Cambridge University, 1976-1977;
Fellow, AAAS (Elected 1978).
Fellow, California Academy of Sciences, (Elected 2000).
Distinguished Fellow in Science and Technology, California State University, Monterey Bay (Awarded, 2004).
Allan A. Cox Medal for Fostering Excellence in Undergraduate Research at Stanford University, 1995
Ed Ricketts Memorial Lecture Award for Lifetime Achievement in Marine Sciences, 2006
Life Fellow, Clare Hall, University.of Cambridge, 2007

PROFESSIONAL SERVICE AND ACTIVITIES:

PROFESSIONAL SOCIETIES:

Member

A.A.A.S.
American Society for Cell Biology
International Cell Research Organization (UNESCO)
Marine Biological Laboratory, Corporation Member
Society for Comparative and Integrative Biology
Society for Developmental Biology
National Association of Biology Teachers
National Marine Educators Association

EDITORIAL ACTIVITIES--

Associate Editor:, Developmental Biology, 1974-1983; Gamete Research, 1977- 1986; Biological Bulletin, 1991-1997
Editorial Board, Cell Differentiation, 1982-1990; Experimental Cell Research, 1984-1989. Zygote, 1993-present; Animal Biology, 1993-present; Biological Bulletin, 1997-2004; Acta Histochemica, 1999-present.Aquatic Biology, 2008-present
Advisory Board, Development, Growth and Differentiation, 1995-present;; Zoological Science (Tokyo), 2002-present.

SERVICE TO PROFESSIONAL ORGANIZATIONS AND GOVERNMENT AGENCIES

Member-at-large, Section G (Biological Sciences) American Association for Advancement of Science (AAAS), 1979-1984;
Chairperson, Section G (Biological Sciences) AAAS, 1997-1998;
Council Member, AAAS, 1998-99.
Member of Council, American Society for Cell Biology (ASCB), 1979-1981. Chairman of Education Policy Committee, (ASCB), 1979-1981; Member, Public Policy Committee 1983-1984, .
Organizing Committee, Xth Congress of the International Society for Developmental Biology, 1984-1985;

Organizing Committee, NATO Advanced Research Workshop on Mechanism of Fertilization;Plants to Humans, 1989;
Organizing Committee, 1st, 2nd and 3rd International Conference on the Cell and Molecular Biology of Egg Coats, 1993, 1997 and 2004.
Chairman, Decennial Review Committee (Representative, National Academy of Sciences), Marine Biological Laboratory, 1984; Member, Decennial Review Committee, 1994.
Member, Visiting Committee, Naval Biological Laboratory, ONR, 1983-1985; Member, ONR Technical Advisory Group - Biological Sciences, 1988
Member, Organizing & Advisory Committee and Director Search Committee, Monterey Bay Aquarium Research Institute, 1986;
Board of Directors, Monterey Bay Aquarium Research Institute, 1987-1989;
Member, NIH Animal Resources Review Committee, 1989-1991
Member, NSF Developmental Biology Panel, 1988-1993
Member, University of California Coastal Toxic Research Advisory Board, 1992-2002
Chairperson, National Cooperative Program on Non-Human *in vitro* Fertilization and Pre-implantation Development (NIH), 1991-1998
Chairperson, Section on Developmental & Cell Biology, American Society of Zoologists, 1991-93. Chairperson, Endowment Committee, 1994-95. Member, Program Committee, 2000-2002.
Organizing Committee, 7th and 9th International Congress of Society for Invertebrate Reproduction, 1995 and 2001.
Organizing Committee, 8th-11th International Conference on Pollution Responses in Marine Organisms, 1997, 1999, 2001, 2003 and 2005.
Member, Monterey County Marine Research Task Force, 2000-present
Scientific Advisory Board, The Environment Agency, United Kingdom, 2003-2004
Founding member and organizer, Ocean Round Table, 2005-2009

RECENT CONGRESS & SYMPOSIA ADDRESSES

American Chemical Society Symposium on "Pharmaceuticals and Personal Care Products in the Environment" (San Francisco)
19thAnnual Meeting of the Brazilian Society of Biochemistry and Molecular Biology. Plenary Lecture (Caxambu, Brazil).
International symposium "Molecular Mechanisms of Cell-Cell Interaction" (San Diego, CA).
13th and 14th Meeting on the Developmental Biology of the Sea Urchin (Woods Hole, MA)
XIth International Congress of Histochemistry and Cytochemistry (York, UK).
11th International Conference on Pollution Responses in Marine Organisms (Plymouth UK)
9th International Congress of Society of Invertebrate Reproduction, Plenary Speaker, (Grahamstown, South Africa)
Gordon Conference on Fertilization and Activation of Development (Holderness, NH).
Society for Integrative and Comparative Biology Symposium "Ecological Developmental Biology: Developmental Biology Meets The Real World.
American Society for Cell Biology, Organizer and Speaker, Symposium on "Emerging Environmental Contaminants: A Role for Cell Biology?" (San Francisco)

International Workshop on Sustainable Aquaculture: Animal Welfare, Human Health and Interactions with the Environment (Siena Italy)
4th International Symposium on Molecular and Cell Biology of Egg and Embryo Coats, Ise-Shima Japan
Plenary Speaker, 10th International Congress on Invertebrate Reproduction and Development Newcastle UK.
Aquatic Models of Human Disease, Athens GA
XIIth Pollution Responses in Marine Organisms, Alessandria Italy

RECENT KEYNOTE OR PLENARY ADDRESSES:
Reproductive Strategies, National Institute Basic Biology, Okazaki Japan
Symposium in memory of Alberto Monroy...20 years later, Palermo Italy
European Society of Comparative Biochemistry and Physiology, Antwerp Belgium
Cell Signaling in Gamete Activation, Tokyo, Japan
10th Annual Green Chemistry and Engineering Conference, American Chemical Society, Washington DC
National Association of Biology Teachers, Albuquerque NM
ICCA-LRI workshop on Integrating new advances in exposure science and toxicity testing: next steps

DEPARTMENTAL AND UNIVERSITY COMMITTEES
Hopkins representative, Monterey Bay Sanctuary Research Advisory Panel
Stanford Environmental Initiative Pedagogy Committee

STANFORD ALUMNI ASSOCIATION AND CONTINUING EDUCATION ACTIVITIES

- **Alumni Association:**

Alumni College on "Biology of the Sea", July 1999 and 2000.

Director and 'Dean' of this College for the 2nd year. The course enrolled 30+ alumni in a 4-day series of lectures and labs, which included lecturers from the Marine Station, Department of Engineering and Earth Sciences (on ocean currents), Law School (on environmental policy) and also a lecture on Ed Ricketts and John Steinbeck.

- **Alumni Travel/Study Program (Faculty Lecturer)**

Baja California Whale Watching, 1989

Belize Snorkeling Adventure, 1999

Galapagos Family Adventure, 2001

Alaska Family Adventure, 2002

- **Continuing Education:**

"The Ocean as a Laboratory" Every year since 1998.

STANFORD FUND RAISING ACTIVITIES—Campaign for Undergraduate Education

Participant in the Think Again Series, New York City and Orange County
Speaker at Alumni Re-union College, Fall 2002

COMMUNITY SERVICE

Trustee, Monterey Bay Aquarium, 1985-1988
Board Member, Hatton Canyon Foundation, 1989-present
Board Member, Sierra Club (Ventana Chapter), 1990-1996, 2001-present
Science Mentor, Seaside High School, since 1990
Guest Faculty, Outward Bound Program (UCSC), Stanford Young Medical Scientist Program, Stanford Young Environmental Scientist Program [These programs promote interest of minority students in environmental science or medicine], 1996-present.
Board Member, Friends of Moss Landing Marine Laboratory, 1994-present.

Recent Research Grants:

1). National Science Foundation
"Efflux Transporters in Sea Urchin Development"
$ 390,000
February 1, 2005-January 31, 2008; no-cost extension through 2008..

2).National Science Foundation-Instructional Materials Development
"Inquiry-based high school biology using sea urchin fertilization and development".
$574,935; no cost extension through 2008

3). Wallenberg Foundation and Stanford University
"Hands-On Possibilities and Experiences in Biology Education (Bio-HOPE)
$50,000 planning grant in collaboration with Goteborg University 2006

4). Wallenberg Foundation and Stanford University
"Hands-On Possibilities and Experiences in Biology Education (Bio-HOPE)
$250,000 grant in collaboration with Goteborg and Linkoping University 2006-2008

5). Wallenberg Foundation and Stanford University
"Inquiry and Insight: Investigating environmental problems"
$113,00 planning grant in collaboration with the Sven Loven Centre for Marine Studies, Kristineberg, Sweden 2009

6). Wallenberg Foundation and Stanford University
"Inquiry and Insight: Investigating environmental problems"
$650,000 full grant in collaboration with the Sven Loven Centre for Marine Studies, Kristineberg, Sweden 2009-2013

PUBLICATIONS

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WEB SITES AND ARTICLES ON SCIENCE EDUCATION

Sea Urchin Embryology. Web site of 275 pages devoted to educational materials for high school and college teachers. Primarily directed toward laboratory exercises. http://www.stanford.edu/group/Urchin/index.html

Virtualurchin.stanford.edu. New web site, funded by the NSF, that provides virtual labs for high school and college students

ESI.stanford.edu. New web site, funded by the Wallenberg Foundation, that explores an unexpected consequence of global warming on salmon migration.

I2i.stanford.edu Current web site that focuses on international dialogue between sisters schools in different countries on shared environmental problems.

Exhibit E

Statement of Rolf Halden

ASU BIODESIGN INSTITUTE
ARIZONA STATE UNIVERSITY

September 26, 2014

I, Rolf Halden, am writing this statement in support of the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. I, Rolf Halden, am Director of the Center for Environmental Security at the Biodesign Institute and Professor in the Ira A. Fulton School for Sustainable Engineering and the Built Environment, Arizona State University. I am also a Senior Sustainability Scientist in the Global Institute of Sustainability at Arizona State University and hold an adjunct faculty appointment at the John Hopkins Bloomberg School of Public Health. I am an environmental scientist and engineer by training, and my research focuses on the movement of chemicals through the environment and their potential health impacts. I received my M.S. (1994) and Ph.D. (1997) in Civil (Environmental) Engineering from the University of Minnesota-Minneapolis. I have authored over 110 peer-reviewed articles, 11 book chapters, 15 patent applications and 160 conference papers. I have also presented over 110 invited lectures and keynote addresses at national and international scientific symposia. I have attached a copy of my *curriculum vitae* and a list of my publications for your reference.

2. I strongly believe that there is a need to regulate hazardous chemicals, such as organohalogen flame retardants, as classes or compound families. Many organohalogen flame retardants have been shown to be persistent, bioaccumulative and/or toxic, and have been detected in the environment, wildlife, and human populations across the globe. Due to these concerns, two major commercial flame retardant formulations, penta- and octa-brominated diphenyl ethers (BDE), were banned by the European Union (EU) in 2004 and voluntarily phased-out in the U.S. in 2005. The fully brominated deca-BDE was banned in electrical and electronic applications within the EU in 2008, while negotiations between the EPA and deca-BDE producers in the U.S. led to an agreement to cease all uses of this product in the U.S. by the end of 2013. Many of the replacement chemicals now finding their way into commerce as substitutes for PBDEs are structurally similar to the original, now banned/phased-out compounds; as a result, they show similar persistence and bioaccumulative characteristics in the environment.[i,ii]

3. In general, the replacement of hydrogen with halogen atoms positively correlates with problematic characteristics such as hydrophobicity (which facilitates bioaccumulation), environmental persistence and toxicity.[iii] It is therefore a not surprising, but underappreciated fact, that 74% of harmful organic compounds regulated by the U.S. EPA (U.S. Environmental Protection Agency) under the Safe Drinking Water Act contain at least one halogen atom[iv].

4. A recent study by our group featured the use of municipal sewage sludge (a solid byproduct of wastewater treatment) for identifying and prioritizing persistent and bioaccumulative chemicals. We identified eight top priority chemicals with high abundance and bioaccumulative potential, including five organohalogens, three of which were brominated flame retardants.[v] The brominated flame retardants were the third most abundant group of chemicals detected in nationally representative U.S. sewage sludges, suggesting their widespread use and ongoing exposures of human populations and wildlife.
The study also revealed that, out of 55 potentially bioaccumulative chemicals detectable in sewage sludge, 93% were halogenated.

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5. The mass manufacture of toxic chemicals that lack effective routes of degradation creates unnecessary problems for current and future generations. The substitution of known harmful organohalogen flame retardants with chemicals sharing structural and functional similarity is not an effective solution to this problem[6]. Substitutes are often chemicals that have minor modifications to the carbon backbone (i.e., the length or shape of the carbon chain) or halogen substitution pattern (i.e., the arrangement of halogens in the molecule) of known hazardous chemicals. These minor changes do not result in major changes in the risk profile of the substitutes relative to the compounds targeted for replacement.

6. In particular, because of their bioavailability and potential for bioaccumulation, organohalogen flame retardants of low molecular weight that are not covalently bonded to the consumer product will very likely pose significant environmental and human health risks, irrespective of any minor modifications to their structure.

7. The solution to this problem ultimately depends on curtailing the use and production of chemicals sharing structural and functional similarity to known hazardous compounds, rather than making minor modifications to the carbon backbone or halogen substitution pattern, and then hoping for a different, better outcome. Pragmatic steps for reducing environmental pollution and adverse human health impacts include[6]: (i) avoiding the use of flame retardants in consumer products that do not pose a significant fire risk in the first place, (ii) avoiding the use of flame retardants that resemble their hazardous predecessors in molecular size and structure, and (iii) developing next-generation flame retardants that are covalently bound to the consumer products to minimize release, and have large molecular sizes (e.g., large polymers) to limit uptake by biota.

8. My professional opinion is that organohalogen flame retardants should be regulated as a class, especially the ones used in additive form (i.e., not covalently bound) in consumer products. Instead of regulating individual formulations such as penta- or octa-BDE and replacing them with similar formulations, a more proactive and adequate strategy is required for chemical safety management. Learning from past failures is necessary for an effective regulatory framework, and organohalogen flame retardants should be the starting point for the redesign of safer and greener consumer products. I therefore support the accompanying petition and urge the CPSC to regulate consumer products containing non-polymeric additive organohalogen flame retardants.

Yours sincerely,

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[i] Covaci A, Harrad S, Abdallah MA, Ali N, Law RJ, Herzke D et al. 2011. Novel brominated flame retardants: A review of their analysis, environmental fate and behaviour. *Environ Int* 37(2):532-556.

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[iv] Halden RU. Invited Talk: Sustainable Chemistry & Human Health in the 21st Century. U.S. EPA Emerging Chemicals Workgroup. Presented on April 6, 2011.

[v] Venkatesan AK, Halden RU. 2014. Wastewater Treatment Plants as Chemical Observatories to Forecast Ecological and Human Health Risks of Manmade Chemicals. *Sci Rep* 4:3731. DOI: 10.1038/srep03731. www.nature.com/srep/2014/140116/srep03731/full/srep03731.html

[6] Venkatesan AK and Halden RU. New Strategies for Monitoring and Regulating Chemical Mixtures and Contaminants Sharing Pathways of Toxicity (Internal White Paper, Arizona State University).

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CURRICULUM VITAE
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Tenured Full Professor

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AFFILIATIONS	Tenured Professor, School of Sustainable Engineering and the Built Environment, Arizona State University School of Biological and Health Systems Engineering (Affiliate), ASU Senior Sustainability Scientist, ASU Global Institute of Sustainability, ASU Center for Biodiversity Outcomes, (Affiliate), ASU Honors Faculty, Barrett Honors College, Arizona State University Chair of Admission, Biological Design Graduate Program, ASU Founding Director, Center for Environmental Security Mass Spectrometry Adjunct Faculty, Johns Hopkins University, Bloomberg School of Public Health, Baltimore, MD Co-Founder & Chief Technical Officer, In Situ Well Technologies, LLC, ASU/AzTE Startup Company
EDUCATION	B.S., 1986 (Pre-diploma), Technical University of Braunschweig, Field: Biology M.S., 1992 (Diploma), Technical University of Braunschweig, Major: Biology; Minors: Microbiology, Biotechnology & Sanitary Engineering M.S., 1994, (Environmental Engineering) Department of Civil Engineering, University of Minnesota, Minneapolis, MN Ph.D., 1997, (Environmental Engineering) Department of Civil Engineering, University of Minnesota, Minneapolis, MN
POSTDOCTORAL	1997-1998, University of California, Lawrence Livermore National Laboratory, Environmental Protection Department, Livermore, CA
PROFESSIONAL REGISTRATION & CERTIFICATION	Management Certificate, University of the Pacific, 2000 Supervisor Certificate, 40-Hour SARA/OSHA 8CCR5192(e)(4) Professional Environmental Engineer, Minnesota, 1997 – Present (#25155); Arizona 2010 – Professional Environmental Engineer Lic. (#51849) Engineer-in-Training, Minnesota, 1996 - 1997
PROFESSIONAL EXPERIENCE	Founding Director, Center for Environmental Security (CES), The ASU Biodesign Institute, 6/2012 – Present. Founding Director, Center for Environmental Security Mass Spectrometry Facility, 7/2013 – Present. Chair of Admissions for the University-wide Biological Design Program at Arizona State University, 12/2012 – Present. Leader, Biosecurity Thrust Area, Security and Defense Systems Initiative,

ASU, 6/2012 – Present.
Barrett Honors Faculty, 2012 – Present.
Co-Founder and Chief Technical Officer, In Situ Well Technologies (ISW), LLC Startup Company, ASU/AzTE, 2011 – Present.
Tenured Full Professor, School of Sustainable Engineering and the Built Environment, Arizona State University. 2011 – Present.
Senior Sustainability Scientist, Global Institute of Sustainability, ASU. 2010 – Present.
Co-founder of the MapStory Health Initiative, 2014 - Present
Interim Co-Director, Center for Health Information & Research (CHiR) 2011 – 2012.
Associate Director, Swette Center for Environmental Biotechnology, ASU Biodesign Institute. 2011 – 2012.
Assistant Director, Center for Environmental Biotechnology, ASU Biodesign Institute. 2009 – 2011.
Adjunct Associate Professor. 2008 – Present. Department of Environmental Health Sciences, Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University
Special Government Employee, Food and Drug Administration, '05 – Present
Tenured Associate Professor. 12/2007 – 7/2011. School of Sustainable Engineering and the Built Environment, Arizona State University
Associate Professor. 2007. Department of Environmental Health Sciences, Johns Hopkins Bloomberg School of Public Health
Joint Appointment in the Department of Geography and Environmental Engineering, Johns Hopkins University
Assistant Professor. 2001 – 2007. Department of Environmental Health Sciences, Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University
Project Engineer & Environmental Scientist. 1998 – 2001. Environmental Protection Department, Lawrence Livermore National Laboratory, Livermore, CA. Principal Responsibilities: Design and Management of Subsurface Remediation Activities with a Cumulative Budget of $6M. Supervisor: Dr. John Ziagos.
Research & Teaching Fellow/Assistant. January 1993 – April 1997. Department of Civil Engineering, University of Minnesota, Twin Cities, MN. Supervisor: Dr. Daryl Dwyer
Research Associate. January 1992 – July 1992. Helmholtz Centre for Infection Research, (formerly German National Institute for Biotechnology (GBF), Braunschweig, Germany. Principal Responsibilities: Microbial Ecology. Supervisor: Dr. Daryl F. Dwyer
Research Assistant. January 1991 – December 1991. Helmholtz Centre for Infection Research, (formerly German National Institute for Biotechnology (GBF), Braunschweig, Germany. Principal Responsibilities: Bioreactors. Supervisor: Dr. Joachim Klein

PROFESSIONAL ACTIVITIES

Society Memberships

American Public Health Association (APHA)
American Society for Mass Spectrometry (ASMS)
American Chemical Society (ACS) – ACS Expert for Media Relations, 2014 - Present
American Society for Microbiology (ASM)
American Society of Civil Engineers (ASCE)
Association of Environmental Engineering and Science Professors (AEESP)
Environmental and Water Resources Institute (EWRI)
Society of Environmental Toxicology and Chemistry (SETAC)

Participation on Advisory Panels and Committees

ACS Expert for Media Relations, American Chemical Society (ACS), 2014 - Present

Member, NIEHS Fish Advisory Information Network, National Institute of Environmental Health Sciences, June 2014 - Present.

Center for Transformative Action, Invited Member of the Independent Review Board, August 2014 - Present.

Invited Presenter and Panel Member: Discussion Forum Micro-plastics in the Marine Environment & Potential Human Health Risks, National Academies, Washington, DC, 3/3/2014.

Community Advisory Board Member, West van Buren Area WQARF Site, Phoenix, AZ, 2013 - Present.

Invited Presenter at Congressional Briefing on the Safety of the Antimicrobial Triclosan, Washington, DC, 2/17/2011.

Food And Drug Administration, Center For Drug Evaluation And Research (CDER) Nonprescription Drugs Advisory Committee. Special Government Employee (10/2005 – 10/2015)

Science Advisor, Johns Hopkins University Center for a Livable Future, 2009 – Present

Invited Panelist, **National Association of Clean Water Agencies** Pretreatment and Pollution Prevention Workshop, St. Louis, MO, 5/19/2011.

Invited Panelist, Workshop on Environmental Estrogens and Endocrine Disrupting Compounds, sponsored by the **Johnson Foundation**, Wingspread, WI, May 2010.

Invited Panelist, Special Symposium on Next Generation Superfund Contaminants sponsored by the **National Institute of Environmental Health Sciences (NIEHS),** Tucson, AZ, August 2009.

Invited Panelist, **American Academy for Microbiology,** "Global Antibiotic Resistance: New Approaches to an Old Problem," Fondation Merieux, Annecy, France, October 2008.

National Research Council of the National Academies. NRSB-O-05-04-A. Conduct a Technical Assessment of Ongoing and Planned Environmental Remediation and Monitoring Programs at the Los Alamos National Laboratory (LANL) and Provide Recommendations to Improve Their Technical and Cost Effectiveness and Reduce Worker, Public, and Environmental Risks. **Invited NRC Committee Member, Dual Appointment in the Areas of Groundwater Monitoring and Chemistry.** 15-Month Term Starting March, 2006.

Invited Panelist, **BIO 2006**, World's Largest Annual International Convention on Biotechnology. Chicago, IL. Environmental Biotechnology Session. 04/9-12/2006

Mid-Atlantic States Section of the Air & Waste Management Association (MASS-A&WMA), Special Symposium on Emerging Environmental Issues and Policies. **Invited Speaker/Panelist.** New Brunswick, NJ, April 6, 2006.

EPA Office of Inspector General, Office of Program Evaluation, Evaluation of Drinking Water Laboratory Procedures. Invited Expert Consultant. 1/19/2006.

Food And Drug Administration, Center For Drug Evaluation And Research (CDER) Nonprescription Drugs Advisory Committee. "Benefits and Hazards of Antiseptic Products Marketed for Consumer Use." **Invited Panelist/Voting Committee Member**. 10/20/2005.

National Congress on Assessing and Mitigating Environmental Impacts of Emerging Contaminants – Renewable Natural Resources Foundation. Co-Sponsored by the United States Geological Survey and the Food and Drug Administration. **Invited Delegate.** 12/1-2/2005

Harvard School of Public Health Risk Assessment Workshop: "Pharmaceuticals and Personal Care Products in the Environment: Emerging Threat or Unwarranted Concern?" **Invited Panelist.** 11/10/2005

International Conference on Safe Water, Exploring Global Demands and Impacts of Natural Disasters, SAFEWATER 2005. San Diego, CA. Groundwater Remediation Session. **Invited Session Chair.** 10/21/2005

DOE/EPA SERDP and ESTCP Expert Panel Workshop on Research and Development Needs for the Environmental Remediation Application of Molecular Biological Tools. **Invited Speaker and Voting Panel Member.** Specialty: Proteomics. 08/9-10/2005

Governor Ehrlich's Maryland Department of the Environment – Maryland State Water Quality Advisory Committee (SWQAC) Public Interest Member. **Selected by JHSPH Dean Al Sommer to be the Johns Hopkins Representative for this Committee.** 1/1/2003 – 12/31/2005

Governor Ehrlich's Maryland Water Security and Wastewater Systems Advisory Council Alternate Member. 01/2004 – 12/2004

Maryland Water Monitoring Council: "Ecological Restoration Assessment & Monitoring" Linthicum, MD. **Invited Panelist.** 11/18/2004

Water Environment Research Foundation (WERF) Project Advisory Committee. "Fate of Pharmaceuticals and Personal Care Products through Wastewater Treatment Processes." **Invited Committee Member.** 2004-2006

Water Environment Research Foundation (WERF) Project Advisory Committee. "Contributions of Household Chemicals to Sewage and their Relevance to Municipal Wastewater Systems and the Environment." **Invited Committee Member.** 2004-06

DOE Natural and Accelerated Bioremediation Research Program (NABIR) Workshop. Warrenton, VA. **Invited Panelist.** 3/18-20/2002

DOE New Perspectives Council, Lawrence Livermore National Laboratory. **Appointed Chairman** of a 14-Member Task Force Assembled to Provide Recommendations for Managing Environmental Cleanup and Research at two CA Superfund Sites, Livermore CA, 2000.

EDITORIAL ACTIVITIES

Book Editor

Contaminants of Emerging Concern: Ecotoxicological and Human Health Considerations, 2010. American Chemical Society (ASC) Book Series. 606 pp. Oxford University Press, New York, NY. ISBN13: 9780841224964; eISBN: 9780841224971; DOI: 10.1021/bk-2010-1048

Peer Review Activities

1. American Chemical Society (ACS) Books
2. American Chemical Society (ACS) Merits Awards, Env. Chem. Division
3. Analytical Chemistry
4. Archives of Environmental Contamination and Toxicology
5. Archives of Microbiology
6. California Environmental Protection Agency
7. Chemosphere
8. Consumer Reports
9. EcoHealth
10. Ecotoxicology and Environmental Safety
11. Environmental Chemistry
12. Environmental Health Perspectives
13. Environmental Pollution
14. Environmental Research
15. Environmental Science & Technology
16. Environmental Science and Pollution Research
17. Environmental Toxicology & Chemistry
18. Environmental Technology
19. Environment International
20. Expert Review of Proteomics
21. Integrated Environmental Assessment and Management (IEAM)
22. International Journal of Industrial Chemistry

23. Journal of Chromatography A
24. Journal of Chromatographic Science
25. Journal of Environmental Science and Health, Part B
26. Journal of Hazardous Materials
27. Journal of Proteome Research
28. Leaking Underground Storage Tank Line
29. Marine Environmental Research
30. Molecular & Cellular Proteomics
31. Renewable Natural Resources Foundation
32. Science
33. Science of the Total Environment
34. Soil & Sediment Contamination: an International Journal
35. Toxicology
36. United States Environmental Protection Agency
37. Water Research
38. Water Science & Technology

PROPOSAL REVIEW ACTIVITIES

2014 Department of Defense, Air Force Ad Hoc Proposal Review
2011 EPA Small Business Innovative Research (SBIR) Panel – Drinking Water
2011 NIH Study Section Community Level Health Promotion (CLHP) Ad Hoc Member
2011 Hudson River Foundation for Science and Environmental Research
2010 Water Resources Research Institutes Program, United States Geological Survey
2009 NIH Study Section ZRG1 HDM-B 11B, Healthcare Delivery and Methodologies-Occupational Health, Small Business Innovative Research (SBIR) Program
2009 NIH Study Section ZRG1 HOP E 11, Health of the Population, Small Business Innovative Research (SBIR) Program
2009 Water Resources Research Institutes Program, United States Geological Survey
2008 NIH Study Section ZRG1 HOP E 10, Health of the Population, Small Business Innovative Research (SBIR) Program
2007 NIH Study Section ZRG1 HOP E 10, Health of the Population, Small Business Innovative Research (SBIR) Program
2007 Natural Sciences and Engineering Research Council of Canada, NSERC's Discovery Grant Program
2007 Caribbean Coral Reef Institute (CCRI) in Cooperation with the University of Puerto Rico – Mayagüez and the National Atmospheric and Oceanic Administration (NOAA)
2006 National Academies, U.S. Agency for International Development (USAID), Middle East Regional Cooperation Program (MERC)
2006 U.S. Environmental Protection Agency (EPA), Office of Research, Small Business Innovative Research (SBIR) Program
2006 International Science and Technology Center (ISTC); Science Center Programs of the U.S. Department of State
2005 Natural Sciences and Engineering Research Council of Canada (NSERC), Collaborative Health Research Project (CHRP) Grant Program
2005 Cooperative Grants Program of the U.S. Civilian Research and Development Foundation (CRDF), Co-founded and Sponsored by the National Science Foundation (NSF)
2004 National Science Foundation (NSF), Microbial Observatories (MO) and Microbial Interactions and Processes (MIP); RFA: NSF-04-586
2004 Water Environment Research Foundation (WERF), Pharmaceuticals and Personal Care Products in the Environment
2003 National Science Foundation (NSF), Microbial Observatories (MO) and Microbial Interactions and Processes (MIP); RFA: NSF-03-571

2002 International Science and Technology Center (ISTC); Science Center Programs of the U.S. Department of State

ACADEMIC SERVICE

Nationwide

National Institute of Environmental Health Sciences (NIEHS) Superfund Research Program, R01 Working Group, National Leader. 2012 – Present

Congressional Briefing, Invited Talk at U.S. Congress: Environmental Health Risks of Triclosan. Capitol Hill Congressional Briefing Room, Washington, DC, February 17, 2011

University Wide

ASU Biological Design Graduate Program, Executive Committee Member. 2013 – Present
ASU Biological Design Graduate Program, Chair of Admission. 2013 – Present
Chief Operating Officer of ASU/AzTE Startup Company, ISW, LLC (2012 – Present)
ASU IPIRC Intellectual Property Institutional Review Committee, Member. 2011 – Present
ASU Biodesign/AzTE Intellectual Property Advisory Committee, Member. 2011 – Present

School Wide

ASU Faculty Search Committee (Member; Process Engineering Position) 2013 – 2014
ASU Faculty Search Committee (Member; Water Resources Position) 2013 – 2014
ASU Faculty Search Committee (Chair; CHiR Director) 2011 – 2012
ASU Faculty Search Committee (Chair; Air Toxics) 2011 – 2012
ASU Curriculum Committee, 2009 – 2011
ASU Fulton Undergraduate Research Initiative (FURI) Committee, 2009 – 2013
ASU Grand Challenges Faculty Search Committee, 2009 – 2011
ASU Faculty Search Committee, 2008 – 2009
Johns Hopkins University Faculty Senator, Dept. of Environ. Health Sciences. Elected 09/2003 – 08/2004
Johns Hopkins University Committee on Information Technology (CIT) Member, JHSPH, 9/04 – 12/07
Faculty Representative at the Technology Transfer Retreat, JHSPH, July 23, 2004
JHSPH Faculty Title Task Force. Invited Representative of the Junior Faculty, 2003
Co-organizer of the JHSPH Junior Faculty Meetings, 2003

Division and Department

ASU Biodesign Personnel Committee, 2014 – Present
ASU Intellectual Property Institutional Review Committee, 2011 – 2012
ASU Biodesign Research & Collaboration Advancement Committee, 2011 – Present
ASU Specialty Area Coordinator for Environmental and Water Resource Engineering. 2008 – 2009
JHU Enrichment and Seminars Committee, EHS, Member, 08/2003 – 07/2004
JHU Ad-hoc Committee for Development of a Mission Statement for the Dept. of EHS, 2003
JHU Center for Water and Health Faculty Search Committee, Member, 2002 – 2005
JHU Academic Affaires Committee, Dept. of Environ. Health Sci., Member, 9/2004 – 8/2005
JHU Organizer of the "Exposure Assessment Session" at the EHS Annual Research Day, Mt. Washington Conference Center, Baltimore, MD, Nov. 14, 2003

Communication and Outreach

Conducted 150+ TV/Radio/Newspaper Interviews; Contributions were featured in, e.g., New York Times, Wall Street Journal, Time Magazine, Science News, and the Los Angeles Times

AWARDS & HONORS

2014	Invited Expert for Media Relations, Expert Program, American Chemical Society (ACS)
2012	Appointed National Leader of R01 Working Group of the NIEHS Superfund Program
2011	Leroy E. Burney Lecturer, Johns Hopkins School of Public Health
2011	List of 20 Public Health Experts Worth Knowing
2010	Senior Sustainability Scientist, Global Institute of Sustainability, ASU. 2010 – Present
2010	Award for Research Excellence, Arizona BioIndustry Association's BIOFEST 2010, Nominee and Finalist
2010	Biodesign Impact Accelerator Program, Selected Startup Company, ASU
2010	Faculty Honoree, School of Sustainable Engineering and the Built Environment, ASU
2007	Faculty Research Initiative Award, Johns Hopkins University
2005	Faculty Research Initiative Award, Johns Hopkins University
2002	Faculty Innovation Award, Johns Hopkins University
2000	Two Recognition Awards, Lawrence Livermore National Laboratory
1998	American Permanent Residency National Interest Waiver, LLNL
1997	American Society for Microbiology, Travel Grant
1996	Dissertation Fellowship, Outstanding Ph.D. Student, University of Minnesota

PUBLICATIONS

Peer-reviewed, Archival Journal Articles (* Indicates Corresponding Author)

1. Done, H., and **R. U. Halden.*** 2014. Reconnaissance of 47 Antibiotics and Microbial Risks in Major Seafood and Aquaculture Products Consumed in the United States. *J. Hazardous Materials* (In Press).

2. **Halden, R. U.*** 2014. Epistemology of Contaminants of Emerging Concern and Literature Meta-analysis. *J. Hazardous Materials* (In Press).

3. Geer, L. A., B. F. Pycke, D. M. Sherer, O. Abulafi, and **R. U. Halden**. 2014. Use of Amniotic Fluid for Determining Pregnancies at Risk of Preterm Birth and for Studying Diseases of Potential Environmental Etiology. *Environmental Research* (In Press).

4. Pycke, B. F. G.; L. A. Geer; M. Dalloul; O. Abulafia; A. M. Jenck; **R. U. Halden**; Human Fetal Exposure to Triclosan and Triclocarban in an Urban Population from Brooklyn, New York. *Environmental Science & Technology*. 48(15):8831–8838. DOI: 10.1021/es501100w.

5. Pycke, B. F. G., I. Roll, B. Brownawell, C. Kinney, E. Furlong, D. Kolpin, and **R. U. Halden.*** 2014. Transformation Products and Human Metabolites of Triclocarban and Triclosan in Sewage Sludge across the United States. *Environmental Science & Technology*. 48(14):7881-7890. DOI: 10.1021/es5006362.

6. Bruton, T., A., B. F. G. Pycke, and **R. U. Halden.*** 2014. Effect of Nanoscale Zero-Valent Iron Treatment on Biological Reductive Dechlorination: A Review of Current Understanding and Research Needs. (In Press in *Critical Reviews in Environmental Science & Technology*).

7. Venkatesan A. and **R. U. Halden.*** 2014. Loss and In Situ Production of Perfluoroalkyl Chemicals in Outdoor Biosolids-soil Mesocosms. *Environmental Research* 132:321–327; 10.1016/j.envres.2014.04.024

8. Venkatesan, A, B. F. G. Pycke, and **R. U. Halden.*** 2014. Detection and Occurrence of N Nitrosamines in Archived Biosolids from the Targeted National Sewage Sludge Survey of the

U.S. Environmental Protection Agency. *Environmental Science & Technology* 48(9):5085-5092. doi: 10.1021/es5001352. Epub 2014 Apr 15.

9. Wells, E. M.,* A. Navas-Ancien, B. J. Apelberg, J. B. Herbstman, J. M. Jarrett, Y. H. Lin, C. P. Verdon, C. Ward, K. L. Caldwell, J. R. Hibbeln, **R. U. Halden**, F. R. Witter, and L. R. Goldman. 2014. Association of Selenium and Copper with Lipids in Umbilical Cord Blood. *Journal of Developmental Origins of Health and Disease*. 5(4), 281-287. DOI:10.1017/S2040174414000233.

10. Hesari, N., C. M. Francis, and **R. U. Halden.*** 2014. Evaluation of Glycol Ether as an Alternative to Perchloroethylene in Dry Cleaning. *Toxics* 2:115-133; doi:10.3390/toxics2020115

11. **Halden, R. U.*** 2014. On the Need and Speed of Regulating Triclosan and Triclocarban in the United States. *Environmental Science & Technology* 48:3603−3611.DOI: 10.1021/es500495p. ES&T Cover & Feature. EPub March 3, 2014.

12. Venkatesan, A., H. Done, and **R. U. Halden.*** 2014. United States National Sewage Sludge Repository at Arizona State University – A New Resource and Research Tool for Environmental Scientists, Engineers, and Epidemiologists. *Environmental Science and Pollution Research* (In Press).

13. Venkatesan A. and **R. U. Halden**.* 2014. Brominated flame retardants in U.S. biosolids from the EPA national sewage sludge survey and chemical persistence in outdoor soil mesocosms. *Water Research* 55, 133-142. http://dx.doi.org/10.1016/j.watres.2014.02.021

14. Venkatesan A. and **R. U. Halden**.* 2014. Wastewater Treatment Plants as Chemical Observatories to Forecast Ecological and Human Health Risks of Manmade Chemicals. *Scientific Reports*, 4: 3731 | DOI: 10.1038/srep03731. www.nature.com/srep/2014/140116/srep03731/full/srep03731.html

15. Marsalla, J., B-O. Kim. and **R. U. Halden**.* 2013. Analysis of Crop Rotations in the U.S. Breadbasket Using Legumes as an Alternative to Industrially-Produced Fertilizer. *J. Agric. Sci. Appl.* 3(2):169-174. http://www.j-asa.org/Download.aspx?ID=5141. PMID TBD.

16. Deo, R. P. and **R. U. Halden**.* 2013. Pharmaceuticals in the Built and Natural Water Environment of the United States. *Water* 5(3):1346-1365. DOI:10.3390/w5031346. PMID TBD.

17. Doudrick, K., N. Corson, G. Oberdorster, A. C. Elder, P. Herckes, **R. U. Halden,** and P. Westerhoff. 2013. Extraction and Quantification of Carbon Nanotubes in Biological Matrices with Application to Rat Lung Tissue. *ACS Nano* (In Press; Article ASAP). DOI: 10.1021/nn403302s

18. Dong, H.-P., Williams, E., Wang, D.-Z., Xie, Z.-X.,3, Hsia, R.-C., Jenck, A., **Halden, R.U.,** Chen, F., Place, A. R. 2013. Responses of *Nannochloropsis oceanica* IMET1 to Long-term Nitrogen Starvation and Recovery. *Plant Physiol.* 162(2):1110-1126. DOI: 10.1104/pp.113.214320

19. Scotch, M, B. Baarson, R. Beard, R. Lauder, A. Varman, and **R. U. Halden**. 2013. Examining the Differences in Format and Characteristics of Zoonotic Virus Surveillance Data on State Agency Websites. *Journal of Medical Internet Research* 15(4):e90. doi:10.2196/jmir.2487.

20. Venkatesan A. and **R. U. Halden**.* 2013. National Inventory of Perfluoroalkyl Substances in Archived U.S. Biosolids from the 2001 EPA National Sewage Sludge Survey. *J. Hazardous Materials* 4:413-418. DOI:10.1016/j.jhazmat.2013.03.016. NIHMS 464002.

21. Ziv-El, M., T. Kalinowski, R. Krajmalnik-Brown and **R. U. Halden**.* 2013. Simultaneous Determination of Chlorinated Ethenes and Ethene in Groundwater using Automated Headspace Solid Phase Microextraction. *Journal of Chromatographic Science* doi 10.1093/chromsci/bms258.

22. North, E. J. and **R. U. Halden**.* 2013. Plastics and Environmental Health: The Road Ahead. Invited paper at *Reviews on Environmental Health* 28(1):1-8. DOI 10.1515/reveh-2012-0030.

23. Venkatesan A. and **R. U. Halden**.* 2013. National Inventory of Alkylphenol Ethoxylate Compounds in U.S. Biosolids and Chemical Fate in Outdoor Soil Mesocosms. *Environmental Pollution* 174:189-193.

24. Love, D. C., **R. U. Halden**, M. F. Davis, and K. E. Nachman. 2012. Response to Comment on Feather Meal: A Previously Unrecognized Route for Reentry into the Food Supply of Multiple Pharmaceuticals and Personal Care Products (PPCPs). *Environ. Sci. Technol.*, 46(24): 13557-13558. DOI: 10.1021/es304181c.

25. Love, D. C., **R. U. Halden**, M. F. Davis, and K. E. Nachman. 2012. Response to Comment on Feather Meal: A Previously Unrecognized Route for Reentry into the Food Supply of Multiple Pharmaceuticals and Personal Care Products (PPCPs). *Environ. Sci. Technol.*, 46(24):13026-13027. DOI: 10.1021/es304180x.

26. Chari, B. P. and **R. U. Halden.*** 2012. Predicting the Concentration Range of Unmonitored Chemicals in Wastewater-dominated Streams and in Run-off from Biosolids-amended soils. *Science of the Total Environment* 440:314-320. doi: 10.1016/j.scitotenv.2012.05.042. PMID 22682556.

27. Kalinowski, T. * and **R. U. Halden**. 2012. Can Stress Enhance Phytoremediation of Polychlorinated Biphenyls? *Environmental Engineering Science* 29(12):1047-1052; DOI: 10.1089/ees.2012.0089.

28. Hartmann. E. M., and **R. U. Halden.*** 2012. Analytical Methods for the Detection of Viruses in Food by Example of CCL-3 Bioagents. *Analytical and Bioanalytical Chemistry* 404(9):2527-2537. PMID 22526652.

29. Pycke, B. F. G., T.-C. Chao, P. Herckes, P. Westerhoff and **R. U. Halden.*** 2012. Beyond nC_{60}: Strategies for Identification of Transformation Products of Fullerene Oxidation in Aquatic and Biological Samples. *Analytical and Bioanalytical Chemistry,* 404(9) (2012):2583-2595. DOI 10.1007/s00216-012-6090-8. PMID 22644149.

30. Chari, B. P. and **R. U. Halden.*** 2012. Validation of Mega Composite Sampling and Nationwide Mass Inventories for 26 Previously Unmonitored Contaminants in Archived Biosolids from the U.S National Biosolids Repository. *Water Research* 36:4814-4824. PMID 22789759.

31. Delgado, A., P. Parameswaran, D. Fajardo-Williams, **R. U. Halden**, and R. Krajmalnik-Brown.* 2012. Role of Bicarbonate as a pH Buffer and Electron Sink in Microbial Dechlorination of Chloroethenes. *Microbial Cell Factories* 1(128):10pp.

32. Ziv-El, M., S. C. Popat, K. Cai, **R. U. Halden**, R. Krajmalnik-Brown, and B. E. Rittmann*. 2012. Managing Methanogens and Homoacetogens to Promote Reductive Dechlorination of Trichloroethene with Direct Delivery of H_2 in a Membrane Biofilm Reactor. *Biotechnol. Bioeng.* 109(9):2200-2210. PMID 22392141.

33. Ziv-El, M., S. C. Popat, P. Parameswaran, D. W. Kang, A. Polasko, **R. U. Halden**, B. E. Rittmann, and R. Krajmalnik-Brown.* 2012. Using Electron Balances and Molecular Techniques to Assess Trichoroethene-induced Shifts to a Dechlorinating Microbial Community. *Biotechnol. Bioeng.* 109(9):2230-2239. PMID 22447387.

34. Venkatesan, A. K., B. F. Pycke, L. B. Barber, K. E. Lee, and **R. U. Halden.*** 2012. Occurrence of Triclosan, Triclocarban, and Its Lesser Chlorinated Congeners in Minnesota Freshwater Sediments Collected Near Wastewater Treatment Plants. *Journal of Hazardous Materials* 229-230:29-35. PMID 22742731.

35. Ziv-El, M., A. G. Delgado, Y. Yao, K. Muto, D.-W. Kang, **R. U. Halden**, R. Krajmalnik-Brown.* 2012. Development and Characterization of DehaloR^2, a Novel Anaerobic Microbial Consortium Performing Rapid Dechlorination of TCE to Ethene. *Applied Microbiology and Biotechnology* 95(1):273-274. PMID 21667274.

36. Hartmann. E. M., J. P. Badalamenti, R. Krajmalnik-Brown, and **R. U. Halden**.* 2012. Quantitative PCR for Tracking Megaplasmid-borne Biodegradation Potential of a Model Sphingomonad. *Appl. Environ. Microbiol.* 78(12):2293-4496. PMID 22492441.

37. Love, D. C., **R. U. Halden**, M. F. Davis, and K. E. Nachman. Response to Comment on Feather Meal: A Previously Unrecognized Route for Reentry into the Food Supply of Multiple Pharmaceuticals and Personal Care Products (PPCPs). *Environ. Sci. Technol.*, 46(10):5631-5631. DOI: 10.1021/es301528a.

38. Hansmeier, N., T.-C. Chao, L. R. Goldman, F. R. Witter, and **R. U. Halden***. 2012. Prioritization of Biomarker Targets in Human Umbilical Cord Blood: Identification of Proteins in Infant Blood Serving as Validated Biomarkers in Adults. *Environmental Health Perspectives* 120(5):764-769. http://dx.doi.org/10.1289/ehp.1104190. PMID 22538116.

39. Love, R. C., **R. U. Halden**, M. F. Davis and K. E. Nachman. 2012. Feather Meal: a Previously Unrecognized Route for Reentry into the Food Supply of Multiple Pharmaceuticals and Personal Care Products (PPCPs). *Environ. Sci. Technol.* 46(7):3795-3802. PMID 22435972.

40. Wells, E. M.,* L.R. Goldman, J. M. Jarrett, B. J. Apelberg, J. B. Herbstman, K. L. Caldwell, **R. U. Halden**, and F. R. Witter. 2012. Selenium and Maternal Blood Pressure During Childbirth. *Journal of Exposure Science and Environmental Epidemiology*. 22(2):191-197. PMID 22108761.

41. Gray, E. P, T. A. Bruton, C. P. Higgins, **R. U. Halden**, P. Westerhoff, and J. F. Ranville. 2012. Analysis of Gold Nanoparticle Mixtures: a Comparison of Hydrodynamic Chromatography (HDC) and Asymmetrical Flow Field-Flow Fractionation (AF4) Coupled to ICP-MS. *J. Analyt. Atomic Spectrometry* 27(9):1532-1539. DOI: 10.1039/c2ja30069a

42. Colquhoun, D., E. M. Hartmann, and **R. U. Halden.*** 2012. Proteomic Profiling of the Dioxin-Degrading Bacterium *Sphingomonas wittichii* RW1. *J. Biomed. Biotech.* Article ID 408690, 9 pages. (In Press). doi:10.1155/2012/408690. PMID 23091346.

43. Ziv-El, M., A. G. Delgado, Y. Yao, K. Muto, D.-W. Kang, **R. U. Halden**, R. Krajmalnik-Brown.* 2011. Development and Characterization of DehaloR^2, a Novel Anaerobic Microbial Consortium Performing Rapid Dechlorination of TCE to Ethene. *Applied Microbiology and Biotechnology* 92(5):1063-1071. PMID 21667274.

44. Novak, P. J., Arnold, W. A., Blazer, V.S., **Halden, R. U.**, Klaper, R. D., Kolpin, D. W., Kriebel, D., Love, N. G., Martinovic-Weigelt, D., Patisaul, H. B., Snyder, S. A., vom Saal, F. S., Weisbrod, A. V., and D. L. Swackhamer. 2011. On the Need for a National (US) Research Program to Elucidate the Potential Risks to Human Health and the Environment Posed by Contaminants of Emerging Concern. *Environmental Science & Technology* 45(9):3829-3830. DOI: 10.1021/es200744f. PMID 21438522.

45. Novak, P. J. with Contributing Authors: Arnold, W. A., Blazer, V.S., **Halden, R. U.**, Klaper, R. D., Kolpin, D. W., Kriebel, D., Love, N. G., Martinovic-Weigelt, D., Patisaul, H. B., Snyder, S. A., vom Saal, F. S., Weisbrod, A. V., and D. L. Swackhamer. 2011. Unite to Assess Contaminant Risk. *Nature* 471(7340):578-578. (See http://www.nature.com.ezproxy1.lib.asu.edu/nature/journal/v471/n7340/extref/471578a-s1.pdf for full list of authors).

46. Chao, T.-C., G. Song, N. Hansmeier, P. Westerhoff, P. Herckes, **R. U. Halden.*** 2011. Characterization and LC-MS/MS based quantification of hydroxylated fullerenes. *Analytical Chemistry* 83(5):1777-1783. PMID 21294534.

47. Wells, E. M.,* B. J. J. M. Jarrett, Y. H. Li, K. L. Caldwell, J. R. Hibbeln, B. J. Apelberg, J. Herbstman, **R. U. Halden**, F. R. Witter and L. R. Goldman. 2011. Body Burdens and Descriptors of Mercury, Lead, Selenium and Copper Among Newborns at an Urban Hospital. *Environ. Res.* 11(3):411-417. doi:10.1016/j.envres.2010.12.009. PMID 21277575.

48. Wells, E. M.,* Navas-Acien, A., Herbstman, J. B., Apelberg, B. J., Silbergeld, E.K., Caldwell, K. L., Jones, R. L., **Halden, R. U.,** Witter, F. R., and L. R. Goldman. 2011. Low level lead exposure and elevated blood pressure during pregnancy. *Environ. Health Perspect.* 119(5):664-669. doi:10.1289/ehp.1002666. PMID 21292600.

49. Neta, G.,* L. R. Goldman, D. Barr, A. Sjödin, N. Fedarko, B. J. Apelberg, F. R. Witter, **R. U. Halden.** 2011. Fetal exposure to chlordane and permethrin mixtures in relation to inflammatory cytokines and birth outcomes. *Environmental Science & Technology* 45(4):1680-1687. PMID 21235202.

50. Benn, T. M.*, B. F. Pycke, P. Herckes, P. Westerhoff, and **R. U. Halden.** 2011. Evaluation of Extraction Methods for the Quantification of Aqueous Fullerenes in Urine. *Anal. Bioanalyt. Chem.* 399(4):1631-1639. PMID 21153587.

51. W. P. Ela,* D. L. Sedlak, M. A. Barlaz, H. F. Henry, D. D. G. Muir, D. L. Swackhamer, E. J. Weber, R. G. Arnold, L. Ferguson, J. A. Field, E. T. Furlong, J. P. Giesy, **R. U. Halden,** T. Henry, R. A. Hites, K. C. Hornbuckle, P. H. Howard, R. G. Luthy, A. K. Meyer, A. E. Sáez, F. S. vom Saal, C. D. Vulpe, and M. R. Wiesner. 2011. Towards Identifying the Next Generation of Superfund and Hazardous Waste Site Contaminants. *Environ. Health Perspect.* 119(1):6-10. PMID 21205582.

52. Higgins, C. P.,* Z. J. Paesani, T. E. A. Chalew, **R. U. Halden**, L. Hundal. 2011. Persistence of Triclocarban and Triclosan in Soils after Land Application of Biosolids and Bioaccumulation in *Eisenia foetida*. *Environ. Toxicol. Chem.* 30(3):556-563. PMID 21128266.

53. Pycke, B. F., T. M. Benn, P. Herckes, P. Westerhoff, and **R. U. Halden***. 2011. Strategies for Quantifying C60 Fullerenes in Environmental and Biological Samples and Implications for

Toxicological Studies in Environmental Health and Ecotoxicology. *Trends in Analytical Chemistry* 30(1):44-57. PMID 21359100.

54. Miller, T. R., A. L. Delcher, S. L. Salzberg, E. Saunders, J. C. Detter, and **R. U. Halden.*** 2010. Genome Sequence of the Dioxin Mineralizing Bacterium *Sphingomonas wittichii* RW1. *J. Bacteriology* 192(22):6101-6102. PMID 20833805.

55. Deo, R. P. and **R. U. Halden.*** 2010. *In Silico* Screening for Unmonitored, Potentially Problematic High Production Volume (HPV) Chemicals Prone to Accumulate in Biosolids. *Journal of Environmental Monitoring* 12(10):1840-8145. DOI:10.1039/c001559h. PMID 20721409.

56. Miller, T. R., D. R. Colquhoun, and **R. U. Halden.*** 2010. Identification of Wastewater Bacteria Involved in the Degradation of Triclocarban and its Non-Chlorinated Congener. *J. Hazard. Mat.* 183(1-3):766-772. PMID 20727675.

57. Walters, E., K. McClellan and **R. U. Halden.*** 2010. Occurrence and loss over three years of 72 pharmaceuticals and personal care products from biosolids-soil mixtures in outdoor mesocosms. *Water Research* 44:6011-6020. PMID 20728197.

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3. McClellan, K., T. Kalinowski, T. A. Bruton, and **R. U. Halden.*** In Situ Microcosm Array (ISMA) Technology for Treatability Studies in Groundwater Remediation – Part 2: Field Application in a Perchlorate-contaminated, Aerobic Aquifer. (In Preparation).

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1. **Halden, R. U.**, K. McClellan and T. Kalinowski. ESTCP Project 200914, Final Report. Parallel *In Situ* Screening of Remediation Strategies for Improved Decision Making, Remedial Design, and Cost Savings. Department of Defense Environmental Security Technology Certification Program, November 2012 (Released: December, 2013) http://www.serdp.org/content/download/22644/231506/file/ER-200914-FR.pdf

2. **Halden, R. U.**, K. McClellan and T. Kalinowski. ESTCP Project 200914, Cost and Performance Report. Parallel *In Situ* Screening of Remediation Strategies for Improved Decision Making, Remedial Design, and Cost Savings. Department of Defense Environmental Security Technology Certification Program, November 2012 (Released: December, 2013) http://www.serdp.org/content/download/22642/231491/file/ER-200914-CP.pdf

3. **Halden, R. U.,** K. McClellan, T. Kalinowski. 2012. Draft Final Report - Parallel *In Situ* Screening of Remediation Strategies for Improved Decision Making, Remedial Design, and Cost Savings; ESTCP DOD Project ER-200914. Environmental Security and Technology Certification Program, 133 pp, Department of Defense, November 2012.

4. **Halden, R. U.,** I. Roll. 2011. Site Selection Memorandum for ESTCP DOD Project ER-201122. Environmental Security and Technology Certification Program, 7 pp, Department of Defense, December 2011.

5. **Halden, R. U.** (Contributor). 2009. Antibiotic Resistance: An Ecological Perspective on an Old Problem. A Report from the American Academy of Microbiology. Online at http://academy.asm.org/images/stories/colloquia_images/antibiotic_resistance.jpg. 32 pp.

6. **Halden, R. U.** (Contributing Author). 2009. White Paper: Pesticides in the Maryland Chesapeake Bay Watershed. Published by the Maryland Pesticide Network. Published Online at http://www.mdpestnet.org/publications/MPN-2009WhitePaper.pdf. 38 Pages.

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8. **Halden, R. U.** (Contributing Author). 2007. Plans and Practices for Groundwater Protection at the Los Alamos National Laboratory—**Final Report**—Committee for the Technical Assessment of Environmental Programs at the Los Alamos National Laboratory Nuclear and Radiation Studies Board Division of Earth and Life Studies. ISBN-10: 0-309-10619-2. 60 Pages. National Research Council of The National Academies, The National Academies Press, Washington, D.C.

9. **Halden, R. U.** (Contributing Author). 2006. Plans and Practices for Groundwater Protection at the Los Alamos National Laboratory—**Interim Status Report**—Committee for the Technical Assessment of Environmental Programs at the Los Alamos National Laboratory Nuclear and Radiation Studies Board Division of Earth and Life Studies, ISBN-10: 0-309-10391-6. National Research Council of The National Academies, The National Academies Press, Washington, D.C.

10. **Halden, R. U.** (Contributing Author). SERDP/ESTCP Strategic Plan Guiding Future Investments in Molecular Biological Tools (MBT). Final Report. pp. 1-64. http://docs.serdp-estcp.org/viewfile.cfm?Doc=MBT%20Workshop%20Report%2Epdf.

11. Gregory, S., V. Madrid, L. Ferry, **R. U. Halden**, and Z. Demir. 2002. Interim Remedial Design for the Building 834 Operable Unit Treatment Facility at Lawrence Livermore National Laboratory Site 300. UCRL-AR-144919 February 2002 (273 pp).

12. Burge S. and R. U. Halden. 1999. Nitrate and Perchlorate Removal from Groundwater by Ion Exchange. UCRL- ID-135639.

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1. **Halden, R. U.** and I. B. Roll. (Contributing Authors). 2011. Monitoring Waste in Groundwater (Without All the Waste). Arab Water World Magazine 35(5):94.

2. Herbstman J. B., Sjödin A., Paterson D. G., Apelberg B. J., Witter F. R., **Halden, R. U.**, Heidler, J., Needham, L. L., Goldman, L. R. 2005. PCBs and PBDEs and Thyroid Hormone Levels in Umbilical Cord Blood in an Urban U.S. Population: A Feasibility Study. *Organohalogen Compounds*, 2005. CD-ROM ID: 2171.

3. **Halden, R. U.** (Contributing Author). Sewage in Baltimore. 2003. Annual Report of the Baltimore Sanitary Sewer Oversight Coalition (BSSOC). http://www.jhsph.edu/Dept/EHS/Faculty/Halden/Full_BSSOC_Report_2003.pdf

4. Madrid, V. M., Demir, Z., Gregory, S., Valett, J., and **R. U. Halden**. 2003. A Geospatial Model for Remedial Design Optimization and Performance Evaluation. UCRL-JC-147302. http://www.osti.gov/servlets/purl/15005954-fMH8E0/native/.

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6. **Halden, R.U.**, and J. P. Ziagos. 2000. Supplemental Deployment Plan for Bioremediation and Natural Attenuation to Achieve In Situ Restoration of Chloroethene-Contaminated Groundwater at LLNL's Building 834 Operable Unit, Site 300, CA. Lawrence Livermore National Laboratory, Livermore, CA. 41 pp. UCRL-AR-136513. http://www-erd.llnl.gov/library/AR-136513.pdf

7. **Halden, R.U.** (Contributor). 1999. Draft Site-Wide Feasibility Study, LLNL Site 300.

8. Burge, S. and **R. U. Halden**. 1999. Optimization Study of Nitrate and Perchlorate Removal from Groundwater by Ion Exchange. LLNL, UCRL-ID-135639. pp 1-97. http://clu-in.org/download/contaminantfocus/perchlorate/LLNL1.pdf.

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10. **Halden, R. U.** Engineered In Situ Biodegradation of Dioxins and Related Compounds. Ph.D. Thesis. University of Minnesota, Department of Civil Engineering, Minneapolis, MN (1997).

11. **Halden, R. U.,** B. G. Fischer, and D. F. Dwyer: Degradation of Carboxydiphenyl Ether Via Bioaugmentation. Proceedings of the North Amer. Water & Environment Congress, ASCE, Somerset, NJ, pp. 2395-2401 (1996).

12. **Halden, R. U.,** G. W. Mundfrom, E. G. Peters, and D. F. Dwyer: Monitoring the Fate and Activity of Diaryl Ether-Degrading Bacteria in Soil. 50th Purdue Industrial Waste Conference Proceedings, Ann Arbor Press, Inc., Chelsea, Michigan, pp. 57-64 (1995).

13. **Halden, R. U.** Biotransformation of Polychlorinated Dibenzo-p-Dioxins, Dibenzofurans, and Diphenyl Ethers. M.S. Thesis. University of Minnesota, Department of Civil Engineering, Minneapolis, MN (1994).

14. **Halden, R. U.** Mikrobiologische Untersuchung einer lösungsmittelabbauenden mikrobiellen Mischkultur aus einem Festbettreaktor zur biologischen Abluftreinigung. M.S. Thesis (Diplomarbeit). Technische Universität Carolina-Wilhelmina Braunschweig, Braunschweig, Germany (1991).

PUBLICATIONS

International and National Conference Proceedings Papers, Abstracts and Presentations (Referred)

1. Pycke, B. F. J., **R. U. Halden,** M. Dalloul, O. Abulafia, A. Jenck, and L. A. Geer. Prenatal Exposure to Triclocarban and Triclosan In Relation to Birth Weight and Size in an Urban Immigrant Population from Brooklyn, NY. 24th Annual International Society of Exposure Science Conference. Cincinnati, Ohio. October 12-16, 2014.
2. Venkatesan, A. and **R. U. Halden.** Occurrence of carcinogenic N-nitrosamines in nationally representative samples of U.S. sewage sludges. 248th American Chemical Society National Meeting and Exposition, San Francisco, August 10-14, 2014.
3. Venkatesan, A. and **R. U. Halden.** Nationwide Occurrence, Release Inventories and Prioritization of Emerging Contaminants in U.S. Sewage Sludges: Results from the National Sewage Sludge Repository of Arizona State University. 248th American Chemical Society National Meeting and Exposition, San Francisco, August 10-14, 2014.

4. Jenck, A. M., D. Lake, and **R. U. Halden.** Development of a proteomic-based analytical method for the isolation and identification of *Coccidioides* spp. proteins detectable in human blood plasma. 248th American Chemical Society National Meeting and Exposition, San Francisco, August 10-14, 2014.
5. Supowit, S. D., I. B. Roll. V. D. Dang, K. J. Kroll, N. D. Denslow, and **R. U. Halden.** Active sorbtive sampling for bioavailability: The in situ sampler for bioavailability assessment (IS2B). 248th American Chemical Society National Meeting and Exposition, San Francisco, August 10-14, 2014.
6. Pycke, B. F. G., L. A. Geer, M. Dalloul, O. Abulafia, and **R. U. Halden.** Human biomonitoring of prenatal exposure to triclosan and triclocarban in a multiethnic urban population from Brooklyn, New York. 248th American Chemical Society National Meeting and Exposition, San Francisco, August 10-14, 2014.
7. **R. U. Halden.** Waste epidemiology: Taking the chemical pulse of a nation at the sewer by example of the United States. 248th American Chemical Society National Meeting and Exposition, San Francisco, August 10-14, 2014.
8. Kidd, J., Pycke, B. F. G., and **R. U. Halden.** Thermal treatment for mobilization and co-metabolic degradation of weathered heavy hydrocarbons in the vadose zone. 248th American Chemical Society National Meeting and Exposition, San Francisco, August 10-14, 2014.
9. Done, H. Y., and **R. U. Halden.** Antibiotics and Aquaculture: Detected Residues and Microbial Resistance Risks. 248th American Chemical Society National Meeting and Exposition, San Francisco, August 10-14, 2014.
10. Done, H., B. F. G. Pycke, and **R. U. Halden.** Antibiotic Residue Screening in United States Seafood. SETAC Europe 24th Annual Meeting, Basel, Switzerland, May 11-15, 2014.
11. **Halden, R. U.** Taking the Chemical Pulse of a Nation by Example of the U.S.A. SETAC Europe 24th Annual Meeting, Basel, Switzerland, May 11-15, 2014.
12. Pycke, B. F. G., I. Roll, D. Kolpin, C. Kinney, B. Brownawell, E. Furlong, and **R. U. Halden**. Determination of Metabolites in U.S. Biosolids to Assess Removal of Parent Antimicrobials in the Built Environment. 9th Battelle International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 19-22, 2014.
13. Thomas, J., L. A. Geer, B. F.G. Pycke, M. Dalloul, O. Abulafia, and **R. U. Halden**. Maternal Exposure to EDCs from Consumer Products: Comparison of Levels in a Caribbean Immigrant Population in the U.S. to National and Global Levels. 5th Annual CUGH Conference. Washington, D.C. May 10-12, 2014.
14. Epshtein, O., D. Childers, and **R. U. Halden**. Cracking the Black Box of Treatment Wetlands. Arizona Water Association (AZ Water) 87th Annual Conference, Glendale, Arizona, May 7-9, 2014.
15. Jenck, A. and **R. U. Halden.** Development of a Proteomic-based Diagnostic Tool for Valley Fever Infection Through the Isolation and Identification of Coccidioides Proteins Detectable in Blood Plasma. 58th Annual Coccidioidomycosis Study Group Meeting in Phoenix, AZ April 5, 2014.
16. Thomas, J., B. F. G. Pycke, **R. U. Halden,** M. Dalloul, O. Abulafia, and L. A. Geer. Maternal Exposure to Endocrine Disrupting Compounds from Consumer Products: Comparison of Levels in a Caribbean Immigrant Population in Brooklyn, NY to National and Global Levels. Brooklyn, NY, April 2, 2014.
17. Venkatesan, A, and **R. U. Halden**. National Sewage Sludge Repository at Arizona State University: A Chemical Observatory to Identify and Prioritize Chemicals of Concern to Environmental and Human Health. WATERCON IWEA 2014 Joint Conference and Expo, Springfield, IL, March 17-20, 2014.
18. Supowit, S. D, V. D. Dang, I.B. Roll, K. J. Kroll, N. D. Denslow, and **R. U. Halden.** Sampling for Bioavailability Using Solid Phase Extraction - the In Situ Sampler for Bioavailability (IS2B). 2014 Arizona State University Civil and Environmental Engineering Graduate Student Poster Symposium, Tempe, AZ. March 6, 2014.

19. Charles, M. N. C., A. Delgado, D. Fajardo-Williams, B. F. G. Pycke, R. Krajmalnik-Brown, G. Elliott, K. Wolf and **R. U. Halden**. Investigating the use of the "*In Situ* Microcosm Array" (ISMA) technology for site-specific remediation of dissolved chlorinated solvents in groundwater. 2014 Arizona State University Civil and Environmental Engineering Graduate Student Poster Symposium, Tempe, AZ. March 6, 2014.
20. Venkatesan, A, and **R. U. Halden**. National Biosolids Repository: A New Research Tool to Identify, Prioritize and Predict Environmental and Human Health Implications of Man-made Chemicals. 2014 AZ Water Research Workshop, Phoenix, AZ. January 15, 2014. (Winner of 2nd Prize in Poster Competition).
21. Charles, M. N. C., A. Delgado, D. Fajardo-Williams, B. F. G. Pycke, R. Krajmalnik-Brown, G. Elliott, K. Wolf and **R. U. Halden**. Investigating the use of the "*In Situ* Microcosm Array" (ISMA) technology for site-specific remediation of dissolved chlorinated solvents in groundwater. 2014 AZ Water Research Workshop, Phoenix, AZ. January 15, 2014.
22. Geer, L. A., B. F. G. Pycke, and **R. U. Halden**. Analysis of Maternal Urine, Amniotic Fluid and Cord Blood for Exploring Fetal Exposure to Endocrine Disrupting Compounds and Potentially Associated Adverse Health Outcomes. SETAC North America 34th Annual Meeting, Nashville, TN, November 17-21, 2013.
23. Supowit, S., V. D. Dang, K. J. Kroll, N. D. Denslow and **R. U. Halden**. Active sampling for bioavailability using solid phase extraction as a surrogate for body burden - the *in situ* sampler for bioavailability assessment (IS2B). SETAC North America 34th Annual Meeting, Nashville, TN, November 17-21, 2013.
24. Kroll, K. J., V. D. Dang, S. Supowit, C. J. Martyniuk, D. Barber, R. Conrow, **R. U. Halden**, and N. D. Denslow. Evaluation of distribution of *p,p'*-DDE and dieldrin in largemouth bass exposed to the chemicals by gavage. SETAC North America 34th Annual Meeting, Nashville, TN, November 17-21, 2013.
25. Dang, V. D., K. J. Kroll, S. Supowit, **R. U. Halden**, and N. D. Denslow. Linking Bioavailability to Bioactivity of Persistent Contaminants in Fish. SETAC North America 34th Annual Meeting, Nashville, TN, November 17-21, 2013.
26. **Halden, R. U.**, S. Supowit, V. D. Dang, K. J. Kroll, and N. D. Denslow. *In Situ* Sampler for Assessing Contaminant Bioavailability and Toxicity in Sediments. 26th Annual Meeting of the Superfund Research Program, Baton Rouge, LA, October 15 - 17, 2013.
27. Supowit, S., V. D. Dang, K. J. Kroll, N. D. Denslow and **R. U. Halden**. Assessing Contaminant Bioavailability Using the *In Situ* Sampler for Bioavailability (IS2B). Annual Meeting of the Superfund Research Program, Baton Rouge, LA, October 15 - 17, 2013.
28. Dang, V. D., K. J. Kroll, S. Supowit, **R. U. Halden** and N. D. Denslow. Evaluating Bioavailability of Persistent Organic Compounds via a Trophic Transfer. Annual Meeting of the Superfund Research Program, Baton Rouge, LA, October 15 - 17, 2013.
29. Venkatesan, A. and **R. U. Halden**. Mass Flows of Contaminants of Emerging Concern in U.S. Biosolids and Chemical Fate in Outdoor Soil Mesocosms. 15th International Conference of the Pacific Basin Consortium; Honolulu, Hawaii, September 24-27, 2013.
30. Pycke, B F. G., L. A. Geer, and **R. U. Halden**. Prenatal Exposure to Endocrine Disrupting Compounds in a Predominantly Caribbean Immigrant Community. 15th International Conference of the Pacific Basin Consortium; Honolulu, Hawaii, September 24-27, 2013.
31. K. McClellan, T. Kalinowski, **R. U. Halden**. "*In Situ* Microcosm Array – A New Tool for Remedial Design". AquaConSoil, Barcelona, Spain, April 16-19 2013.
32. Kalinowski. T, I. Bennett and R. U. Halden. Facilitating Mutual Understanding Among Diverse Stakeholders Through Participatory Assessment Of An Emerging Technology. DuPont Summit on Science, Technology and Environmental Policy, Washington, DC, December 2012.
33. McClellan, K., T. Kalinowski, T. A. Bruton, I. B. Roll, **R. U. Halden.** Bringing The Lab To The Field - The In Situ Microcosm Array. DECHEMA International Environmental Remediation Symposium. Frankfurt am Main, Germany, November 26-27, 2012.

34. North, E. J. and **R. U. Halden**. Exploring Opportunities and Obstacles in Society's Transition to Environmentally Sustainable Plastics / Plastics and Environmental Health: The Road Ahead. SETAC North America 33rd Annual Meeting, Long Beach, CA, November 11 – 15, 2012.
35. Fernandez, J., H. A. Sanderson and **R. U. Halden**. Comparison of Policies in the United States and Europe Concerning Pesticide Use, by Example of Herbicide Atrazine. SETAC North America 33rd Annual Meeting, Long Beach, CA, November 11 – 15, 2012.
36. Dang, V. D., K. J. Kroll, S. D. Supowit, S.D., **R.U. Halden** and N. D. Denslow. Assessing Bioavailability of Hydrophobic Organic Contaminants (HOCs) Using Microcosms. SETAC North America 33rd Annual Meeting, Long Beach, CA, November 11 – 15, 2012.
37. North, E. J. and **R. U. Halden**. Exploring Opportunities and Obstacles in Society's Transition to Environmentally Sustainable Plastics. SETAC North America 33rd Annual Meeting, Long Beach, CA, November 11 – 15, 2012.
38. Supowit, S.D., I. B. Roll, V. D. Dang, K. J. Kroll, N. D. Denslow, and R.U. Halden. Sampling for Bioavailability Using Solid Phase Extraction – the In Situ Sampler for Bioavailability (IS2B). SETAC North America 33rd Annual Meeting, Long Beach, CA, November 11 – 15, 2012.
39. Geer, L. A., B. F. G. Pycke, M. Dalloul, O. Abulafia, and **R.U. Halden.** Maternal Exposure to Environmental Aromatic Compounds from Consumer Products. 22nd Annual Meeting of the International Society of Exposure Science, Seattle, WA, October 28-November 1, 2012.
40. Supowit, S.D., I. B. Roll, V. D. Dang, K. J. Kroll, N. D. Denslow, and **R.U. Halden**. Sampling for Bioavailability Using Solid Phase Extraction – the In Situ Sampler for Bioavailability (IS2B). 25th Annual Meeting of the Superfund Research Program, Raleigh, NC, October 21-24, 2012.
41. Lee, H., E. W. Wells, J. I. Feinberg, S. Brown, R. A. Irizarry, J. Herbstman, F. R. Witter, **R. U. Halden**, L. R. Goldman, A. P. Feinberg, and M. D. Fallin. Genome-wide Association Between DNA Methylation and Neonatal Heavy Metal Exposures During Pregnancy. Annual ECHO Conference, Baltimore, October 2012.
42. Kalinowski. T, K. McClellan, K., T. A. Bruton, I. B. Roll, and **R. U. Halden**. Assessing the Predictive Performance of the In Situ Microcosm Array. 25th Annual Meeting of the Superfund Research Program, Raleigh, NC, October 21-24, 2012.
43. Roll, I. B., S. D. Supowit, and **R. U. Halden**. Performance Data for a System for In Situ Sample Preparation, the In Situ Sampler (IS2). 25th Annual Meeting of the Superfund Research Program, Raleigh, NC, October 21-24, 2012.
44. Charles, M., K. McClellan, T. Kalinowski, B. F. G. Pycke, D. W. Kang, R. Krajmalnik-Brown, and **R. U. Halden**. Effects of Nutrient Delivery Mode on the Composition of Microbial Communities Relevant to Bioremediation Using the "In Situ Microcosm Array" (ISMA). 25th Annual Meeting of the Superfund Research Program, Raleigh, NC, October 21-24, 2012.
45. Kalinowski. T., K. McClellan, T. A Bruton, I. B. Roll, S. Supowit and **R. U. Halden**. Introducing the In Situ Microcosm Array: A New Tool for Evaluating In Situ Remediation technologies In Situ. Motorola 52nd St. Superfund Site Community Information Meeting, Sonoran Science Academy, Phoenix, AZ, October 2012.
46. Kalinowski. R. Rushforth, F. Rider, **R. U. Halden**, and A.Wiek. Motorola 52nd St. Community Workshop on Emerging Remediation Technology: In Situ Microcosm Array. Gateway Community College, Phoenix, AZ, August 2012.
47. Love, D. K., **R.U. Halden**, M. Davis and K. Nachmann. Are Animal Feed Ingredients Contributing to Antimicrobial Resistance? Feather Meal Contains Multiple Antimicrobials, and Enrofloxacin at Levels that Inhibit Susceptible E. coli22nd Annual Meeting of the American Society for Microbiology (ASM) San Francisco, June 19-22, 2012.
48. Kalinowski. T., K. McClellan, T. A. Bruton, I. B. Roll, R. Krajmalnik-Brown and **R. U. Halden**. Bioremediation of TCE and Hexavalent Chromium: Comparing Bench-Scale Treatability Studies to the In Situ Microcosm Array. Battelle's 8th International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 2012.

49. Kalinowski, T., K. McClellan, T. A. Bruton, and **R.U. Halden.** In Situ Microcosm Array: A Novel Tool for Conducting Treatability Studies In Situ. 22nd Annual International Conference on Soil, Water, Energy, and Air and AEHS Foundation Annual Meeting, San Diego, California, March 19-22, 2012.
50. Kalinowski, T., K. McClellan, T. A. Bruton, I. B. Roll, R. U. Halden. "In Situ Microcosm Array (ISMA) Vs. Standard Laboratory Assessment Of Candidate Remediation Technologies – A Trichloroethylene And Hexavalent Chromium Case Study" ACS National Meeting, San Diego, CA, March 29-29, 2012.
51. Bruton, T. A., K. McClellan, T. Kalinowski, I. B. Roll, R. U. Halden. "Use of the *In Situ* Microcosm Array for Predicting the Effectiveness of Persulfate ISCO for the Treatment of Trichloroethene" ACS National Meeting, San Diego, CA, March 29-29, 2012
52. McClellan, K., T. Kalinowski, T. A. Bruton, I. B. Roll, R. U. Halden. "Bringing the Lab to the Field - The *In Situ* Microcosm Array" ACS National Meeting, San Diego, CA, March 29-29, 2012
53. McClellan, K., Kalinowski, T., K., T. A. Bruton, and **R.U. Halden.** Lowering the Barrier for Novel *In Situ* Remediation Approaches - the *In Situ* Microcosm Array. 22nd Annual International Conference on Soil, Water, Energy, and Air and AEHS Foundation Annual Meeting, San Diego, California, March 19-22, 2012.
54. Venkatesan, A. K., and **R. U. Halden**. Nationwide Occurrence in Biosolids of Alkylphenol Ethoxylate Compounds and Their Fate in Soil Amended With Biosolids. 2012 Summer Specialty Conference: Contaminants of Emerging Concern, Denver, CO, June 25 -27, 2012.
55. Venkatesan, A.K., B.F.G. Pycke, T-C Chao, and **R. U. Halden**. Occurrence of triclosan, triclocarban, and their transformation products in sediments up- and downstream of U.S. wastewater treatment plants. Industrial Wastewater Seminar 2011. Atlantic City, NJ, USA. May 10, 2011.
56. Gray, E.P., Bruton, T.A., Higgins, C.P., **Halden, R.U.**, Westerhoff, P., Ranville, J.F. Comparison of Two Nanoparticle Separation Techniques, Asymmetrical Field Flow Fractionation and Hydrodynamic Chromatography Using Gold Particles, 32nd Annual SETAC North America Meeting, Boston, MA, November 13-17, 2011.
57. **Halden, R. U.**, A. K. Venkatesan and N. Hansmeier. Mixtures of Manmade Hazardous Compounds in the Anthroposphere and in Humans. International Toxicology of Mixtures Conference, Arlington, VA, October 21-23, 2011.
58. McClellan, K., T. Kalinowski, T. A. Bruton, I. B. Roll, and **R.U. Halden.** In Situ Microcosm Array (ISMA) vs. Standard Laboratory Assessment of Candidate Remediation Technologies – A Perchlorate Case Study
Annual Symposium of the NIEHS Superfund Program, October 23-26, 2011, Lexington, KY.
59. Kalinowski, T., K. McClellan, T. A. Bruton, I. B. Roll, R. Krajmalnik-Brown and **R.U. Halden.** Evaluating Bioremediation of TCE and Hexavalent Chromium: A Case Study of the *In Situ* Microcosm Array (ISMA). Annual Symposium of the NIEHS Superfund Program, October 23-26, 2011, Lexington, KY.
60. Kalinowski, T., K. McClellan, T. A. Bruton, I. B. Roll and **R.U. Halden.** *In Situ* Microcosm Array (ISMA): A Novel Device for Conducting Treatability Studies. Geological Society of America Annual Meeting, October 9-12, 2011, Minneapolis, MN.
61. McClellan, T. Kalinowski, K. T. A. Bruton, I. B. Roll and **R.U. Halden.** *In Situ* Microcosm Array (ISMA) vs. Standard Laboratory Assessment of Candidate Remediation Technologies – A Perchlorate Case Study. Geological Society of America Annual Meeting, October 9-12, 2011, Minneapolis, MN.
62. Bruton, T. A., K. McClellan, T. Kalinowski, I. B. Roll and **R.U. Halden.** Field Application of the In Situ Microcosm Array. Groundwater Resources Association of California (GRAC) conference, October 5, 2011, Sacramento, CA.

63. **Halden, R. U.** Biosolids: A Diagnostic Matrix Foretelling Exposures in the Anthroposphere. 3rd International Conference on Occurrence, Fate, Effects, and Analysis of Emerging Contaminants in the Environment, Copenhagen, Denmark, August 23-26, 2011.
64. Hartmann, E. M., M. L. Fisher, and **R. U. Halden**. Site-Directed Mutagenesis of the Dioxin Dioxygenase to Improve Activity Towards 2,3,7,8-Tetrachloro-Dibenzo-*p*-Dioxin. National Science Foundation East Asia and Pacific Summer Institute, Toyama, Japan, August 2011.
65. Miller, T. R., D. R. Colquhoun and **R. U. Halden**. Analysis of Wastewater Bacteria-Degrading Triclocarban. International Symposium on Bioremediation and Sustainable Environmental Technologies, Battelle Conference, Reno, NV. June 27 – 30, 2011.
66. Ziv-El, M., S. Popat, K. Cai, **R. U. Halden**, R. Krajmalnik-Brown and B. E. Rittmann. Optimization of the Membrane Biofilm Reactor for Biological Reduction of Trichloroethylene. International Symposium on Bioremediation and Sustainable Environmental Technologies, Battelle Conference, Reno, NV. June 27 – 30, 2011.
67. Hartmann, E. M. and **R. U. Halden**. Use of AQUA and MALDI-TOF/TOF MS to Quantify a Dioxin-Degrading Enzyme. Science Foundation Arizona Grand Challenges Conference, Flagstaff, AZ. May 22 - 24, 2011.
68. Delgado, A. G., M. Ziv-El, **R. U. Halden**, and R. Krajmalnik-Brown. Microbial Trichloroethene Dechlorination by a Novel Enriched Consortium. Science Foundation Arizona Grand Challenges Conference, Flagstaff, AZ. May 22 - 24, 2011.
69. Pycke, B. F. G., T.-C. Chao, T. M. Benn, R. Scholze, P. Herckes, **R. U. Halden**, and P. Westerhoff. 2011. Mass spectrometry-based detection of aqueous and oxidized fullerenes in biological and environmental samples. Nanotechnology GO Meeting, NIEHS, Bethesda, MD, March 4-5, 2011.
70. Wells, E. M., J. Jarrett, C. Verdon, C. D. Ward, K. Caldwell, F. R. Witter, **R. U. Halden,** L. R. and Goldman. Umbilical Cord Blood Methyl and Inorganic Mercury Concentrations and Their Relationship With Ponderal Index. 2011 International Conference on Mercury as a Global Pollutant. Halifax, Nova Scotia, July 24-29, 2011.
71. Seager, T., M. Fraser, M. Holl and **R. U. Halden**. The SUMMIT Approach to Sustainability in Superfund Research Translation. International Conference on Sustainable Remediation. Amherst, MA, June 1-3, 2011.
72. Venkatesan, A. K., B. Pycke, T.-C. Chao and **R. U. Halden**. Occurrence of Triclosan, Triclocarban, and Their Transformation Products in Sediments Up and Downstream of U.S. Wastewater Treatment Plants. Water Environment Federation: Industrial Wastewater Conference. Bally's Hotel, Atlantic City, New Jersey, May 9-10, 2011.
73. Doudrick, K, A. K. Venkatesan, E. M. Hartmann, T. Kalinowski and **R. U. Halden**. Assessment of the Contribution of Triclosan to Dioxin Emissions from Sludge Incineration in the U.S. Using a Mathematical Model. Water Environment Federation: Industrial Wastewater Conference. Bally's Hotel, Atlantic City, New Jersey, May 9-10, 2011.
74. Hartmann, E. M. and **R. U. Halden**. Use of AQUA and MALDI-TOF/TOF MS to Quantify a Dioxin-Degrading Enzyme. 23rd Annual Sanibel Conference on Mass Spectrometry, American Society for Mass Spectrometry (ASMS), St. Pete Beach, FL, January 21-24, 2011.
75. McClellan, K., T. A. Bruton, T. Kalinowski, and **R. U. Halden**. Use of the "In Situ Microcosm Array"(ISMA) Technology for Evaluation of 1,4-Dioxane and Trichloroethene Co-Remediation. Partners in Environmental Technology Technical Symposium & Workshop, Washington, D.C., November 30 - December 2, 2010.
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82. Lee, H.-S., A. G. Delgado, C. I. Torres, **R. U. Halden**, B. E. Rittmann and R. Krajmalnik-Brown. Anaerobic Dechlorination of Trichloroethene with Hydrogen Produced from a Microbial Electrolysis Cell. Leading Edge Technologies Conference, Phoenix, AZ, June 1, 2010.
83. Goldman, L. R., G. Neta, J. B. Herbstman, A. Sjödin, F. R. Witter, and **R. U. Halden**. Use of principal component analysis to elucidate independent effects of in utero exposure to PBDE and PCB mixtures on newborn thyroid hormone measures. Dioxin 2010 - 30th International Symposium on Halogenated Persistent Organic Pollutants (POPs), San Antonio, TX, September 12-17, 2010.
84. Ziv-El, M. A. Delgado, **R. U. Halden**, and R. Krajmalnik-Brown. 2010. Molecular-biological characterization of a novel, sediment-free mixed culture showing exceptionally rapid dechlorination of TCE to ethane. 13th International Symposium on Microbial Ecology (ISME), Seattle, WA, August 22–27, 2010.
85. Delgado, A., M. Ziv-El, **R. U. Halden**, and R. Krajmalnik-Brown. 2010. Role of pH Buffering on TCE Reduction and Composition of Dechlorinating Consortia. 13th International Symposium on Microbial Ecology (ISME), Seattle, WA, August 22–27, 2010.
86. **Halden, R. U.** Sustainable Management of Hazardous Mixtures. A Proposal. Arizona Department of Environmental Quality, Phoenix, AZ, August 13, 2010.
87. Wells, E. M., J. M. Jarrett, B. J. Apelberg, J. B. Herbstman, A. Navas-Acien, K. L. Caldwell, **R. U. Halden**, F. R. Witter, and L. R. Goldman. The non-monotonic relationship of selenium exposure with blood pressure and hypertension during late pregnancy. The 23rd Annual Meeting of the Society for Pediatric and Perinatal Epidemiologic Research (SPER), Seattle, WA, June 23-26, 2010.
88. Neta, G., L. R. Goldman, D. Barr, A. Sjödin, B. Apelberg, F. Witter, **R. U. Halden**. Distribution and Determinants of in utero Pesticide Mixtures using Principal Component Analysis. Society for Epidemiologic Research (SER) 43rd Annual Meeting Seattle, WA, June 23-26, 2010.
89. Hartmann, E. M. and **R. U. Halden**. Concept for a Brain Tissue Screening Procedure to Ensure Prion Exclusion. Arizona Alzheimer's Consortium Annual Conference, Glendale, AZ, May 21, 2010.
90. Wells E. M., A. Navas-Acien, B. J. Apelberg, J. B. Herbstman, J. M. Jarrett, K. L. Caldwell, **R. U. Halden**, F. R. Witter, and L. R. Goldman. Association of selenium and copper with triglycerides in umbilical cord blood serum. Research ShowCASE 2010, Case Western Reserve University: Cleveland, Ohio, 15 April 2010.

91. Hartmann, E.M. and **R. U. Halden.** 2010. Discovery and Detection of Biomarkers of Petroleum-degrading Bacteria. Science Foundation Arizona Grand Challenges Conference, Phoenix, Arizona, April 12–13, 2010.
92. **R. U. Halden**. Concluding Remarks on Policies for Promoting Sustainable Chemistry. Spring 2010 National Meeting & Exposition of the American Chemical Society, San Francisco, CA, March 21-25, 2010.
93. **R. U. Halden**. Introduction to Policies for Promoting Sustainable Chemistry. Spring 2010 National Meeting & Exposition of the American Chemical Society, San Francisco, CA, March 21-25, 2010.
94. **R. U. Halden**. Concluding Remarks on Antimicrobial Agents and Sustainability. Spring 2010 National Meeting & Exposition of the American Chemical Society, San Francisco, CA, March 21-25, 2010.
95. **R. U. Halden**. Introduction to Antimicrobial Agents and Sustainability. Spring 2010 National Meeting & Exposition of the American Chemical Society, San Francisco, CA, March 21-25, 2010.
96. **R. U. Halden**. Examining the Sustainability of Persistent Antimicrobial Compounds. Spring 2010 National Meeting & Exposition of the American Chemical Society, San Francisco, CA, March 21-25, 2010.
97. Deo, R. P. and **R. U. Halden**. Impact of Sample Processing Procedures on the Quality of Environmental Monitoring Data Influencing Policy Decisions. Spring 2010 National Meeting & Exposition of the American Chemical Society, San Francisco, CA, March 21-25, 2010.
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100. McClellan, K., T. Kalinowski and **R. U. Halden**. ESTCP Project 200914: A New Technology for Remedial Design. Annual Technical Symposium & Workshop hosted by the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP), Washington, DC, December 1-3, 2009.
101. T. Kalinowski, K. McClellan, and **R. U. Halden**. In Situ Sediment Column Microcosms for Studying Bioremediation. Annual Technical Symposium & Workshop hosted by the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP), Washington, DC, December 1-3, 2009.
102. Guerrero-Preston, R., C. LeBron, J. B. Herbstman, **R U. Halden,** D. Sidransky, and L. Goldman. Global DNA Hypomethylation in Cord Blood Serum of Babies Exposed to Maternal Smoking *In Utero*. 137th APHA Annual Meeting & Exposition, San Antonio, TX, November 7-11, 2009.
103. T. Kalinowski, McClellan, K., and **R. U. Halden**. Novel Approaches to Studying the In Situ Bioremediation Potential of Complex Mixtures. Superfund Research Program 2009 Annual Conference, Columbia University, New York, NY, November 3, 2009.
104. **R. U. Halden**. *In Situ* Downhole Technology for Commercialization. First ASU Spartan Workshop for Technology Commercialization, Scottsdale, AZ, September 19, 2009.
105. **R. U. Halden**. Toward Sustainable Chemistry and Engineering. ASU School of Sustainability and the Built Environment, Student Organization, Invited Seminar, Tempe, AZ, September 4, 2009.
106. Walters, E. K. McClellan and **R. U. Halden**. Fate of Pharmaceuticals and Personal Care Products in Agricultural Soils Modified With Biosolids. 238th American Chemical Society (ACS) National Meeting, Washington, DC, August 16-20, 2009.

107. McClellan and **R. U. Halden**. Analysis of PPCPs in biosolids originating from the 2001 EPA National Sewage Sludge Survey. 238th American Chemical Society (ACS) National Meeting, Washington, DC, August 16-20, 2009.
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110. Fox, A. and **R. U. Halden**. Applicability of Passive Sampling Modules for the Determination of Contaminants of Emerging Interest in Digested Municipal Sewage Sludge (Biosolids). 238th American Chemical Society (ACS) National Meeting, Washington, DC, August 16-20, 2009.
111. Higgins, C. P., Z. J. Paesani, T. E. A. Chalew, **R. U. Halden**, and L. S. Hundal. Persistence and Bioaccumulation of Triclocarban and Triclosan in Soils After Land Applications of Municipal Biosolids. EmCon 2009, 2nd International Conference on Occurrence, Fate, Effects, and Analysis of Emerging Contaminants in the Environment, August 4-7, 2009.
112. Walters, E. K. McClellan and **R. U. Halden**. Fate of Pharmaceuticals and Personal Care Products in Agricultural Soils Modified With Biosolids. Micropol/Ecotox, Burlingame, CA, June 8 – 10, 2009.
113. McClellan, K. and **R. U. Halden**. Nationwide Assessment of Pharmaceuticals and Personal Care Products in U.S. Biosolids. Micropol/Ecotox, Burlingame, CA, June 8 – 10, 2009.
114. Doom, T. R. and **Halden, R. U.:** BME Capstone Design Project Presentation. Tempe, May 1, 2009.
115. Doom, T. R. and **Halden, R. U.:** In Situ Remediation of Contaminated Subsurface Environments: Assessing Industry Needs for Technical Innovations. 19th Annual AEHS Meeting and West Coast Conference on Soils, Sediments, and Water. San Diego, CA, March 10, 2009.
116. Geer, L. and **R. U. Halden**. Triclosan and Triclocarban Levels in Urine and Cord Blood of Mother/Infant Pairs. Annual Meeting of the Superfund Basic Research Program of the National Institute of Environmental Health Sciences, Pacific Grove, CA, December 7-9, 2008.
117. Hartmann, E., McClellan, K. and **R. U. Halden**. Toward Proteomics-informed Optimization of In Situ Bioremediation. Annual Meeting of the Superfund Basic Research Program of the National Institute of Environmental Health Sciences, Pacific Grove, CA, December 7-9, 2008.
118. Higgins, C. P., Z. J. Paesani, T. E. A. Chalew, and **R. U. Halden**. Bioaccumulation of Triclocarban in Lumbriculus variegates. SETAC Meeting, November 2008.
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120. Hartmann, E. M., D. R. Colquhoun, and **R. U. Halden.** Identification of Pollutant-Degrading Bacteria Using Peptide Mass Fingerprinting and Mass Spectrometry. American Chemical Society Middle Atlantic Regional Meeting, Philadelphia, PA, May 16–18, 2007.
121. DeLaquil, A., T. R. Miller, and **R. U. Halden.** Accumulation of Antimicrobial Chemicals in Sediment. American Chemical Society Middle Atlantic Regional Meeting, Philadelphia, PA, May 16–18, 2007.
122. Wells, E., Goldman, L. R., Jones, R., Caldwell, K., Apelberg, B. J., Herbstman, J., Needham, L., Witter, F. R. and **R. U. Halden.** Modeling low-level cord blood lead exposure and maternal blood pressure. 19th Annual Conference of the International Society for Environmental Epidemiology, Mexico City, Mexico, September 5–7, 2007.
123. Herbstman J. B., Witter F. R., Apelberg B. J., Sjödin A., Patterson D. G., **Halden, R. U.**, Needham, L. L., and Goldman, L. R. Prenatal PCB and PBDE Exposure and Thyroid Hormone

Levels. 19th Annual Conference of the International Society for Environmental Epidemiology, Mexico City, Mexico, September 5–7, 2007.

124. Wells, E., Goldman, L. R., Jones, R., Caldwell, K., Apelberg, B. J., Herbstman, J., Needham, L., Witter, F. R. and **R. U. Halden.** Public Health Policy Implications of Socioeconomic and Demographic Correlates of Prenatal Lead Exposure. 135th Annual Meeting of the American Public Health Association, Washington, D.C., November 3–7, 2007.
125. Heidler, J., and **R. U. Halden.** Behavior of Persistent Biocides During Wastewater Treatment: Mass Balances and Meta Analysis. American Water Resources Association (AWRA) Summer Specialty Conference on "Emerging Contaminants of Concern in the Environment," Vail, Colorado, June 25–27, 2007.
126. Heidler, J., and **Halden, R. U.** Detection of Persistent Biocides in Sewage Sludge and Human Blood Using LC-ESI-MS and LC-ESI-MS/MS. 55th ASMS Conference on Mass Spectrometry, Indianapolis, IN, June 3–7, 2007.
127. Colquhoun, D. R. and **R. U. Halden.** Comparative Proteomic Analysis of Cells of the Dioxin Degrading Bacterium *Sphingomonas wittichii* RW1 Grown on Various Substrates. 107th ASM General Meeting, Toronto, Ontario, Canada, May 21–25, 2007.
128. Miller, T. R., Salzberg, S. L., Eisen, J. A., and **R. U. Halden.** Comparative Sequence Analysis of Catabolic Megaplasmids from *Sphingomonas wittichii* RW1 and Related Bioremediation Agents. 107th ASM General Meeting, Toronto, Ontario, Canada, May 21–25, 2007.
129. Miller, T. R., Salzberg, S. L., and **R. U. Halden.** Sequence Analysis of Megaplasmids from the Dioxin Mineralizing Bacterium *Sphingomonas wittichii* RW1. Joint Genome Institute User Conference, Walnut Creek, CA, March 28–31, 2007.
130. Higgins, C. P., J. P. Bressler and **R. U. Halden**. Mechanisms of Perfluorochemical Surfactant Bioaccumulation: The Potential Role of Organic Anion Transporters. 15th Annual Scientific Workshop of the JHU-NIEHS Center In Urban Environmental Health. Baltimore, MD, February 28, 2007.
131. Goldman, L. R., B. J. Apelberg, J. B. Herbstman, **R. U. Halden**, F. R. Witter, A. M. Calafat, Z. Kuklenyik, L. L. Needham. Possible Etiologies of PFAA-Induced Developmental Effects: Reflections from a Pediatric Perspective. Society of Toxicology Conference: Current Concepts in Toxicology—Perfluorinalkyl Acids and Related Chemistries: Toxicokinetics and Mode-of-Action Workshop. Arlington, VA, February 14–16, 2007.
132. **Halden, R. U.**, and T. R. Miller. In Situ Microcosm Array Technology for Remedial Feasibility Assessment and Design. Partnership in Environmental Technology Technical Symposium & Workshop (ESTCP/SERDP), Washington, D.C., November 28–30, 2006.
133. Herbstman J. B., Sjödin A., Apelberg B. J., Witter F. R., Patterson D. G., **Halden, R. U.**, Jones, R. S., Park, A., Heidler, J., Needham, L. L., and Goldman, L. R. Determinants of Prenatal Exposure to Polybrominated Diphenyl Ethers (PBDEs) in an Urban Population. International Conference on Environmental Epidemiology & Exposure, Paris, France, September 2–6, 2006.
134. Apelberg B. J., Calafat, A. M., Herbstman J. B., **Halden, R. U.**, Heidler, J., Witter, F. R., Needham, L. L., and Goldman, L. R. Magnitude and Determinants of Fetal Exposure to Perfluorinated Chemicals. International Conference on Environmental Epidemiology & Exposure, Paris, France, September 2–6, 2006.
135. **Halden, R. U.**, D. R. Colquhoun, R. N. Cole and K. J. Schwab. Mass Spectrometry Method for the Epidemiological Surveillance of Norovirus. 106th General Meeting of the American Society for Microbiology, Orlando, FL, May 21–25, 2006.
136. Colquhoun, D. R., T. R. Miller, E. M. Hartmann, and **R. U. Halden.** Rapid Characterization of Pollutant Degrading Bacteria Using Matrix Assisted Laser Desorption Ionization—Time of Flight Mass Spectrometry. 106th General Meeting of the American Society for Microbiology, Orlando, FL, May 21–25, 2006.

137. **Halden, R. U.**, and T. R. Miller. Novel Diagnostic In Situ Monitoring Technology. BIO 2006. Annual International Convention. Environmental Biotechnology Session. Chicago, IL, April 9–12, 2006.

138. Miller, T. R., Colquhoun, D. R., and **R. U. Halden.** Characteristics of a Bacterial Enrichment Culture Utilizing the Antimicrobial Compound Triclocarban as Sole Carbon and Energy Source. 106th General Meeting of the American Society for Microbiology, Orlando, FL, May 21–25, 2006.

139. Heidler, J., and **Halden, R. U.:** Preliminary Assessment of Biocide Inputs to U.S. Water Resources and Soils. 5th International Conference on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, Costa Mesa, California, March 13-15, 2006.

140. Colquhoun, D. R. and **Halden, R. U.:** Phenotypic Characterization of a Dioxin-degrading Bacterium Using MALDI-TOF MS. American Society for Mass Spectrometry, Fall Workshop on Characterization of Microorganisms by Mass Spectrometry, San Diego, CA, December 9, 2005.

141. **Halden, R. U.:** Effect of Lifestyle on Mother/Infant Exposure to Ubiquitous Pollutants. CLF Research Day: Insights Along the Path of Sustainability, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, November 30, 2005.

142. **Halden, R. U.**, A. Sapkota, J. Heidler, J. Keehner, N. Haws, and B. G. Halden: Municipal Sludge Disposal and Sustainable Agriculture: A Pilot Study Showcasing the Challenge of Combining the Two. CLF Research Day: Insights Along the Path of Sustainability, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, November 30, 2005.

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144. Miller, T. R. and **Halden, R. U.**: Enrichment of Xenobiotic-Degrading Bacteria Using a New In Situ Monitoring Device. SETAC 26th Annual Meeting in North America, Baltimore, MD, November 17, 2005. http://abstracts.co.allenpress.com/pweb/setac2005/document/?ID=56786

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147. Herbstman, J., A. Sjodin, D. Patterson, B. Apelberg, F. Witter, **R. U. Halden**, J. Heidler, L. Needham, and L. Goldman: PCBs and PBDEs and Thyroid Hormone Levels in Umbilical Cord Blood in an Urban U.S. Population: A Feasibility Study. Dioxin 2005, Toronto, Canada, August 21-26, 2005.

148. **Halden, R. U.**: Innovative Method for Environmental Monitoring and Bioprospecting. 8th In Situ and On-Site Bioremediation Symposium, Baltimore, MD, June 6-9, 2005.

149. **Halden, R. U.**: Pharmaceuticals and Personal Care Products in Biosolids. New Jersey Water Environment Association Annual Conference, Tropicana Hotel, Atlantic City, NJ, May 4, 2005.

150. **Halden, R. U.**: Pharmaceuticals and Personal Care Products as Indicators of Sewage Spills. Maryland Water Monitoring Council 10th Annual Conference, Linthicum, MD, November 18, 2004. http://www.mgs.md.gov/mwmc/conf/2004/

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153. Matos, C. and **R. U. Halden**: Antimicrobial Compounds as Indicators of Sewage Contamination in Surface Waters. Annual Biomedical Research Conference for Minority Students (ABRCMS), Dallas, TX, November 10 – 13, 2004.
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158. Paull, D.H., and **R. U. Halden**: Monitoring Antimicrobial Compounds as Indicators of Sewerage Problems Impacting Urban Streams. Maryland Water Monitoring Council 9th Annual Conference: Ecological Restoration Assessment and Monitoring, Linthicum, MD, 2003. http://www.mgs.md.gov/mwmc/conf/abspost03.html#paull
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160. Franklin, M. P., Madrid, V., Gregory, S., and **R. U. Halden**: Spatial Analysis of a Microbial Community Mediating Intrinsic Reductive Dechlorination of TCE to *cis*-DCE at a DOE Superfund Site. 103rd General Meeting of the American Society for Microbiology, Washington, D.C., 2003. http://www.asmusa.org/memonly/abstracts/AbstractView.asp?AbstractID=80900
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164. **Halden, R. U.:** Microarrays for Bioremediation. Presenter and Session Moderator. DOE-NABIR PI Workshop, Warrenton, VA, 2002.
165. Lowe, M., A. Spiro, G. Xie, and **R. U. Halden:** Development of a Multiplexed, Bead-based Assessment Tool for Rapid Identification and Quantitation of Microorganisms in Field Samples. DOE-NABIR PI Workshop, Warrenton, VA, 2002.
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172. Semprini, L., S. Vancheeswaran, S. Yu, M.-Y. Chu, and **R. U. Halden**: Tetraalkoxysilanes as Slow-release Substrates to Promote Aerobic and Anaerobic Dehalogenation Reactions in the Subsurface. General Meeting of the American Chemical Society, Washington, D.C., 2000.
173. Happel, A. M., E. H. Beckenbach, B. P. Dooher, K. Emmerson, S. R. Kane, C. Koester, **R. U. Halden**, H. R. Beller, and T. C. Legler: Evaluating Attenuation of MTBE. EPA MTBE Biodegradation Workshop, Cincinnati, OH, 2000.
174. Brown, D., R. Holley-Shanks, D. Maeder, K. Schindler, M. Lowe, F. Brockman, **R. U. Halden**, and F. Robb: Comparison of ISR and 16S-ISR Analysis of VOC Effect on Microbial Communities at Two DOE Sites. 100th General ASM Meeting, Los Angeles, CA, 2000. http://www.asmusa.org/memonly/abstracts/AbstractView.asp?AbstractID=30677
175. Ziagos, J. P., **R. U. Halden**, P. W. Krauter, and W. D. Daily: The Proposed Application of "Green" Technology to Achieve Cleanup Goals. 11th National DOE Technology Information Exchange Workshop, Las Vegas, NV, 1999.
176. **Halden, R. U.**, A .M. Happel, H. R. Beller, C. Koester, B. G. Halden, S. R. Kane, and T. C. Legler: Evidence for Intrinsic Bioremediation of MTBE at a LUFT Site. In-Situ Alternatives for MTBE Impacted Aquifers, Oxnard, CA, 1999.
177. **Halden, R. U.**, V. Madrid, P. Daley, M. Lima, S. Gregory and J. P. Ziagos: Silicon Lubricants Facilitate Bioattenuation of TCE at LLNL's Superfund Site 300. 5th In Situ and On-Site Bioremediation Symposium, San Diego, CA, 1999.
178. **Halden, R. U.**, S. R. Schoen, Y. Galperin, I. R. Kaplan, and A. M. Happel: Evaluation of EPA and ASTM Methods for Analysis of Oxygenates in Gasoline-Contaminated Ground Water. 8th Annual AEHS West Coast Conference on Contaminated Soil and Groundwater, Oxnard CA, 1998.
179. **Halden, R. U.**, W. W. McNab Jr., R. Ruiz, and A. M. Happel: Palladium-Catalyzed Transformation of TCE and MTBE in Groundwater, 1st International Symposium on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, 1998.
180. Rhodes, I., J. Milazzo, L. Brzuzy, L. Harvey, A. Verstuyft, **R. U. Halden**, S. Schoen, Y. Galperin, I. R. Kaplan, and A. M. Happel: Analytical Methods for the Determination of Oxygenates in Gasoline-contaminated Groundwater: Modified EPA and ASTM Methods. 21st EPA Conference on Analysis of Pollutants in the Environment, Norfolk, VA, 1998.
181. **Halden, R. U.**, B. G. Halden, and D. F. Dwyer: A Kinetic Analysis of Dioxin Degradation in Bioaugmented Soils. 97th General ASM Meeting, Miami Beach, FL, 1997.
182. **Halden, R. U.**, and D. F. Dwyer: Biodegradation of Dioxins in Soils. 4th International Battelle Bioremediation Symposium, New Orleans, LA, 1997.
183. **Halden, R. U.:** A Kinetic Analysis of Dioxin Degradation in Bioaugmented Soils. 5th Environmental Science & Engineering Conference, Minneapolis, MN, 1997.

184. **Halden, R. U.**, and D. F. Dwyer: Biotransformation of Dioxin-Related Compounds Via Angular Dioxygenation: Bacterial Strains, Degradative Pathways and Their Potential Use for Bioremediation. 3rd International ISEB Symposium, Boston, MA, 1996.
185. **Halden, R. U.**, and D. F. Dwyer: Small Inocula Can Effect In Situ Biodegradation of Carboxydiphenyl Ether in Soil. Proceedings of the North Amer. Water & Environment Congress, ASCE, Somerset, NJ, 1996.
186. **Halden, R. U.**, and D. F. Dwyer: Colonization of Soil by Low Numbers of a Bacterium Constructed to Degrade Dioxin-Related Pollutants. 96th General ASM Meeting, New Orleans, LA, 1996.
187. Raatz, W. A., K. Anderson, **R. U. Halden**, and D. F. Dwyer: Bioremediation of Aquifers Using Introduced Bacteria. 96th General ASM Meeting, New Orleans, LA, 1996.
188. **Halden, R. U.:** Detection and Environmental Fate of Bacteria Able to Degrade Dioxin-Related Compounds. 4th Annual Environmental Science & Engineering Conference, St. Paul, MN. 1996.
189. **Halden, R. U.**, G. W. Mundfrom, E. G. Peters, and D. F. Dwyer: Detection and Environmental Fate of Bacteria Able to Degrade Dioxin-Related Compounds," 55th Annual ASM North Central Branch Meeting, Iowa City, IA, 1995.
190. **Halden, R. U.**, G. W. Mundfrom, E. G. Peters, and D. F. Dwyer: In Situ Bioremediation: Tracking Introduced Diaryl Ether-Degrading Bacteria In Soil. National ASCE Environmental Engineering Conference, Pittsburgh, PA, 1995.
191. **Halden, R. U.**, G. W. Mundfrom, E. G. Peters, and D. F. Dwyer: Bioaugmentation: Monitoring Diaryl Ether-Degrading Bacteria Introduced Into Contaminated Environments Using Molecular-Genetic Methods. 3rd International Bioreclamation Symposium, San Diego, CA, 1995.
192. **Halden, R. U.:** In Situ Biodegradation of Diaryl Ether Compounds in Soil and Sediment. 3rd Annual Environmental Science & Engineering Conference, Minneapolis, MN, 1995.

PUBLICATIONS

Invited Keynotes, Invited Presentations, Invited Webinars, Invited Expert Panel Member & Conference Session Moderation

1. **Halden, R. U.** Analytical Methods for Detecting and Prioritizing Contaminants of Concern. ACS-Invited Symposium Chair. 248th ACS National Meeting & Exposition San Francisco, CA, August 10-14, 2014.
2. **Halden, R. U.** Invited Keynote Address: Sewage Epidemiology - Taking the Chemical Pulse of a Nation at the Sewer. AZ Engineers Club of the West Valley: Sun City West, AZ. March, 7, 2014.
3. **Halden, R. U.** Invited Talk: Sewage Metrology - Taking the Chemical Pulse of our Nation at the Sewer. Johns Hopkins University, School of Public Health. April 24, 2014.
4. **Halden, R. U.** Invited Talk and Nationally Broadcasted Webinar: Chemical Composition of U.S. Sewage Sludges Informed by Analysis of EPA-Collected Biosolids Samples from Across the United States. United States Environmental Protection Agency Headquarter, Washington, DC, April 22, 2014.
5. **Halden, R. U.** Invited Talk and Nationally Broadcasted Webinar: Update on Antimicrobials in the U.S. Environment. United States Food and Drug Administration, Headquarter, Washington, DC, April 22, 2014.
6. **Halden, R. U.** Invited Talk, Panel Member, and Panel Moderator: Potential Human Health Risks of Microplastics. U.S. National Academies, Washington, DC, April 23, 2014.
7. **Halden, R. U.** Fate, Transport, and Toxicity of Wastewater-borne Contaminants by Example of Widely Used Persistent Antimicrobials. SETAC North America 34th Annual Meeting, Nashville, TN, November 17-21, 2013.
8. **Halden, R. U.** Environmental Fate and Human Health Risks of Contaminants of Emerging Concern in the U.S. Environment. Invited Seminar. Distinguished Lecture Series. Simulcast and Taped. http://icsde.ifas.ufl.edu/Accordent/live/Haden05-21-13/ University of Florida, Gainesville, FL, May 21, 2013.
9. **Halden, R. U.,** K. McClellan and T. Kalinowski. *In Situ* Microcosm Array – A New Decision-Making and Design Tool for In Situ Remediation. Invited Webinar. Technical Practices Network – In Situ Bioremediation Group, AECOM. Presented Online. December 11, 2012.
10. **Halden, R. U.,** S. D. Supowit, I. A. Roll, V. D. Dang, K. J. Kroll and N. D. Denslow. Addressing Risk Assessment Needs for Traditional and Emerging Contaminants Using the Innovative In Situ Sampling/Bioavailability (IS2B) Device. SETAC North America 33rd Annual Meeting, Long Beach, CA, November 11 – 15, 2012. (Invited talk).
11. **Halden, R. U.** Antimicrobials, Antimicrobial Resistance and New Risk Assessment Tools. SETAC North America 33rd Annual Meeting, Long Beach, CA, November 11 – 15, 2012.
12. **Halden, R. U.** Understanding and Minimizing the Health Risks of Plastics. SETAC North America 33rd Annual Meeting, Long Beach, CA, November 11 – 15, 2012.
13. Kalinowski T., K. McClellan and **R. U. Halden**. An Emerging Remediation Technology: The *In Situ* Microcosm Array. Community Informational Group meeting for the Motorola 52nd St. Superfund Site community hosted by the EPA. Sonoran Science Academy-Phoenix K-12 School. Oct. 24, 2012. (Invited talk).
14. **Halden, R. U.,** K. McClellan and T. Kalinowski. *In Situ* Microcosm Array – A New Decision-Making and Design Tool for In Situ Remediation. Invited Interactive Webinar. Remedial Design (In-Situ) Network. Presented Online. September 19, 2012.
15. **Halden, R. U.** and N. Denslow. *In Situ* Sampling Tool for Assessing Bioavailability and Toxicity of Sediments. Invited Webinar Presented Online on May 7, 2012. http://www.clu-in.org/conf/tio/srpfunding/

16. **Halden, R. U.,** K. McClellan and T. Kalinowski. *In Situ* Microcosm Array – A New Decision-Making and Design Tool for In Situ Remediation. Invited EPA Clu-in Webinar. Presented Online. August 15, 2012. http://www.clu-in.org/conf/tio/isma/
17. **Halden, R. U.** Invited Member of 5-Expert Panel Discussion. *Feed 8 Billion.* Arizona State University, Tempe Campus, AZ, February 2, 2012.
18. **Halden, R. U.** Invited Talk. Polluting While Cleaning: *How Personal Care Products Affect Environmental Quality and Human Health.* Polytechnic Campus, Arizona State University, Mesa, AZ, January 10, 2012.
19. Benny F.G. Pycke, L. A. Geer, A. K. Venkatesan, K. E. Lee, L. B. Barber, A. Crabbé, N. Leys, P. Monsieurs, M. Mergeay, G. Vanermen, H. De Wever, W. Verstraete, and **R. U. Halden.** Invited Talk. Antimicrobial Exposure Assessment From The Cradle To The Grave. *International Conference of the Flemish Centre of Expertise for Environment and Health.* Brussels, Belgium, December 21-22, 2011.
20. **Halden, R. U.** Invited Talk (Webcast). Sustainable Chemistry: Public Health at the Crossroads. Biomedical Informatics Symposium Series, Department of Biomedical Informatics, ASU Mayo Campus, Scottsdale, AZ, November 17, 2011.
21. **Halden, R. U.** Invited Talk. Novel Approaches to Assessing the *In Situ* Treatability and Health Impacts of Toxic Mixtures. Pacific Northwest National Laboratory (PNNL), Richland, WA, November 14, 2011.
22. **Halden, R. U.**, K. McClellan, T. Kalinowski, T. A. Bruton, E. M. Hartmann, T. R. Miller, M. Ziv-El, A. Delgado, D. R. Colquhoun, T.-C. Chao, N. Hansmeier, R. P. Deo, J. Heidler, J. B. Herbstman, B. J. Apelberg, E. M. Wells, G. Neta, F. R. Witter, L. R. Goldman, and R. Krajmalnik-Brown. Novel Approaches to Understanding and Managing Complex Mixtures. Annual Conference of the NIEHS Superfund Program, Lexington, KY, October 23 – 26, 2011.
23. **Halden, R. U.** Invited Talk: Overuse of Antimicrobial Household Products: Environmental and Human Health Effects. American Public Health Association (APHA) Annual Meeting, Washington, DC, October 31, 2011.
24. **Halden, R. U.** Invited Panel Member: Beyond the Hospital: Antibiotic Resistance as a Problem of the Community Environment. American Public Health Association (APHA) Annual Meeting, Washington, DC, October 31, 2011.
25. **Halden, R. U.** Invited Talk: Biosolids: A Diagnostic Matrix Foretelling Exposures in the Anthroposphere. Institute for Food Toxicology and Analytical Chemistry, University of Veterinary Medicine, Hanover, Germany, August 29, 2011.
26. **Halden, R. U.** Invited Talk: Antimicrobial Agents and Sustainable Chemistry, *Science Cafe* Series, hosted by the Center for Nanotechnology in Society, Phoenix, AZ, May 20, 2011.
27. **Halden, R. U.** Invited Talk: Public Health Engineering: From Problem Recognition to Regulation. Presented to the IGERT Program at the University of Minnesota, Minneapolis, MN, May 5, 2011.
28. **Halden, R. U.** Invited Talk: In Situ Microcosm Array and In Situ Sampling Technologies for Technology Transfer. ASU Biodesign Institute, April 21, 2011.
29. **Halden, R. U.** Invited Talk: Sustainable Chemistry & Human Health in the 21st Century. U.S. EPA Emerging Chemicals Workgroup. Presented on April 6, 2011.
30. **Halden, R. U.** Invited Talk at Leroy E. Burney Lecturer Series: Sustainable Chemistry and Human Health in the 21st Century, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, March 7, 2011.
31. **Halden, R. U.** Invited Talk at the U.S. Congress: Environmental Health Risks of Triclosan. Capitol Hill Congressional Briefing Room, Washington, DC, February 17, 2011.
32. **Halden, R. U.** and T. Jones-Lepp. Invited Session Chairs: Contaminants of Emerging Concern in the Natural and Built Environment. 241st American Chemical Society National Meeting & Exposition, Anaheim, California, March 27-31, 2011.
33. **Halden, R. U.** Invited Talk: In Situ Microcosm Array Technology and the SUMMIT Center. Arizona Department of the Environment, Phoenix, AZ, January 31, 2011.

34. **Halden, R. U.** Invited Talk: Sustainable Chemistry and Human Health, *The Wiseguise* Seminar Series, Scottsdale, AZ, November 19, 2010.
35. **Halden, R. U.** Invited Chalk Talk. Sustainable Chemistry for the 21[st] Century and Beyond. Center for Biological Physics Seminar Series, Arizona State University, Tempe, AZ, October 26, 2010.
36. **Halden, R. U.** Invited Presentation. Antimicrobial Personal Care Products: Are They Good for Us? Science Salon. Spirit of the Senses Seminar Series. Biodesign Institute, Arizona State University, Tempe, AZ, September 30, 2010.
37. **Halden, R. U.** Invited Presentation. The SUMMIT Project. CHiR-Arizona HealthQuery Stakeholder Meeting, ASU Biomedical Campus, Phoenix, AZ, September 20, 2010.
38. **Halden, R. U.:** Invited Seminar. Examining the Sustainability of Persistent Antimicrobial Compounds. Department of Chemical and Environmental Engineering, University of Arizona, Tucson, AZ, April 20, 2010.
39. **Halden, R. U.:** Parallel *In Situ* Screening of Remediation Strategies for Improved Decision Making, Remedial Design, and Cost Savings. Department of Defense, ESTCP Program, Arlington, VA, February 10, 2010.
40. **Halden, R. U.:** Chemicals of Emerging Concern in the U.S. Environment. American Chemical Society Meeting, Las Vegas, November 10, 2009.
41. **Halden, R. U.:** Wastewater Treatment Plants as Chemical Observatories of Persistent and Problematic Contaminants in the Environment. 238[th] American Chemical Society (ACS) National Meeting, Washington, DC, August 16-20, 2009.
42. **Halden, R. U.** and J. Katz: Occurrence, Fate, and Impact of Triclosan and Other Antimicrobials to Wastewater Treatment Utilities. Microconstituents and Industrial Water Quality, Water Environment Federation (WEF), Baltimore, MD, July 26-29, 2009.
43. **Halden, R. U.:** Invited Panel Member. "Superfund Contaminants: The Next Generation." Invitation-only Special Symposium Tucson, AZ, August 12-14, 2009.
44. **Halden, R. U.:** Invited Speaker. "State of the Science – Antimicrobial Resistance." FDA Discussion: the Problem of Triclosan, Food and Drug Administration, Washington, D.C., July 13, 2009.
45. **Halden, R. U.:** Invited Speaker. "State of the Science – Environmental Fate & Persistence." FDA Discussion: the Problem of Triclosan, Food and Drug Administration, Washington, D.C., July 13, 2009.
46. **Halden, R. U.:** Toward Sustainable Chemistry and Engineering. Invited Seminar presented at the 1[st] Biological Design Graduate Program Symposium, Tempe, May 6, 2009.
47. Hartmann, E. and **R. U. Halden**. Invited presentation: "Challenges of Detecting Bioterrorism Agents in Complex Matrices." NATO ARW Workshop on "Detection of Biological Agents and Toxins for the Prevention of Bioterrorism in Homeland Security by Advanced Mass Spectrometric Methods," Spezzano Albanese Terme, Italy, June 26-July 2, 2009.
48. **Halden, R. U.:** Invited Speaker. High-throughput Diagnostic Screening and Proteomics in Bioremediation - Opportunities & Challenges. The 19[th] Annual AEHS Meeting and West Coast Conference on Soils, Sediments, and Water. San Diego, CA, March 10, 2009.
49. **Halden, R. U.:** Invited Speaker. What's in Our Water? National Research Council 6[th] Workshop of the Standing Committee on Risk Analysis Issues and Reviews. Characterizing the Potential Human Toxicity from Low Doses of Pharmaceuticals in Drinking Water: Are New Risk Assessment Methods or Approaches Required? The National Academies, Washington, D.C., December 11-12, 2008.
50. **Halden, R. U.** and B. Anderson: SBRP Technology Transfer: Statistics & Case Study. Annual Conference of the Superfund Basic Research Program (SBRP) of the National Institute of Environmental Health Sciences. Member of Steering Committee and Invited Speaker of Technology Transfer Session, Pacific Grove, CA, December 7-9, 2008.

51. **Halden, R. U.:** Pharmaceuticals and Personal Care Products in U.S. Water Resources. Invited Keynote at the 2008 Fall Meeting of the Interstate Technology & Regulatory Council (ITRC). Phoenix, AZ, October 21, 2008.
52. **Halden, R. U.:** Invited Panel Member. Antibiotic Resistance: New Approaches to an Old Problem. The American Academy of Microbiology. Invitation-Only International Symposium, Annecy, France, October 12-14, 2008.
53. **Halden, R. U.:** Invited Speaker and Session Chair. Environmental Fate of Antimicrobials: 50 years in 15 minutes. Pacific Southwest Organic Residuals Symposium 2008. Sacramento, October 1-2, 2008.
54. **Halden, R. U.:** Parallel *In Situ* Screening of Remediation Strategies for Improved Decision Making, Remedial Design, and Cost Savings. Department of Defense, ESTCP Program, Arlington, VA, September 16, 2008.
55. **Halden, R. U.:** Occurrence of and Exposure Routes to Triclosan and Triclocarban in the U.S. Environment. State University of New York, Downstate Medical Center, Department of Preventive Medicine and Community Health Seminar, August 28, 2008.
56. **Halden, R. U.:** Work Plan for Field Deployment of the *In Situ* Microcosm Array Technology, Lawrence Livermore National Laboratory, Livermore, CA, July 11, 2008.
57. **Halden, R. U.:** Exposure Sources of Triclosan and Triclocarban in the Environment. Invited Talk at the Food and Drug Administration, Washington, DC, February 27, 2008.
58. **Halden, R. U.:** Field Deployment of the *In Situ* Microcosm Array Technology, Lawrence Livermore National Laboratory, Livermore, CA, February 25, 2008.
59. **Halden, R. U.:** Innovative Technologies. Session Moderator and Planning Committee Member, 20th Anniversary Meeting of the Superfund Basic Research Program, Durham, NC, December 3, 2007.
60. **Halden, R. U.:** Findings from the Johns Hopkins Nationwide Study on the Fate of Pharmaceuticals and Personal Care Products in the Environment. U.S. EPA, Office of Science and Technology, November 28, 2007.
61. **Halden, R. U.:** Forensic Tools for Environmental Assessment and Remediation. University of Delaware, Newark, DE, Department of Civil and Environmental Engineering, October 19, 2007.
62. **Halden, R. U.:** Keynote Speaker. Emerging Knowledge on Emerging Contaminants. New England Interstate Water Pollution Control Commission's (NEIWPCC) 2007 Northeast Water Science Forum – Pharmaceuticals and Personal Care Products: State of the Science Conference, Portland, ME, August 8–9, 2007.
63. **Halden, R. U.:** Guest Speaker. Risks and Benefits of Using Persistent Antimicrobials in Public Health Practice. Public Health Practice Grand Rounds, Live Webcast, MidAtlantic Public Health Training Center (MAPHTC), Baltimore, MD, June 20, 2007.
64. **Halden, R. U.** and K. J. Schwab: Guest Speaker. Environmental Issues Related to Industrial Food Animal Production. National Commission on Industrial Farm Animal Production. Denver, CO, June 5, 2007.
65. **Halden, R. U.:** Keynote Speaker. Antimicrobial Pesticides as Environmental Pollutants. Beyond Pesticides 25th National Pesticide Forum: *"New Opportunities for Protecting Health and the Environment,"* Chicago, IL, June 2, 2007.
66. **Halden, R. U.:** Guest Speaker. Antimicrobial Pesticides in Aquatic Environments – Implications for the Great Lakes. Beyond Pesticides 25th National Pesticide Forum: *"New Opportunities for Protecting Health and the Environment,"* Chicago, IL, June 3, 2007.
67. **Halden, R. U.:** Guest Speaker. Rachel Carson Open House and Centennial Celebration: "U.S. Environmental Quality 45 Years after the Publication of Silent Spring," Silver Spring, MD, May 19, 2007.
68. **Halden, R. U.:** Guest Speaker. USGS Symposium: Rachel Carson Centennial Celebration: "Considering the Microbial Loop in Wildlife Conservation," USGS Patuxent Wildlife Research Center, Laurel, MD, May 18, 2007.

69. **Halden, R. U.:** Guest Speaker & Session Moderator. Antimicrobial Agents in the Chesapeake Bay Watershed. Pesticides in Chesapeake Waterways: Working Group Meeting, Reisterstown, MD, May 14, 2007.
70. **Halden, R. U.:** Guest Speaker. Emerging Contaminants in U.S. Surface Waters: Challenges and Potential Solutions. Potomac River Basin Drinking Water Source Protection Partnership's Mini-Workshop. Rockville, MD, May 7, 2007.
71. **Halden, R. U.:** Moderator of Film Screening and Invited Discussant. Lifecycle Analysis of Polyvinyl Chloride Products. Chesapeake Sustainable Business Alliance, Visionary Arts Museum, Baltimore, MD, March 19, 2007.
72. **Halden, R. U.:** Keynote Speaker. Antimicrobial Agents in the Environment and Human Exposure Assessment. Chesapeake Potomac Chapter of SETAC Winter Meeting, Washington, DC, February 22, 2007.
73. **Halden, R. U.:** Panel Chair and Keynote Speaker. Reducing Our Ecological Footprint. 10th Anniversary of the Johns Hopkins Center for a Livable Future – Charting A Course To Sustainability Through Research, Education And Service, Baltimore, MD, December 6, 2006.
74. **Halden, R. U.:** Overused Household Biocides Cause Nationwide Pollution. 10th Anniversary of the Johns Hopkins Center for a Livable Future – Charting A Course To Sustainability Through Research, Education And Service, Baltimore, MD, December 6, 2006.
75. **Halden, R. U.:** Persistent Antimicrobials as Emerging Endocrine Disrupting Chemicals in U.S. Water Resources, Biosolids and Sediments. Endocrine Disruptors – What We Know & What We Don't Know. Research Symposium of the Mid-Atlantic Regional Water Program, A Partnership of USDA CSREES & Land Grant Colleges and Universities, Frederick, MD, November 16, 2006.
76. **Halden, R. U.:** Environmental Routes of Human Exposure to Persistent Antimicrobial Compounds – A Human Exposure Assessment. Municipal Institute of Medical Research, Barcelona, Spain, November 3, 2006.
77. **Halden, R. U.:** Environmental Toxins. 44th Annual New Horizons in Science Briefing, sponsored by the Council for the Advancement of Science Writing, hosted by The Johns Hopkins University, Baltimore, MD, October 30, 2006. http://www.jhu.edu/newhorizons/
78. **Halden, R. U.:** Persistent Antimicrobial Compounds in the Environment – A Human Health Concern? Christine Mirzayan Science and Technology Policy Graduate Fellowship Program at the National Academies—National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research, Washington, DC, October 25, 2006.
79. **Halden, R. U.:** Contemporary Technologies for Combating Emerging Contaminants. Biodesign Institute, Center for Environmental Biotechnology. Tempe, AZ, October 12, 2006.
80. **Halden, R. U.:** In Situ Microcosm Array (ISMA) Technology for Environmental Monitoring and Toxicity Testing. U.S. Army Invitation-Only Symposium, Massachusetts Institute of Technology. Boston, MA, September 15, 2006.
81. **Halden, R. U.:** Novel Approaches in Environmental Biotechnology. Arizona State University. Tempe, AZ, August 16, 2006.
82. **Halden, R. U.:** Use of Proteomics and In Situ Microcosm Arrays in Environmental Biotechnology. BIO 2006. Annual International Convention. Environmental Biotechnology Session. Chicago, IL, April 9-12, 2006.
83. **Halden, R. U.:** Study on Consumer Products and Pharmaceuticals in the Environment. The Mid-Atlantic States Section of the Air & Waste Management Association (MASS-A&WMA), New Brunswick, NJ, April 6, 2006.
84. **Halden, R. U.:** Environmental Fate of Persistent Antiseptic Compounds. Southern Nevada Water Authority. Las Vegas, NV, February 9, 2006.
85. **Halden, R. U.:** A Novel Tool in Environmental Restoration: Proteomics-enabled In Situ Microcosm Array. Lawrence Livermore National Laboratory, CA, February 6, 2006.
86. **Halden, R. U.:** Fate of Persistent Antimicrobials in the Environment: From Germ Killers to Culinary Curiosities. Colorado School of Mines, Golden, CO, December 14, 2005.

87. **Halden, R. U.:** Environmental Exposure to Persistent Antimicrobial Compounds – A Human Health Concern? Municipal Institute of Medical Research, Barcelona, Spain, November 18, 2005.
88. **Halden, R. U.:** Through a Glass Safely: How Healthy is Our Drinking Water? A Woman's Journey—Johns Hopkins Premier Woman's Health Conference, Baltimore, MD, November 12, 2005.
89. **Halden, R. U.:** Sources, Occurrences, and Fate of Pharmaceuticals and Personal Care Products in the Environment. Public Health Risk Assessment Workshop. Harvard School of Public Health, Boston, MA, November 10, 2005.
90. **Halden, R. U.:** Screening of Groundwater Remediation Technologies Using In Situ Microcosm Arrays. Presenter and Chair of Groundwater Remediation Session. International Conference on Safe Water: Exploring Global Demands and Impact of Natural Disasters, San Diego, CA, October 21, 2005.
91. **Halden, R. U.:** Secondary Routes of Exposure to Biocides. Food And Drug Administration, Center For Drug Evaluation And Research (CDER) Nonprescription Drugs Advisory Committee. "Benefits and Hazards of Antiseptic Products Marketed for Consumer Use." Silver Spring, MD, October 20, 2005.
92. **Halden, R. U.:** Use of Proteomics in Bioremediation. The 21st Annual International Conference on Soils, Sediments, and Water. University of Massachusetts, Amherst, MA, October 18, 2005.
93. **Halden, R. U.:** Measuring Antibacterial Agents in Biosolids and Predicting Their Environmental Fate. Mid-Atlantic Biosolids Association Research Symposium, Washington, DC, September 28, 2005.
94. **Halden, R. U.:** Proteomics in Bioremediation: Opportunities and Challenges. University of Maryland, Department of Chemistry and Biochemistry. College Park, MD, September 9, 2005.
95. **Halden, R. U.:** Potential Application of Proteomics. DoD SERDP/ESTCP Molecular Biological Tools Workshop, Charlottesville, VA, August 9, 2005.
96. **Halden, R. U.:** Fate of Personal Care Products During Wastewater Treatment. 35th Annual Joint Conference and Exhibition. The Chesapeake Water Environment Association and the Waters and Waste Operators Association of Maryland, Delaware and the District of Columbia, Ocean City, MD, July 8, 2005.
97. **Halden, R. U.:** Use of Proteomic Mass Spectrometry and Bioinformatics for the Identification of Environmental Microorganisms. U.S. Department of Agriculture, Beltsville, MD, June 27, 2005.
98. **Halden, R. U.:** ISMA – A Platform Technology with Biomedical Applications. Johns Hopkins University, School of Medicine. Alliance for Science and Technology. Spring 2005 Meeting. April 12, 2005.
99. **Halden, R. U.:** Fate of Polychlorinated Antimicrobial Compounds in the U.S. Environment. U.S. Headquarters of the Soap and Detergent Association (SDA), Washington, D.C., March 29, 2005.
100. **Halden, R. U.:** Polychlorinated Antimicrobials as Indicators of Sewage Spills. Presented at the American Chemical Society Meeting, Maryland Chapter, Baltimore, MD, February 23, 2005.
101. **Halden, R. U.:** Triclocarban: A New Contaminant in Baltimore Streams. Maryland State Water Quality Advisory Committee (SWQAC), Baltimore, MD, December 3, 2004.
102. **Halden, R. U**.: Pharmaceuticals and Personal Care Products as Indicators of Sewage Spills. Presenter and Panelist at the Maryland Water Monitoring Council 10th Annual Conference, Linthicum, MD, November 18, (2004). http://mddnr.chesapeakebay.net/MWMC/pub/MWMC10conf.pdf.
103. **Halden, R. U.:** Antimicrobials Signal High Levels of Pathogens in Baltimore Streams. Herring Run Watershed Association Annual Meeting, Baltimore, MD, November 16, 2004.
104. **Halden, R. U.:** Invited Discussant for Seminar by Dr. Leigh English, Director of the Monsanto Protein Science Team, titled: Genetically Modified Crops: A Jelly Donut of Social Issues Surrounded by Technical Explanations. Institute for Global Studies in Culture, Power and History; Fall Seminar Series: Feeding the World: Ethical, Moral, Legal and Scientific Dimensions, Baltimore, MD, November 11, 2004.

105. **Halden, R. U.:** JHU Center for Water and Health On-going Research. Chesapeake Bay Foundation Research Retreat, Port Isobel, VA, October 3, 2004.
106. **Halden, R. U.:** The Johns Hopkins University Center for Water and Health Nationwide Study on the Fate of Pharmaceuticals and Personal Care Products in the Environment – Preliminary Results for the State of Maryland. Johns Hopkins University, Baltimore, MD, September 21, 2004.
107. **Halden, R. U.:** Pharmaceuticals and Personal Care Products in the Environment. Chesapeake Biological Laboratory, University of Maryland, Solomon, MD, September 9, 2004.
108. **Halden, R. U.:** Leaky Pipes and Cross-Contamination – Is Baltimore's Aging Sewer System a Threat to Public Health? Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, August 13, 2004.
109. **Halden, R. U.:** Chemical Analysis and Treatment of Perchlorate. Aberdeen Proving Ground, MD, July 23, 2002.
110. **Halden, R. U.:** Aberdeen Proving Grounds Environmental Research. National Defense Industrial Association TACOM – ARDEC Technical Symposium, Rockaway, NJ, April 10, 2002.
111. **Halden, R. U.:** Pharmaceuticals in U.S. Streams – A Public Health Concern? Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, March 27, 2002.
112. **Halden, R. U.:** Microcontaminants in Food and Water. Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, March 12, 2002.
113. **Halden, R. U.:** Toxins as Modifiers of Human Vulnerability to Disease. University of Pennsylvania, 2002 Health-Environment Symposium, Hershey, PA, March 7, 2002.
114. **Halden, R. U.:** Bioremediation: From Pure Culture to the Dirty Reality. Johns Hopkins University, Department of Geography and Environmental Engineering, Baltimore, MD, October 23, 2001.
115. **Halden, R. U.:** From Cloning to Cleaning: Bioremediation in the Real World. University of Maryland Biotechnology Institute – Center of Marine Biotechnology, Baltimore, MD, September 26, 2001.
116. **Halden, R. U.:** Detection and Bioremediation of Fuel Oxygenates, Perchlorate and Trichloroethene. University of Minnesota, School of Public Health, Minneapolis, MN, August 21, 2001.
117. **Halden, R. U.:** Detection and Destruction of Anthropogenic Toxins in Drinking Water Resources. University of California at Berkeley, Center for Environmental Biotechnology Video-taped Lecture Series, Berkeley, CA, March 6, 2001.
118. **Halden, R. U.:** Detection and Destruction of Anthropogenic Toxins in Drinking Water Resources. Johns Hopkins University, Department of Environmental Health Sciences, October 15, 2000.
119. **Halden, R. U.:** Analytical Methods for the Detection of Oxygenates in Ground Water. United States Environmental Protection Agency, MTBE Scientist-to-Scientist Meeting, Argonne National Laboratory, Argonne, IL, June 20, 2000.
120. **Halden, R. U.:** ASTD Deployment of Bioremediation and Natural Attenuation at the Building 834 Complex at Site 300. Lawrence Livermore National Laboratory, Subcon Focus Area Meeting, Livermore, CA, October 9, 2000.
121. **Halden, R. U.:** The Building 834 Study Area at Site 300, CA. Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID, September 9, 1999.
122. **Halden, R. U.:** Where Did that TCE End Up? – Refining the Conceptual Model for Contaminant Fate at LLNL's Site 300, Building 834. Oregon State University, Department of Civil Engineering, Corvallis, OR, February 5, 1999.
123. **Halden, R. U.:** Engineered In Situ Biodegradation of Dioxins – Do Laboratory Bacteria Function in the Real World? University of Florida at Gainesville, Department of Environmental Engineering Sciences, Gainesville, FL, March 4, 1997.
124. **Halden, R. U.:** Engineered In Situ Biodegradation of Dioxins. Lawrence Livermore National Laboratory, Environmental Protection Department, Livermore, CA, January 16, 1997.

SPONSORED RESEARCH

Halden (0% Effort) 04/15/2014 – 01/15/2014
In Situ Delivery of Remediation Agents
Chevron.
Role: PI. (60% Recognition) $38,725

Halden (5% Effort) 01/1/2014 – 12/31/2014
Thermal *In Situ R*emediation of Weathered Heavy Hydrocarbons
Chevron.
Role: PI. (100% Recognition) $75,000

Halden (10% Effort) 09/20/2011 – 07/31/2014
NIEHS-R01 1R01ES020889
In Situ Sampling Tool for Assessing Bioavailability and Toxicity of Sediments
This Project Explores the Bioavailability of Traditional and Emerging Contaminants
Role: PI. (100% Recognition) $830,943

DoD ESTCP Project 201122 Halden (16.6% Effort) 03/01/2011 – 2/28/2014
Cost-effective, Ultra-sensitive Groundwater Monitoring for Site Remediation and Management
Role: Sole PI. (100% Recognition) $1,151,152

Halden (0% Effort) 06/1/2013 – 05/30/2014
Arizona Technology Enterprises (AzTE)
The ASU Catalyst Fund
Role: PI. (100% Recognition) $25,000

Halden (0% Effort) 08/1/2013 – 07/31/2014
NIEHS-R01 Supplement 3R01ES020889-03S1
In Situ Sampling / Bioavailability Assessment (IS2B) Tool Addressing Remediation Market Needs
This Project Supports the Development for Commercial Application of a Small Sampling Device
Role: PI. (100% Recognition) $42,597

Salt River Project (SRP) Halden (8.3% Effort) 01/01/2013 – 06/30/2014
In Situ Bioremediation – An Innovative Approach for Elevated Chlorinated Volatile Organic Compounds in Groundwater
Role: Sole PI. (100% Recognition) $60,000

Halden (10% Effort) 06/1/2012 – 05/30/2015
Piper Charitable Trust
Center for Environmental Security/AZ Public Health Observatory
Role: PI. (100% Recognition) $450,000

Halden (0% Effort) 5/24/2013 – 11/23/2014
AZ Board of Regents
Planning, Development and Implementation of a State-wide Research Initiative in Environmental Informatics: "Arizona Environmental Grid Infrastructure Service (AEGIS)"
Role: ASU-PI. (PD: Petuskey) $40,000 subcontract of $450K Total

Halden (0% Effort) 01/1/2013 – 12/30/2013
TRIF Biodesign
Mass Spectrometry Recharge Facility Trial Run
Role: PI. (0% Recognition) $60,000

Halden (0% Effort) 03/1/2012 – 02/28/2013
NASA 2012-T72247
Analysis of Hormones, Steroids, Pharmaceuticals, and Personal Care Products in Water, Wastewater and Preserved Urine Samples
Role: PI. (100% Recognition) $15,000

WRF Water Research Foundation 9/30/2010 – 8/31/2012
(PI: Westerhoff, Co-PI: Halden, 8.3% Effort)
Constructed Wetlands for Treatment of Organic and Nanomaterial Pollutants.
The major goal of this project is to develop design criteria for constructed wetlands for removal of emerging contaminants.
Role: Co-PI (30% Recognition or $100,200) $334,000 ($84,000 match. funds)

NIH-NIEHS-RC2 1RC2ES018801-01 9/30/2009 – 7/31/2011
(PI: Westerhoff; Co-PI: Halden, Herckes, Hristovski)
Detection of Engineered Nanomaterials in Drinking Water, Food, Commercial Products and Biological Samples.
The major goal of this project is to develop and validate analytical methods for the determination of nanomaterials in environmental and biological samples.
Role: Co-PI (28% Recognition or $355,144; 8.3% Effort) $1,268,370

Halden (0% Effort; PI: B. Bakkaloglu) 01/01/2011 – 12/31/2011
ASU Grand Challenges Seed Funding
Research Center for Integrated Sub-mm Environmental & Molecular Sensors (iSEMS)"
Role: Co-PI. (15% Recognition) $100,000

Halden (16.6% Effort) 03/01/2009 – 12/312013
DoD ESTCP ER-200914
Parallel In Situ Screening of Remediation Strategies for Improved Decision Making, Remedial Design, and Cost Savings.
Role: Sole PI. (100% Recognition) $1,060,125

Halden (16.6% Effort) 02/01/2008 – 12/31/2011
Biocides in the U.S. Environment.
Role: Sole PI. (100% Recognition) $373,031

Halden (0% Effort) 02/01/2008 – 12/31/2011
Anonymous Gift, JHU
Hopkins Graduate Student Initiative
Role: Sole PI. (100% Recognition) $131,468

Halden (0% Effort) 08/12/2009 – 07/31/2012
NIEHS-R01 3R01ES015445-04W1
Cooperative Supplement to: Novel Approaches to Studying the In Situ Bioremediation Potential of Complex Mixtures
Detection of Triclocarban in Human Specimens.
Role: Sole PI at ASU. (100% Recognition) $228,164

Halden (0% Effort) 08/12/2009 – 07/21/2012
NIEHS-R01 3R01ES015445-04S-TT
Technology Transfer Supplement to: Novel Approaches to Studying the In Situ Bioremediation Potential of Complex Mixtures
Development of a Nutrient Injection Unit for the In Situ Microcosm Array.

Role: Sole PI. (100% Recognition) $152,843

Halden (0% Effort) 09/28/2009 – 09/27/2012
NIEHS-R01 1R01ES015445S
Supplement to: Novel Approaches to Studying the In Situ Bioremediation Potential of Complex Mixtures
Evaluation of In Situ Microcosms Arrays for the Study of Chemical Mixtures in Contaminated Environments.
Role: Sole PI. (100% Recognition) $109,375

Halden (16.6% Effort) 09/28/2006 – 07/31/2012
NIEHS-R01 1R01ES015445
Novel Approaches to Studying the In Situ Bioremediation Potential of Complex Mixtures
Evaluation of In Situ Microcosms Arrays for the Study of Chemical Mixtures in Contaminated Environments.
Role: Sole PI. (100% Recognition) $624,261

Halden (8.3% Effort) 01/01/2008 – 04/30/2009
Central Arizona Project (PI: Westerhoff, Co-PI: Halden and Herckes)
Enhancement Project by Central Arizona Project (CAP): Regional Water Quality Monitoring and Evaluation for the Metropolitan-Phoenix Area Water Supply.
Role: Co-PI. (25% Recognition or $7,500) $30,000

Halden (0% Effort) 07/01/2007 – 06/30/2010
City of Phoenix Planning Dept. (PI: Westerhoff, Co-PI: Halden and Herckes)
Regional Water Quality Monitoring and Evaluation for the Metropolitan-Phoenix Area Water Supply.
Role: Co-PI. (0% Recognition) $155,250

Salt River Project (SRP) Halden (8.3% Effort) 06/01/2011 – 5/30/2012
In Situ Bioremediation – An Innovative Approach for Elevated Chlorinated Volatile Organic Compounds in Groundwater
Role: Sole PI. (100% Recognition) $75,000

Halden (0% Effort) 01/01/2007 – 12/31/2009
DOE BER Genome Sequencing Program Free Genome Sequencing
Genome Sequencing of the Dioxin-Mineralizing Bacterium *Sphingomonas wittichii* RW1
Sequencing and Annotation of the Genome of a Dioxin-Metabolizing Bacterium.
Role: Sole PI. (100% Recognition) ~$100,000

Halden (PI: Ketner) 03/01/2007 – 2/28/2009
JHSPH-Faculty Research Initiative
Proteomic Approach to Understanding Viral Infection and Pathogenesis
Elucidation of viral infection mechanisms and identification of intervention strategies.
Role: Co-PI. (50% Recognition or $17,500) $35,000

Halden (PI: Schwab; Co-PI: Halden, Graczyk) R83300201 04/01/2006 – 12/31/2008
U.S. EPA Science to Achieve Results (STAR) Program
Quantitative Assessment of Pathogens in Drinking Water
Development and Evaluation of Novel Methods for the Detection of Emerging Waterborne Pathogens.
Role: Co-PI. (30% Recognition or $180,000) $600,000

Halden (PI: Lawrence; Co-PI: Silbergeld, Schwab, Halden) 10/01/2005 - 12/31/2007

The Pew Charitable Trusts
National Commission on Industrial Farm Animal Production
A Collaboration Was Formed Between The Pew Charitable Trusts and the Johns Hopkins Bloomberg School of Public Health to Investigate and Summarize in a Report, Issues of Environmental Quality, Public Health, and Ethics Linked to Concentrated Animal Feeding Operations (CAFOs) in the United States.
Role: Co-I. (20% Recognition or $84,600) $423,000 (JHU of $2.4M total)

Halden 10/01/2005 – 09/30/2006
State of Maryland TEDCO
Supporting Funds for International Patent Rights to a Hopkins' Technology (International Patent Application PCT WO 2004/081530).
Role: Sole PI. (100% Recognition) $10,000

Halden (PI: Goldman) 10/01/2005 – 09/30/2006
JHU-Center for a Livable Future Pilot Project
Exposures to Persistent Contaminants in Food and Fetal Growth and Development.
Determination of Potential Linkages Between Fetal Exposure to Polybrominated Flame Retardants / Perfluorinated Organic Compounds and Adverse Health Outcomes.
Role: Co-I. (10% Recognition) $20,000

Halden 01/01/2005 – 06/30/2007
JHSPH-Faculty Research Initiative
Carcinogens in Biosolids as Determinants of Human Morbidity and Mortality
Creation of a Nationwide Repository and Database for Application of Municipal Sludge (Biosolids) in Agriculture.
Role: PI. (100% Recognition) $50,000

Halden 01/1/2006 – 07/30/2006
JHU-NIOSH ERC Pilot Project
Application of Proteomics for the Development of Biomarkers of Occupational Exposure
Proteomic Analysis of Baltimore Cord Blood Serum Samples for the Discovery of Protein Biomarkers of Exposure to Toxic Occupational Contaminants.
Role: Sole PI and Advisor. (100% Recognition) $14,995

Halden 9/1/2004 – 8/31/2005
JHU-Center for a Livable Future Pilot Project
Municipal Sludge Disposal and Sustainable Agriculture – A Pilot Study Showcasing the Challenge of Combining the Two
Explore the Fate of Persistent Antimicrobial Compounds in Municipal Sludge and Their Potential Uptake into Agricultural Plants as a Pathway for Human Exposure to Carcinogens. Role: Sole PI. (100% Recognition) $20,000

Halden 06/01/2004 – 05/30/2005
CRF—Maryland Cigarette Restitution Fund
(Matching Funds by the CDC; PI: Needham)
Human Fetal Exposure to Drinking Water Carcinogens in Maryland
Creation and Analysis of a Cord Blood/Cord Tissue Repository and Determination of Fetal Exposure Levels to Carcinogens in Maryland Drinking Water Resources and Water Supply. Role: Sole PI. (100% Recognition) $150,000

Halden 06/01/2004 – 05/30/2005

CDC—Centers for Disease Control and Prevention
(Matching Funds for CRF Study; PI: Needham)
Human Fetal Exposure to Drinking Water Carcinogens in Maryland
Creation and Analysis of a Cord Blood/Cord Tissue Repository and Determination of Fetal Exposure Levels to Carcinogens in Maryland Drinking Water Resources and Water Supply. Role: Sole PI of Parent Grant. (10% Recognition) $250,000

Halden (PI: Buckley; Co-PI: Halden) 11/1/2004 – 10/30/2005
CRF—Maryland Cigarette Restitution Fund
Statistical Analysis of Drinking Water Quality vis-à-vis Cancer Morbidity and Mortality
Geospatial Analysis to Identify Potential Links Between Drinking Water Quality and Cancer Morbidity and Mortality in the State of Maryland.
Role: Co-PI. (50% Recognition or $10,000) $20,000

Halden 11/1/2003 – 10/31/2004
JHSPH—Technology Transfer Seed Grant
Production and Testing of an In Situ Microcosm Array Prototype
Design, Construction and Initial Testing of an Innovative Environmental Monitoring Device.
Role: Sole PI. (100% Recognition) $25,000

Halden 9/1/2003 – 8/31/2004
JHU-Center for a Livable Future Pilot Project
Mass Spectrometric Determination of Microbial Pathogens in Waste Streams of
Explore the Use of Mass Spectrometry for Detecting the Bacteriophage MS2 as an Indicator of Microbial Pathogens Originating from Concentrated Animal Feeding Operations.
Role: Sole PI, Advisor. (100% Recognition) $20,000

Halden 10/1/2003 – 9/30/2004
JHU-Center for a Livable Future Pilot Project
Effect of Lifestyle on Mother/Infant Exposure to Ubiquitous Pollutants
Determine Whether Exposure to Polyfluorinated Environmental Contaminants is Associated with Lifestyle Choices. (100% Recognition)
Role: Sole PI. $20,000

Halden 10/1/2003 – 8/31/2005
JHU-CLF Pre-doctoral Fellowship/Mentor Award
Proteomic Approach to Monitoring Microbes in Waste Streams from Animal Production Facilities
Explore the Use of Mass Spectrometry for Detecting Viruses and Bacterial Pathogens in Samples from Concentrated Animal Feeding Operations Using MALDI-TOF MS, Nanospray ESI-MS/MS, and AP-MALDI and ESI-IT-MS Techniques.
Role: Sole PI and Advisor. (100% Recognition) $99,000

Halden 7/1/2003 – 12/31/2003
JHU-CLF Donor's Gift (No Title)
Environmental Fate of Persistent Personal Care Products.
Role: Sole PI. (100% Recognition) $3,000

Halden 3/1/2003 – 2/28/2004
JHSPH—Technology Transfer Seed Grant
Down-Well Diagnostic Device for Environmental Monitoring and Bioprospecting
Conceptually Develop and Refine Plans for a Novel Environmental Monitoring Device Amenable to Automated, High-throughput Analysis Using Genomic and Proteomic Analyses.
Role: Sole PI. (100% Recognition) $25,000

Halden 10/1/2003 – 9/30/2004
JHU-NIOSH Education and Research Center Grant
LC-MS Analysis of a Urinary Biomarker of Occupational Exposure to PAHs
Detection of a Urinary PAH Biomarker in Human Specimens Targeting the Underivatized Conjugate.
Role: Sole PI. (100% Recognition) $9,000

Halden 06/01/2004 – 05/30/2005
Donor's Gift (No Title)
In Support of Technology Transfer Activities Directed Toward a Down-Well Diagnostic Device for Environmental Monitoring and Bioprospecting (International Patent Application PCT WO 2004/081530).
Role: Sole PI. (100% Recognition) $20,000

Halden 10/1/2002 – 6/30/2003
JHU-Center for a Livable Future Pilot Project
Bioaccumulation of Methyl Triclosan in Agriculturally Applied Sewage Sludge and in Breast Milk
Trace Analysis of Biocides in Municipal Sludge and Human Milk.
Role: Sole PI. (100% Recognition) $17,500

Halden 6/1/2002 – 5/30/2003
JHU-NIEHS Center Pilot Project; P30ES03819
Development of an Exposure Assessment Tool for the Biocide Triclosan
Development an LC-MS Technique Suitable for Trace Analysis of the Biocides.
Role: Sole PI. (100% Recognition) $15,000

Halden 7/1/2002 – 9/30/2002
JHU-Center for a Livable Future Internship/Mentoring Award
Sponsored Research Internship in Environmental Health Sciences
Provide Laboratory Study Opportunities for an Undergraduate Student.
Role: Sole PI; Student Advisor. (100% Recognition) $4,000

Halden 5/1/2002 – 6/30/2003
JHSPH—Faculty Innovation Award
Environmental Sources, Occurrence and Biodegradation of the Biocide Triclosan
Pilot Study Designed to Explore the Extent of Environmental Contamination with the Biocide Triclosan.
Role: Sole PI. (100% Recognition) $30,000

Halden 2/12/2002 – 12/31/2002
Bechtel BWXT Idaho, LLC, Research Contract
Determination of the Microbial Community Structure at a Trichloroethene-Contaminated Area at Site 300, CA, in Support of a Proposed In Situ Bioremediation Deployment
Use Non-culture-dependent Techniques to Determine the Impact of Chlororethenes on the Microbial Community of a Polluted Aquifer.
Role: Sole PI (100% Recognition) $57,500

Halden 7/1/2001 – 6/30/2002
Shimadzu Corp. Instrumentation Grant (No Title)
Improve Laboratory Instrumentation Infrastructure for Trace Analysis of Environmental Toxicants.
Role: Sole PI. (100% Recognition) $56,000

Halden (PI: Naples; Co-PI: Shiff, Halden) 11/1/2003 – 10/31/2004

JHSPH—Technology Transfer Seed Grant
A Product for the Detection and Focal Control of Schistosome Cercariae to Reduce Disease Burden and Cercariae Dermatitis, Both in Endemic Areas, and in U.S. Lacustrine Habitats
Explore the Use of Natural Essential Oils for the Control of Cercariae in Surface Waters. Role: Co-PI. (25% Recognition or $6,250) $25,000

Halden (PI: Lowe; Co-PI: Halden) 2/12/2002 – 12/31/2002
DOE—NABIR Research Grant (DE-FG02-01ER63264)
Development of a Multiplexed, Bead-based Assessment Tool for Rapid Identification and Development of Novel Diagnostic Tool for Microbial Community Analysis at Contaminated Subsurface Sites.
Role: Co-PI. (30% Recognition or $19,444) $64,812

Halden (Project Director: Rice) 10/1/2000 – 9/30/2001
LLNL Work-In-the-Public-Interest Grant
Dioxins in San Francisco Bay
Determine Potential Avenues for Reducing Environmental Contamination with Dioxin-like Compounds.
Role: PI (20% Recognition or $26,000) $130,000

Halden (PI: Happel) 10/1/2000 – 9/30/2001
DOE—Fossil Fuel Research Project
Detection and Biodegradation of MTBE from Leaking Underground Storage Tanks
Determine the Bioremediation Potential of LUFT Sites.
Role: Co-PI. (10% Recognition or $5,000) $50,000

TEACHING

Graduate Students Supervised

Ph.D. Students

1. Sung-Roul Kim (Ph.D.) Environmental Health Sciences, Johns Hopkins. "Assessment of Urban Air Pollution Exposure Among New Mothers and Nursing Infants and Internal Dose Measured in Breast Milk" (2006). (Committee member)
2. Tanya Oxenberg (Ph.D.) Environmental Engineering, Hopkins. "Subsurface Transformation of Depleted Uranium at Aberdeen Proving Ground, Maryland" (2006). (Co-Advisor)
3. David R. Colquhoun (Ph.D.) Environmental Health Sciences, Johns Hopkins. "Public Health Applications of Quantitative Protein Biomarkers" (2007). (Chairman)
4. Jochen Heidler (Ph.D.) Environmental Health Sciences, Johns Hopkins. (Chairman) "Environmental Fate of Persistent Biocides and Human Exposure" (2007).
5. Talia E. A. Chalew (Ph.D.) Environmental Health Sciences, Johns Hopkins. (Expected 2011)." (Past Advisor)
6. Kristin McClellan (Ph.D.) Environmental Engineering, ASU. "A New Approach to Groundwater Remediation Treatability Studies – Moving Flow-through Column Experiments from Laboratory to *In Situ* Operation" (8/2008 – 4/3/2013). (Chairman)
7. Erica M. Hartmann (Ph.D.) Biological Design, ASU. "Application of Proteomic Mass Spectrometry in Bioremediation" (8/2008 – 6/2012). (Chairman)
8. Tomasz Kalinowski (Ph.D.) Biological Design, ASU. "Technical, Economical and Social Aspects of Moving Treatability Studies for the *In Situ* Bioremediation of Contaminated Aquifers from the Laboratory to the Field" (8/2008 – 4/4/2013). (Chairman)
9. Thomas Bruton (Ph.D.) Environmental Engineering, ASU. "Use of Nano Zerovalent Iron in Groundwater Remediation" (2009 - 2012). (Transferred to UC Berkeley)

10. Arjun K. Venkatesan (Ph.D.) Environmental Engineering, ASU. "Contaminants of Emerging Concern in U.S. Sewage Sludges and Forecasting of Associated Ecological and Human Health Risks Using Sewage Epidemiology Approaches" (8/1/2010 - 11/14/2013). (Chairman)
11. Isaac Roll (Ph.D.) Environmental Engineering, ASU. "Novel Tools for Environmental Analysis of Trace Contaminants at Ultra-low Detection Limits" (Expected 2014). (Chairman)
12. Samuel Supowit (Ph.D.) Environmental Engineering, ASU. "Application of and Active Sampling Device for Bioavailability Assessment of Contaminants in Sediment." (Expected 2014). (Chairman)
13. Hansa Done (Ph.D.) Biological Design, ASU. "Antibiotics and Antibiotic Resistant Microbes in U.S. Seafood." (Expected 2016). (Chairman)
14. Alizee Jenck (Ph.D.) Environmental Engineering, ASU. "Application of MALDI-TOF/TOF Mass Spectrometry to Environmental Health Monitoring." (Expected 2016). (Chairman)
15. Maurissa Charles (Ph.D.) Environmental Engineering, ASU. "Application of the In Situ Microcosm Array Technology to Environmental Remediation." (Expected 2016). (Chairman)
16. Burcu Yavuz (Ph.D.) Environmental Engineering, ASU. "To Be Determined (Expected 2017). (Chairman)
17. Erin Driver (Ph.D.) Environmental Engineering, ASU. "To Be Determined." (Expected 2017). (Chairman)
18. Jing Chen (Ph.D.) Biological Design, ASU. "To Be Determined." (Expected 2017). (Chairman)
19. Justin Kidd (Ph.D.) ASU "To Be Determined." (Expected 2018). (Chairman)

M.S., M.S.E, and M.P.H. Students

20. Sharri Hollist (M.P.H.) Public Health, Hopkins. "Incidence of Illness Associated with Recreational Water Contact: Determining and Evaluating a Potential Public Health Problem" (2005). (Capstone Advisor)
21. Toni Nunes (M.P.H.) Public Health, Hopkins. "Pesticides in Ground and Surface Waters of the Chesapeake Bay Watershed: Occurrence, Risks and Potential Solutions" (2007). (Capstone Advisor)
22. Christopher von Seggern (M.P.H.) Public Health, Hopkins. "Biodetection Utilizing Matrix-assisted Laser Desorption/Ionization Mass Spectrometry" (2005). (Capstone Advisor)
23. Meredith Lewis (M.S.E.) Environmental Engineering, ASU. (2009).
24. Guozheng Li (M.S.) Biological Design, ASU (2011).
25. Alison D. Fox (M.S.) Technology (Environmental Management), ASU. "Use of Passive Sampling Devices for Determination of Contaminants in Sewage Sludge" (2010 - 2012). (Graduate Advisor)
26. Sara Carey (M.S.) Environmental Engineering, ASU. "Policy Solutions for Limiting Environmental Release of Persistent, Bioaccumulative and Toxic Compounds." (2012). (Temporary Advisor)
27. Bipin Chari (M.S.) Environmental Engineering, ASU. "Analysis and Modeling of Residual Compounds in Process Streams From U.S. Wastewater Treatment Plants" (4/12/2012). (Thesis Advisor)

Other Graduate Students

28. Peter D'Amato (Ph.D.) Environmental Engineering, Hopkins. "Biodegradation of Polycyclic Aromatic Hydrocarbons" (2003). (Committee Member)
29. Denise Taylor (Ph.D.) Environmental Engineering, Hopkins (2003). (Committee Member)
30. Amir Sapkota (Ph.D.) Environmental Health Sciences, Hopkins (2004). (Committee Member)

31. Kristen Malecki Chossek (Ph.D.) Health Policy and Management, Hopkins (2005). (Committee Member)
32. Michelle Hladik (Ph.D.) Environmental Engineering, Hopkins (2005). (Committee Member)
33. Henry Schuver (Dr.P.H.) Epidemiology, Hopkins (2007). (Committee Member)
34. Ying Yao (M.S.) Environmental Engineering, ASU. (2009). "Development of a Novel Dechlorinating Culture" (2009). (Committee Member)
35. Ed Hilyard (Ph.D.) Marine Biotechnology, University of Maryland, (Expected 2010) (Committee Member 2005-2009)
36. Liang Chen (M.S.) Environmental Engineering, ASU. (2009). (Committee Member)
37. John Schloendorn (Ph.D.) Molecular and Cellular Biology, ASU. "Progress Towards Medical Bioremediation by Enzymatic Transformation of 7-Ketocholesterol and the Pyridinium Bisretinoid A2e" (2009). (Committee Member)
38. Katherine Muto (M.S.) Environmental Engineering, ASU. (2010). (Committee Member)
39. Prathap Parameswaran (Ph.D.) Environmental Engineering, ASU. (2010). (Committee Member)
40. Youneng Tang (Ph.D.) Environmental Engineering, ASU. Biofilm Reduction of Oxidized Contaminants" (2/19/2011). (Committee Member)

Postdoctoral Researchers

41. Guibo Xie (10/2001 – 06/2003)
42. Wenming Dong (2002) (Currently: Staff Scientist, U.S. National Laboratory)
43. Mark P. Franklin (04/2002 – 12/2003)
44. Eric S. Wisniewski (06/2003 – 08/2003) (Currently: Staff Scientist, U.S. Government)
45. Amir Sapkota (11/2004 – 10/2005) (Currently: Tenure-track Assistant Professor, University of Maryland)
46. Todd R. Miller (10/2004 – 10/2007) (Currently: Assistant Professor, University of Wisconsin, Milwaukee)
47. Christopher Higgins (11/2006 – 12/2007) (Currently: Tenure-track Assistant Professor, Colorado School of Mines)
48. Jay Graham (02/2008 – 07/2008) (Currently: Assistant Professor, George Washington University, Washington, DC)
49. Randhir Deo (04/2008 – 2012) (Currently: Assistant Professor, Grand Canyon University, Phoenix, AZ)
50. Tzu-Chiao Chao (01/2009 – 01/2011) (Currently: Faculty, University of Regina, Canada)
51. Gopianth Nallani (02/2011 – 06/2011)
52. Nicole Hansmeier (12/2008 – 6/2012) (Currently: Assistant Professor, Osnabrück University, Germany)
53. Benny Pycke (02/2010 – Present)
54. Bhagyashree Manivannan (03/2013 – 04/2014)
55. Manivannan Yegambaram (03/2013 – 04/2014)
56. Arjun Venkatesan (12/2013 – Present)

Graduate Independent Projects Supervised

57. Jacqueline Heilman, Johns Hopkins University Research Intern (2002) "Antimicrobial Compounds and Their Possible Breakdown Products in Biosolids"
58. Edward Kruse (2007). (M.P.H.) Public Health, Hopkins. "Assessing the Impact of Point and Nonpoint Sources of Pollution on Recreational and Drinking Water Quality in the Springfield Watershed in Dominica" (2007). (Capstone Advisor)
59. Katherine Muto (Spring 2010) "Method for Detection of Chlorinated Carbanilides"
60. Chen Zhou (Spring 2010) "Versatile Roles of Sulfate Reducing Bacteria in Contaminant Remediation"
61. Kristin McClellan (Spring 2010) "Demonstration Plan: Parallel In Situ Screening of Remediation Strategies for Improved Decision Making, Remedial Design, and Cost Savings"

62. Isaac Roll (Fall 2010) "Cost-effective, Ultra-sensitive Groundwater Monitoring for Site Remediation and Management"
63. Thomas Bruton (Fall 2010) "Investigation of Fate and Transport of Zero Valent Iron Nanoparticles Using an In-Situ Microcosm Array"
64. Arjun Venkatesan (Fall 2010) "Analysis of compounds of emerging concern in Biosolids by GC/MS"
65. Kristin McClellan (Fall 2010) "Review Paper on Treatability Studies"
66. Jing Chen (Fall 2013) Rotational Student of the Biological Design Graduate Program, "Determination of Contaminants in Autopsy Tissues of Alzheimer's Disease Fatalities"
67. Stephen Hart (Fall 2013) Rotational Student of the Biological Design Graduate Program, "Application of the In Situ Microcosm Array in a Fractured Bedrock Aquifer Contaminated with Perchlorate"

Undergraduate Students and High School Interns

68. Stephanie Burge (Research Intern, LLNL) "Optimization Study of Nitrate and Perchlorate Removal by Ion Exchange" (1999).
69. Daniel Paull (Undergraduate Research Intern, Johns Hopkins) "Detection of Antimicrobials by Liquid Chromatography/Mass Spectrometry)" (2002).
70. Daniel Paull (Undergraduate Research Intern, Johns Hopkins) "Detection of Triclocarban in Environmental Waters by Liquid Chromatography/Mass Spectrometry)" (2003).
71. Beth Links (High School Intern, Johns Hopkins) "Uptake into Plants of Contaminants from Biosolids-Amended Soils" (2004).
72. Cristina Matos (Diversity Research Intern, Johns Hopkins) "*Ab Initio* and *In Situ* Comparison of Organic Wastewater Compounds as Indicators of Sewage-derived Microbes in Surface Waters" (2004).
73. Anna Kalmykov (High School Intern, Johns Hopkins) (2004 – 2005).
74. Amelia DeLaquil (Undergraduate Research Intern, Johns Hopkins) "Fate of Triclosan and Triclocarban in Estuarine Sediment" (2006).
75. Jocelyn Keehner (High School Intern, Johns Hopkins) "Uptake into Plants of Contaminants from Biosolids-Amended Soils" (2006).
76. Erica Hartmann (Undergraduate Research Intern, Johns Hopkins) "Detection of Bioremediation Agents by MALDI Mass Spectrometry" (2006 – 2008).
77. Travis Doom. (B.S.E.) Biomedical Engineering, ASU. "Nutrient Injection Unit: Subsurface Environmental Engineering with In Situ Microcosm Array Tool" (2009).
78. Benjamin Duong (High School Intern, ASU) "Development of a Laboratory Web Page" (2008 – 2009).
79. Patrick Trang (High School Intern, ASU) "Development of a Laboratory Web Page" (2008 – 2009).
80. David E. C. Adams (B.S.E.) Environmental Engineering, ASU. (2010). "Fluorinated Chemicals and the Impacts of Anthropogenic Use" (2010) (Honor Thesis Advisor).
81. James Fernandez (Undergraduate Research Intern, ASU) "Policy Analysis for Atrazine" (2011 – 2012).
82. Benjamin Duong (Undergraduate Research Intern, ASU) "Programming of a Bioremediation Device" (2009 – 2012).
83. Patrick Trang (FURI Undergraduate Research Intern, ASU) "Programming the Nutrient Injection Module" (2009 – 2012).
84. Kristen Latta (Undergraduate Research Intern, ASU) "Environmental Research" (2012).
85. Justin Kidd (Undergraduate Research Intern, ASU) "Theoretical Examination of the Bioavailability of Contaminants in Soils" (2012 – 2013).
86. Olga Epshtein (Undergraduate Research Intern, ASU) "Modeling of the Tres Rios Wetland" (2012 – 2013).
87. Amitis Karris (High School Intern, ASU) "Environmental Research" (2013).
88. Cody Moore (Barrett Honors College Intern, ASU) "Environmental Research" (2012 – 2013).

89. Chris Bean (Undergraduate Research Intern, ASU) "Environmental Research" (2013).
90. Emily North (Barrett Honors College Intern, ASU) "Safety of Plastics" (2012 – 2013).
91. Olga Epshtein (B.S.) Civil Engineering, ASU (Expected 5/2014)
92. Justin Kidd (B.S.) Biology, ASU (Expected 5/2014)

Technicians Employed and Co-supervised

93. Tina Legler (1998 – 1999)
94. Thayer Young (01/2005 – 2007)
95. Kristin McClellan (4/2008 – 8/2008)
96. Sara Murch (11/2012 – 5/2014)

Synergistic Activities

- Supervisor Certificate, 40-Hour SARA/OSHA 8CCR5192(e)(4) (1999).
- Management Certificate, University of the Pacific, 2000.
- DOE Natural and Accelerated Bioremediation Research Program (NABIR) Workshop. Warrenton, VA. Invited Panelist. 3/18-20/2002.
- Johns Hopkins School of Public Health Faculty Title Task Force. Invited Representative of the Junior Faculty, 2003
- Co-organizer of the Johns Hopkins School of Public Health Junior Faculty Meetings, 2003.
- Organizer of the "Exposure Assessment Session" at the Environmental Health Sciences Annual Research Day of the Johns Hopkins Bloomberg School of Public Health, Mount Washington Conference Center, Baltimore, MD, November 14, 2003.
- Water Environment Research Foundation (WERF) Project Advisory Committee. "Contributions of Household Chemicals to Sewage and their Relevance to Municipal Wastewater Systems and the Environment." Invited Committee Member. 2004-06.
- Water Environment Research Foundation (WERF) Project Advisory Committee. "Fate of Pharmaceuticals and Personal Care Products through Wastewater Treatment Processes." Invited Committee Member. 2004-2006.
- Maryland Water Monitoring Council: "Ecological Restoration Assessment & Monitoring" Linthicum, MD. Invited Panelist. 11/18/2004.
- Governor Ehrlich's Maryland Water Security and Wastewater Systems Advisory Council Alternate Member. 01/2004 – 12/2004.
- Governor Ehrlich's Maryland Department of the Environment – Maryland State Water Quality Advisory Committee (SWQAC) Public Interest Member. Selected by JHSPH Dean Al Sommer to be the Johns Hopkins Representative for this Committee. 1/1/2003 – 12/31/2005.
- DOE/EPA SERDP and ESTCP Expert Panel Workshop on Research and Development Needs for the Environmental Remediation Application of Molecular Biological Tools. Invited Speaker and Voting Panel Member. Specialty: Proteomics. 08/9-10/2005.
- International Conference on Safe Water, Exploring Global Demands and Impacts of Natural Disasters, SAFEWATER 2005. San Diego, CA. Groundwater Remediation Session. Invited Session Chair. 10/21/2005.
- Harvard School of Public Health Risk Assessment Workshop: "Pharmaceuticals and Personal Care Products in the Environment: Emerging Threat or Unwarranted Concern?" Invited Panelist. 11/10/2005.
- National Congress on Assessing and Mitigating Environmental Impacts of Emerging Contaminants – Renewable Natural Resources Foundation. Co-Sponsored by the United States Geological Survey and the Food and Drug Administration. Invited Delegate. 12/1-2/2005.
- Food And Drug Administration, Center For Drug Evaluation And Research (CDER) Nonprescription Drugs Advisory Committee. "Benefits and Hazards of Antiseptic Products Marketed for Consumer Use." Invited Panelist/Voting Committee Member. 10/20/2005.

- EPA Office of Inspector General, Office of Program Evaluation, Evaluation of Drinking Water Laboratory Procedures. Invited Expert Consultant. 1/19/2006.
- Mid-Atlantic States Section of the Air & Waste Management Association (MASS-A&WMA), Special Symposium on Emerging Environmental Issues and Policies. Invited Speaker/Panelist. New Brunswick, NJ, April 6, 2006.
- Invited Panelist, BIO 2006, World's Largest Annual International Convention on Biotechnology. Chicago, IL. Environmental Biotechnology Session. 04/9-12/2006
- National Research Council of the National Academies. NRSB-O-05-04-A. Conduct a Technical Assessment of Ongoing and Planned Environmental Remediation and Monitoring Programs at the Los Alamos National Laboratory (LANL) and Provide Recommendations to Improve Their Technical and Cost Effectiveness and Reduce Worker, Public, and Environmental Risks. Invited NRC Committee Member, Dual Appointment in the Areas of Groundwater Monitoring and Chemistry. 15-Month Term Starting March, 2006.
- Panel Chair and Keynote Speaker. Reducing Our Ecological Footprint. 10th Anniversary of the Johns Hopkins Center for a Livable Future – Charting A Course To Sustainability Through Research, Education And Service, Baltimore, MD, December 6, 2006.
- Co-Organizer, Annual Conference of the Superfund Basic Research Program (SBRP) of the National Institute of Environmental Health Sciences (NIEHS). Innovative Technologies. Session Moderator and Planning Committee Member, 20th Anniversary Meeting of the Superfund Basic Research Program, Durham, NC, December 3, 2007.
- Co-Organizer, Annual Conference of the Superfund Basic Research Program (SBRP) of the National Institute of Environmental Health Sciences (NIEHS). Member of Steering Committee and Invited Speaker of Technology Transfer Session, Pacific Grove, CA, December 7-9, 2008.
- Invited Panelist, American Academy for Microbiology, "Global Antibiotic Resistance: New Approaches to an Old Problem," Fondation Merieux, Annecy, France, October 2008.
- Invited Speaker and Session Chair. Environmental Fate of Antimicrobials. Pacific Southwest Organic Residuals Symposium 2008. Sacramento, October 1-2, 2008.
- Invited Panelist, Special Symposium on Next Generation Superfund Contaminants sponsored by the National Institute of Environmental Health Sciences (NIEHS), Tucson, AZ, August 2009.
- Symposium Chair and Organizer, Pharmaceuticals, Personal Care Products and Organohalogens in Biosolids, 238th American Chemical Society (ACS) National Meeting, Washington, DC, August 16-20, 2009.
- Symposium Chair and Organizer, Toward Sustainable Use of Organohalogens. Spring 2010 National Meeting & Exposition of the American Chemical Society, San Francisco, CA, March 21-25, 2010.
- Symposium Chair and Organizer, Policy Options for Sustainability. Spring 2010 National Meeting & Exposition of the American Chemical Society, San Francisco, CA, March 21-25, 2010.
- Invited Panelist, Workshop on Environmental Estrogens and Endocrine Disrupting Compounds, sponsored by the Johnson Foundation, Wingspread, WI, May 2010.
- Co-Organizer, 25th Anniversary Conference of the Superfund Research Program (SRP) of the National Institute of Environmental Health Sciences (NIEHS). Scientific Session 2: Risk Assessment and Remediation. Planning Committee Member, 25th Anniversary Meeting of the Superfund Basic Research Program, Raleigh, NC, October 21-24, 2012.

Classroom Instruction

	Principal Instructor
CEE470	Sustainable Environ. Biotechnologies (87936) (3 credits). Fall 2014. Enrollment: 15
CEE570	Sustainable Environ. Biotechnologies (87937) (3 credits). Fall 2014. Enrollment: 7
HON494	Sustainable Environ. Biotechnologies (88753) (3 credits). Fall 2014. Enrollment: 5
HON494	Biological Design Seminar (89949). Lecture (1 credit). Fall 2014. Enrollment: 9
BDE598	Biological Design Seminar (84106). Lecture (1 credit). Fall 2014. Enrollment: 7
BDE598	Biological Design Seminar (89564). Lecture (1 credit). Fall 2013. Enrollment: 8
HON494	Biological Design Seminar (89591). Lecture (1 credit). Fall 2013. Enrollment: 12
CEE361	Introduction to Environmental Engineering, Lecture (3 credits). Spring 2013 Enrollment: 61
CEE361	Introduction to Environmental Engineering, Laboratory (1 credit). Spring 2013 Enrollment: 61
CEE563	Environmental Chemistry Laboratory (3 credits). Fall 2012. Enrollment: 18
ASU101	The ASU Experience (1 credit). Fall 2011. Enrollment: 16
CEE598*	Sustainable Environmental Biotechnologies (3 credits). Fall 2011. Enrollment: 16
CEE494	Sustainable Environmental Biotechnologies (3 credits). Fall 2011. Enrollment: 2
CEE361	Introduction to Environmental Engineering, Lecture (3 credits). Spring 2011. Enrollment: 56
CEE361	Introduction to Environmental Engineering, Laboratory (1 credit). Spring 2011 Enrollment: 56
CEE790	Reading and Conference, Spring 2011 Enrollment: 1
CEE563	Environmental Chemistry Laboratory (3 credits). Fall 2010. Enrollment: 19
ASU101	The ASU Experience (1 credit). Fall 2010. Enrollment: 19
E2 Camp	Taught one module of ASU101 at Fall 2010 Freshman Camp in Prescott, AZ
CEE790	Reading and Conference. Fall 2010. Enrollment: 3
ASU101-1	The ASU Experience (1 credit). Fall 2009. Enrollment: 19
ASU101-2	The ASU Experience (1 credit). Fall 2009. Enrollment: 19
CEE790	Reading and Conference. Fall 2009. Enrollment: 2
CEE563	Environmental Chemistry Laboratory (3 credits). Fall 2009. Enrollment: 17
CEE598*	Sustainable Environmental Biotechnologies (3 credits). Spring 2009. Enrollment: 7
CEE494	Sustainable Environmental Biotechnologies (3 credits). Spring 2009. Enrollment: 33
CEE598	Environmental Engineering Analytical Laboratory (3 credits). Fall 2008. Enrollment: 11
JHU-Spain	Air, Water and Food Toxics (3 credits). Barcelona, Spain. JHU Fall Institute on Health Policy and Management (October 2008). Enrollment: 7.
182.638	Water & Health (4 credits), 4th Term, 2006/07. Enrollment: 12.
182.852	Air, Water, and Food Toxics (3 credits), 3rd Annual JHU Fall Institute in Health Policy and Management, Barcelona, Spain, 2006. Enrollment: 14.
182.638	Fundamentals of Water Quality Engineering for Public Health (4 credits), 4th Term, 2005/06. Enrollment: 13.
182.639	Introductory Principles of Water Quality Engineering for Public Health Water (3 credits). Highest-ranked Course of the 2nd Annual JHU Fall Institute in Health Policy and Management, Barcelona, Spain, 2005. Enrollment: 6.
183.849	SSR: Water-borne Diseases: Emerging Threats To Potable Water Supplies. 2004. Enrollment: 6.
	Online Training Modules for the Center of Public Health Preparedness
(No Code)	Chemical Weapons and Water Safety, 2005. http://www.jhsph.edu/ preparedness/ training/ online/chemagents_water_safety.html.
(No Code)	Water Safety, 2005. http://www.jhsph.edu/preparedness/training/online/water_safety.html

(No Code)	Water Safety—A Case Study, 2005. http://www.jhsph.edu/preparedness/ training/online/water_ safety_case_study.html
(No Code)	Monitoring Chemical Agents, 2005. http://www.jhsph.edu/preparedness/ training/online/ monitoring_chem_agents.html
	Guest Lectures
MIC445	Molecular Biology & Genetics, Fall 2012. Enrollment: 50
PFF	Preparing Future Faculty, Fall 2012. Enrollment: 32
BDE 598	Biological Design. Fall 2011. Enrollment: 13.
BDE 701	Biological Design. Fall 2009. Enrollment: 13.
CEE 100	Introduction to Civil and Environmental Engineering. Spring 2009. Enrollment: 60.
BDE 598	Biological Design. Fall 2008. Enrollment: 13.
180.609	Principles of Environmental Health I. 2004, 2006. Sources and Types of Water Contamination.
180.609	Principles of Environmental Health I. 2004. Water and Wastewater Treatment Systems.
182.640	Food and Waterborne Diseases, 3rd Term, 2002, 2004, 2006. Microcontaminants in Water.
180.880	Special Studies in Environmental Health Community Outreach. 2004. Sewage Spills: Turning a Community Concern into a Science Project.
(No Code)	Diversity Student Summer Seminar Series. 2004. Pharmaceuticals and Personal Care Products in the Environment.
(No Code)	Maryland Public Television Summer Institute. 2004.
550.865	Public Health Perspectives on Research. 2002. Environmental Health Engineering—Making a Career of Protecting the Environment and Human Health.
AS 020.151	General Biology I. Fall. Bioremediation. Enrollment: 297 (2004), 250 (2005). TBD (2006).
AS 020.161	Biology Workshop I. Fall. Bioremediation. Enrollment: 48 (2004), 48 (2005), TBD (2006).
(Taped)	Environmental Biotechnology Lecture Series, UC Berkeley, Berkeley, CA. 2001. Detection and Destruction of Anthropogenic Toxins in Drinking Water.

OTHER SIGNIFICANT TEACHING ACTIVITIES AND INSTRUCTIONAL TRAINING

2009	Spartan Entrepreneurial Workshop, Crash Course for Faculty Entrepreneurs. ASU Sky Song, Scottsdale, September 17-19.
2009	Preparing Future Faculty, Conducted Mock Interviews with Graduate Students, ASU.
2007	Teaching Well, Saving Time. A Teaching Workshop, Johns Hopkins University, January 12, 2007.
2005	Extreme Course Make-overs: Using Student Evaluations to Improve Your Course. Johns Hopkins University Workshop, Bloomberg School of Public Health, January 19.
2004	Creating the Loop: Developing Learning Objectives and Assessment Methods. Johns Hopkins University Workshop, Bloomberg School of Public Health, July 26.
2004	Lecturing & Active Learning: Strategies for Excellence Johns Hopkins University Workshop, Bloomberg School of Public Health, January 13-14.
1998 – 2001	Mentor, Science & Technology Education Program, Lawrence Livermore National Laboratory. Supervised four undergraduate research semester (URS) and two summer students.
1999 – 2001	Supervisor, 40 Hour SARA/OSHA Hazardous Waste Site Operator, 8CCR5192(e)(4), Lawrence Livermore National Laboratory.
1996 – 1997	Participant, University of Minnesota, Graduate School. Participated in the Bush Faculty Development Program for Excellence and Diversity in Teaching Program Preparing Doctoral Candidates for Their Role as Future Faculty: Introduction to

Diverse Teaching Methods, Peer-reviewed Practice Teaching, Design of Effective Courses/Exams/Homework Assignments, Acknowledging Students' Diversity and Learning Styles.

1993 – 1997 Teaching Assistant, University of Minnesota, Department of Civil Engineering. Organized and Conducted Laboratory Section of Graduate Courses Titled "Microbiology for Environmental Engineers" and "Groundwater Microbiology."

Exhibit F

Statement of Kim Harley

I, Kim Harley, am writing this statement in support of the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. I, Kim Harley PhD, am Associate Adjunct Professor in Maternal and Child Health and Associate Director for Health Effects, Center for Environmental Research and Children's Health at UC Berkeley. I am an environmental epidemiologist by training, and my research interests include the reproductive effects of PBDEs, prenatal exposure to environmental contaminants and the effects of endocrine disrupting compounds on birth outcome, fertility and the onset of puberty. I have been working in this field for 14 years and have attached my CV and list of publications.

2. I am one of the researchers running the CHAMACOS Study, a longitudinal birth cohort study investigating the role of chemicals and other environmental factors in the health of low-income, Mexican-American children living in the Salinas Valley of California. In 1999-2000, we enrolled 601 pregnant women living in Salinas and monitored the women and their children's health for the past 14 years. We carried out detailed physical exams and neurodevelopmental tests on the children every 1 to 2 years. At the time the mothers were pregnant, the organohalogen Penta PBDE mixture was the predominant flame retardant used in furniture. We found a strong positive correlation between the levels of flame retardants in pregnant mothers' bodies and the length of time they had lived in California[1]. We also found a significant increase of over 26% in total PBDE levels among women who had three or more pieces of upholstered furniture in their homes, suggesting that indoor contamination was contributing to this exposure.[2] The levels of flame retardants in the blood of these Latino children, who were all born in California, were among the highest levels ever published[3], three times higher than their mothers during pregnancy, and seven times higher than children living in Mexico[4]. The PBDE levels in children were positively correlated with the total PBDE levels in maternal serum during pregnancy, duration of exclusive breastfeeding, and absence of a safe place to play in their neighborhood.[5] In terms of health effects, we found that the women with higher levels of flame retardants in their blood: (i) took significantly longer to get pregnant, i.e. had reduced fecundability[6]; (2) had babies with lower birth weight (over 100 g decrease in birth weight for every 10 fold increase in PBDE levels)[7]; and (iii) had lower thyroid hormone levels during pregnancy[8], which may have implications for both maternal health and development of the fetus. We also assessed the development of over 300 children and found that, by the time they were 5 to 7 years old, their mother's flame retardant exposure during pregnancy was associated with lower IQ (a decrease by 6 points on average), attention problems, and impaired

fine motor coordination, particularly in the non-dominant hand[9]. Thus, pregnant women's exposure to PBDEs is of concern because it may have long-term adverse effects on the children.

3. Other scientific studies of completely different populations found similar adverse health effects, including alterations in thyroid hormone during pregnancy[10,11], decreased birth weight[12], and impaired neurodevelopment, cognitive and behavioral performance in children[13,14,15,16,17,18,19]. Other studies also found associations between PBDEs and decreased semen quality[20], hormonal changes in men[21,22,23], cryptorchidism (undescended testicles, which increases the risk of infertility and testicular cancer later in life)[24,25], and early puberty in girls[26]. These human studies are corroborated by several studies on rats and mice showing adverse neurodevelopmental effects[27,28,29,30,31,32,33,34,35,36,37,38,39,40,41] and adverse reproductive effects, including alterations in sex hormone levels, reduced sperm count and changes in the structure of the ovaries[42,43,44,45,46,47].

4. Our published studies on pregnant women and children relate to the Penta BDE mixture, which was the predominant chemical used to meet TB117 in 2000 when the study began. According to the Center for Disease Control biomonitoring studies, 97% of the US population has PBDEs in their blood. This is because additive organohalogen flame retardants such as PBDEs migrate out of consumer products into dust and get into people's bodies.

5. Now Penta BDE has been replaced in upholstered furniture by other organohalogen flame retardant chemicals such as chlorinated Tris and FireMaster 550, both found in 100% of California homes and childcare facilities tested[48]. Chlorinated tris has been listed as a carcinogen by the state of California under Proposition 65[49] and recently banned in several states[50], which exemplifies the problem of regrettable substitution. Human studies are also starting to show effects of some of these other organohalogen flame retardants on thyroid hormone levels[51], and animal studies have found adverse reproductive and developmental[52,53,54,55,56], neurobehavioral[57,58,59] and endocrine[60,61,62,63,64] effects.

6. Based on my research on the impacts of PBDE flame retardants on the health of pregnant women and their children and the increasing evidence of harm from the replacement flame retardants, it is my professional opinion that all organohalogen flame retardants may pose similar risks, especially to fetuses and young children. To protect the health of our population, including the most vulnerable pregnant women and children, I support this petition to ban certain household products containing additive organohalogen flame retardants. This ban is necessary to avoid exposure of pregnant women and children to this class that includes chemicals that I studied and found to be harmful to human health.

Yours sincerely,

Kim Harley, Ph.D.

Associate Adjunct Professor, Maternal & Child Health

Associate Director for Health Effects, Center for Environmental Research & Children's Health

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[1] Castorina R., Bradman A., Sjodin A., Fenster L., Jones R. S., Harley K., Eisen E. A., Eskenazi B. (2011) Determinants of serum polybrominated diphenyl ether (PBDE) levels among pregnant women in the CHAMACOS cohort. Environ Sci Technol. 45(15):6553-6560

[2] Castorina R., Bradman A., Sjodin A., Fenster L., Jones R. S., Harley K., Eisen E. A., Eskenazi B. (2011) Determinants of serum polybrominated diphenyl ether (PBDE) levels among pregnant women in the CHAMACOS cohort. Environ Sci Technol. 45(15):6553-6560

[3] Eskenazi B., Chevrier J., Rauch S. A., Kogut K., Harley K. G., Johnson C., Trujilo C., Sjodin A., Bradman A. (2012) In utero and childhood polybrominated diphenyl ether (PBDE) exposures and neurodevelopment in the CHAMACOS study. Environ Health Perspect. 121(2):257-262

[4] Eskenazi B., Fenster L., Castorina R., Marks A. R., Sjodin A., Rosas L. G., Holland N., Guerra A. G., Lopez-Carillo L., Bradman A. (2011). A comparison of PBDE serum concentrations in Mexican and Mexican-American children living in California. Environ Health Perspect. 119(10):1442-1448

[5] Bradman A., Castorina R., Sjodin A., Fenster L., Jones R. S., Harley K. G., Cevrier J., Holland N. T., Eskenazi B. (2012) Factors associated with serum polybrominated diphenyl ether (PBDE) levels among school-age children in the CHAMACOS cohort. Environ Sci Technol. 46(13):7373-7381

[6] Harley K. G., Marks A. R., Chevrier J., Bradman A., Sjodin, A., Eskenazi B. (2010) PBDE concentrations in women's serum and fecundability. Environ Health Perspect. 118(5):699-704

[7] Harley K. G., Cevrier J., Schall R. A., Sjodin A., Bradman A., Eskenazi B. (2011) Association of prenatal exposure to polybrominated diphenyl ethers and infant birth weight. Am J Epidemiol. 174(8):885-892

[8] Chevrier J., Harley K. G., Bradman A., Gharbi M., Sjodin A., Eskenazi B. (2010) Polybrominated diphenyl ether (PBDE) flame retardants and thyroid hormone during pregnancy. Environ Health Perspect. 118(10):1444-1449

[9] Eskenazi B., Chevrier J., Rauch S. A., Kogut K., Harley K. G., Johnson C., Trujilo C., Sjodin A., Bradman A. (2012) In utero and childhood polybrominated diphenyl ether (PBDE) exposures and neurodevelopment in the CHAMACOS study. Environ Health Perspect. 121(2):257-262

[10] Stapleton H. M., Eagle S., Anthopolos R., Wolkin A., Miranda M. L. (2011) Associations between polybrominated diphenyl ether (PBDE) flame retardants, phenolic metabolites, and thyroid hormones during pregnancy. Environ Health Perspect. 119(10):1454-1459

[11] Zota A. R., Park J. S., Wang Y., Petreas M., Zoeller R. T., Woodruff T. J. (2011) Polybrominated diphenyl ethers, hydroxylated polybrominated diphenyl ethers, and measures of thyroid

function in second trimester pregnant women in California. Environ Sci Technol. 45(18):7896-7905. doi: 10.1021/es200422b
[12] Chao H. R., Wang S. L., Lee W. J., Wang Y. F., Papke O. (2007) Levels of polybrominated diphenyl ethers (PBDEs) in breast milk from central Taiwan and their relation to infant birth outcome and maternal menstruation effects. Environ Int. 33(2):239-245
[13] Herbstman J. B., Sjolin S., Kurzon M., Lederman S. A., Jones R. S., Raugh V., Needham L. L., Tang D., Niedzwiecki M., Wang R. Y., Perera F. (2010) Prenatal exposure to PBDEs and neurodevelopment. Environ Health Perspect. 118(5):712-719
[14] Gascon M., Fort M., Martinez D., Carsin A. E., Forns J., Grimalt J. O., Santa Marina L., Lertxundi N., Sunyer J., Vrijheld M. (2012) Polybrominated diphenyl ethers (PBDEs) in breast milk and neurophysiological development in infants. Environ Health Perspect. 120(12):1760-1765
[15] Gascon M., Vrijheid M., Martinez D., Forns J., Grimalt J. O., Torrent M., Sunyer J. (2011) Effects of pre and postnatal exposure to low levels of polybromodiphenyl ethers on neurodevelopment and thyroid hormone levels at 4 years of age. Environ Int. 37(3):605-611
[16] Roze E., Meijer L., Bakker A., Van Braeckel K. N., Sauer P. J., Bos A. F. (2009) Prenatal exposure to organohalogens, including brominated flame retardants, influences motor, cognitive, and behavioral performance at school age. Environ Health Perspect. 117(12):1953-1958. doi: 10.1289/ehp.0901015
[17] Hoffman K., Adgent M., Goldman B. D., Sjödin A., Daniels J. L. (2012) Lactational exposure to polybrominated diphenyl ethers and its relation to social and emotional development among toddlers. Environ Health Perspect. 120(10):1438-1442. doi: 10.1289/ehp.1205100
[18] Costa L. G., Giordano G. (2007) Developmental neurotoxicity of polybrominated diphenyl ether (PBDE) flame retardants. Neurotoxicology. 28(6):1047-1067
[19] Jurewicz J., Polańska K., Hanke W. (2013) Exposure to widespread environmental toxicants and children's cognitive development and behavioral problems. Int J Occup Med Environ Health. 26(2):185-204. doi: 10.2478/s13382-013-0099-x
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[22] Meeker J. D., Johnson P. I., Camann D., Hauser R. (2009) Polybrominated diphenyl ether (PBDE) concentrations in house dust are related to hormone levels in men. Sci Total Environ. 407(10):3425-3429. doi: 10.1016/j.scitotenv.2009.01.030
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[24] Toppari J. (2012) Male reproductive health as a sentinel for environmental endocrine disruption. Acta Vet Scand. 54(Suppl. 1)
[25] Krysiak-Baltyn K., Toppari J., Skakkebaek N. E., Jensen T. S., Virtanen H. E., Schramm K. W., Shen H., Vartiainen T., Kiviranta H., Taboureau O., Audouze K., Brunak S., Main K. M. (2012)

Association between chemical pattern in breast milk and congenital cryptorchidism: modeling of complex human exposures. Int J Androl. 35(2):294-302. doi: 10.1111/j.1365-2605.2012.01268.x
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KIM HARLEY

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CURRENT POSITIONS

Associate Adjunct Professor, Maternal and Child Health Division
School of Public Health, U.C. Berkeley

Associate Director for Health Effects, Center for Environmental Research and Children's Health
School of Public Health, U.C. Berkeley

EDUCATION

Ph.D. **University of California at Berkeley**
Epidemiology, 2004

Dissertation: *Examining an Epidemiologic Paradox: The Role of Acculturation, Nutrition, and Social Support in the Birth Outcomes of Women of Mexican Descent*

M.P.H. **University of California at Berkeley**
Maternal and Child Health, 1998

Thesis: *Maternity Hospital Practices that Affect Breastfeeding at Four Months in Egypt*

B.A. **Vassar College**
Anthropology, 1992

Independent Study Project: *Modern Magic: Medical Care in Rural Bali*

RESEARCH INTERESTS

- Reproductive and perinatal epidemiology
- Endocrine disruptor exposure to adolescent girls and effects on puberty and fertility
- Reproductive and developmental effects of Bisphenol A, PBDEs, pesticides, and other endocrine disruptors

TEACHING EXPERIENCE

Spring 2008 - Present	**Instructor,** Practical Issues in Maternal and Child Health Data Analysis (PH 293-6)	UC Berkeley
Spring 2007 - Present	**Instructor,** Reproductive and Perinatal Epidemiology (PH 210D)	UC Berkeley
Spring 2004 Spring 2003	**Graduate Student Instructor,** Reproductive and Perinatal Epidemiology (PH 210D)	UC Berkeley
Fall 2000	**Graduate Student Instructor,** Epidemiologic Methods II (PH 250B)	UC Berkeley

MENTORING EXPERIENCE (MASTER'S PROJECT COMMITTEE)

2012-2013 Mariko Sweetnam (Committee Chair)
Ayca Erkin-Cakmak
Kristina Kastler
Emily Murphy

2011-2012 Rasika Behl (Committee Chair)
Shayla Livingston (Committee Chair)
Brett Augspurger
Vidita Chopra
Marlowe Dieckmann

2010-2011 Alison Gemmill (Committee Chair)
Jocelyn Audelo
Dewight Cowley
Aarti Kale
Hannah Sheehy
Emilia Wilkins

2009-2010 Maria Elena Young
Hatav Khademi
Elizabeth Cretti

2008-2009 Lauren Hubner

2007-2008 Celina Trujillo

2006-2007 Jennifer Wright

RESEARCH EXPERIENCE

1998-present **CENTER FOR CHILDREN'S ENVIRONMENTAL HEALTH RESEARCH** U.C. Berkeley
Associate Director (2007-present)

- Manage research study investigating the health of pregnant women and children in a farmworker community. (Salinas Valley, CA)
- Supervise staff of study coordinator, data analysts, interviewers, graduate students.
- Devise research questions, design studies, oversee data collection
- Analyze data, author scientific research articles
- Present research findings to scientists, public health providers, funders.
- Write grant applications and reports to funders.

Study Coordinator (2004-2007), **Researcher/Graduate Student** (1998-2004)

OTHER PUBLIC HEALTH EXPERIENCE

2008-2010 **ENVIRONMENTAL HEALTH SCIENCES** Charlottesville, VA
Science Communication Fellow

- Work with media relations and policy experts to advance public understanding of environmental health issues.
- Identify scientific studies to be prioritized for media attention.
- Translate and explain relevance of findings for journalists.

Summer 1997 **WELLSTART INTERNATIONAL** San Diego, CA
Evaluation and Resource Development Consultant
- Fundraising and grant-writing for public health non-profit organization.
- Evaluated changes in breastfeeding practices over a ten-year international promotion project.
- Conducted cost-benefit analysis of breastfeeding promotion in US hospitals.

1993-1996 **PROJECT CONCERN INTERNATIONAL** San Diego, CA
Grants Coordinator (1996)
- Managed grant proposal submissions, resulting in $800,000 for international public health programs.
- Monitored progress, ensured grant obligations were met, represented Project Concern to donors.
- Coordinated proposal and report writing process, collaborated with overseas staff and headquarters staff in fundraising, program and finance departments.
- Supervised two full-time employees and one part-time employee.

Foundation Grants Officer (1994 - 1995), **Corporate Grants Officer** (1993 - 1994)

1992-1993 **JOHN SNOW INC.** Arlington, VA
Staff Associate
- Coordinated USAID-funded shipments of contraceptives to developing nations.
- Responsible for processing USAID missions' contraceptive orders, tracking the progress of shipments and communicating instructions to shipping company.
- Provided headquarters support to overseas advisors.

GRANT SUPPORT

Decreasing Endocrine Disruptor Exposure in Latina Teens (HERMOSA Study)
Principal Investigator: K. Harley
Grant Number: 18BB1800 Funder: CA Breast Cancer Research Amount: $646,431
Grant Period: 9/30/2009 - 7/31/2011
Role: PI

Bisphenol A and Children's Growth and Development
Principal Investigator: K. Harley and B. Eskenazi (Multiple PIs)
Grant Number: 1RC2ES018792 Funder: NIEHS Amount: $1,493,880
Grant Period: 9/30/2009 - 7/31/2011
Role: PI

Administrative Supplement to Bisphenol A and Children's Growth and Development
Principal Investigator: K. Harley
Grant Number: 3RC2ES018792-S1 Funder: NIEHS Amount: $76,620
Grant Period: 5/28/2010 - 7/31/2011
Role: PI

Center for Children's Environmental Health Research
Principal Investigator: B. Eskenazi
Grant Number: PO1 ES009605 Funder: NIEHS/EPA Amount: $4,160,551
Grant Period: 9/24/2009 – 7/31/2014
Role: Co-investigator

DDT & PBDE Exposure, Puberty Onset, and Neurodevelopment in Mexican-American Girls.

Principal Investigator: B. Eskenazi
Grant Number: RO1 ES017054 Funder: NIEHS Amount: $3,285,313
Grant Period: 8/1/2009 – 4/30/2014
Role: Co-investigator

PBDEs, DDT and Neurodevelopment in School-Aged Mexican-American Children
Principal Investigator: B. Eskenazi
Grant Number: RO1 ES015572 Funder: NIEHS Amount: $1,960,631
Grant Period: 8/7/2007 – 4/30/2011
Role: Co-investigator

PON1 and Developmental Sensitivity to OP Pesticides
Principal Investigator: N. Holland
Grant Number: RO1 ES012503 Funder: NIEHS Amount: $1,748,016
Grant Period: 1/1/2006 – 12/31/2010
Role: Co-investigator

PROFESSIONAL AFFILIATIONS

International Society for Environmental Epidemiology

PROFESSIONAL SERVICE

Reviewer: American Journal of Epidemiology, Environmental Health Perspectives, Environmental Health, Journal of Exposure Science and Environmental Epidemiology.

Publication List – Kim Harley

1. Eskenazi, B. and **Harley, K.** (2001). Commentary: Revisiting the primipaternity theory of pre-eclampsia. International Journal of Epidemiology, 30(6): p. 1323-1324.

2. Eskenazi, B., **Harley, K.**, Bradman, A., Weltzien, E., Jewell, N.A., Barr, D.B., Furlong, C.E., and Holland, N.T. (2004). Association of in utero organophosphate pesticide exposure and fetal growth and length of gestation in an agricultural population. Environmental Health Perspectives, 112(10): p. 1116-1124.

3. **Harley, K.**, Eskenazi, B., and Block, G. (2005). The association of time in the US and diet during pregnancy in low-income women of Mexican descent. Paediatric and Perinatal Epidemiology, 19(2): p. 125-134.

4. Duramad, P., **Harley, K.**, Lipsett, M., Bradman, A., Eskenazi, B., Holland, N.T., and Tager, I.B. (2006). Early environmental exposures and intracellular Th1/Th2 cytokine profiles in 24-month-old children living in an agricultural area. Environmental Health Perspectives, 114(12): p. 1916-1922.

5. Fenster, L., Eskenazi, B., Anderson, M., Bradman, A., **Harley, K.**, Hernandez, H., Hubbard, A., and Barr, D.B. (2006). Association of in utero organochlorine pesticide exposure and fetal growth and length of gestation in an agricultural population. Environmental Health Perspectives, 114(4): p. 597-602.

6. **Harley, K.** and Eskenazi, B. (2006). Time in the United States, social support and health behaviors during pregnancy among women of Mexican descent. Social Science & Medicine, 62(12): p. 3048-3061.

7. Warner, M.L., **Harley, K.**, Bradman, A., Vargas, G., and Eskenazi, B. (2006). Soda consumption and overweight status of 2-year-old Mexican-American children in California. Obesity, 14(11): p. 1966-1974.

8. Eskenazi, B., Marks, A.R., Bradman, A., **Harley, K.**, Barr, D.B., Johnson, C., Morga, N., and Jewell, N.A. (2007). Organophosphate pesticide exposure and neurodevelopment in young Mexican-American children. Environmental Health Perspectives, 115(5): p. 792-798.

9. **Harley, K.**, Stamm, N.L., and Eskenazi, B. (2007). The effect of time in the US on the duration of breastfeeding in women of Mexican descent. Maternal and Child Health Journal, 11(2): p. 119-125.

10. Eskenazi, B., Rosas, L.G., Marks, A.R., Bradman, A., **Harley, K.**, Holland, N., Johnson, C., Fenster, L., and Barr, D.B. (2008). Pesticide toxicity and the developing brain. Basic & Clinical Pharmacology & Toxicology, 102(2): p. 228-236.

11. **Harley, K.G.**, Marks, A.R., Bradman, A., Barr, D.B., and Eskenazi, B. (2008). DDT exposure, work in agriculture, and time to pregnancy among farmworkers in California. J Occup Environ Med, 50(12): p. 1335-42.

12. **Harley, K.G.**, Macher, J.M., Lipsett, M., Duramad, P., Holland, N.T., Prager, S.S., Ferber, J., Bradman, A., Eskenazi, B., and Tager, I.B. (2009). Fungi and pollen exposure in the first months of life and risk of early childhood wheezing. Thorax, 64(4): p. 353-8.

13. Huen, K., **Harley, K.**, Brooks, J., Hubbard, A., Bradman, A., Eskenazi, B., and Holland, N. (2009). Developmental changes in PON1 enzyme activity in young children and effects of PON1 polymorphisms. Environ Health Perspect, 117(10): p. 1632-8.

14. Rosas, L.G., **Harley, K.**, Fernald, L.C., Guendelman, S., Mejia, F., Neufeld, L.M., and Eskenazi, B. (2009). Dietary Associations of Household Food Insecurity among Children of Mexican Descent: Results of a Binational Study. J Am Diet Assoc, 109(12): p. 2001-9.

15. Chevrier, J., **Harley, K.G.**, Bradman, A., Gharbi, M., Sjodin, A., and Eskenazi, B. (2010). Polybrominated diphenyl ether (PBDE) flame retardants and thyroid hormone during pregnancy. Environ Health Perspect, 118(10): p. 1444-9.

16. Eskenazi, B., Huen, K., Marks, A., **Harley, K.G.**, Bradman, A., Barr, D.B., and Holland, N. (2010). PON1 and Neurodevelopment in Children from the CHAMACOS Study Exposed to Organophosphate Pesticides in Utero. Environ Health Perspect, 118(12): p. 1775-81.

17. **Harley, K.G.**, Marks, A.R., Chevrier, J., Bradman, A., Sjodin, A., and Eskenazi, B. (2010). PBDE concentrations in women's serum and fecundability. Environ Health Perspect, 118(5): p. 699-704.

18. Huen, K., **Harley, K.**, Bradman, A., Eskenazi, B., and Holland, N. (2010). Longitudinal changes in PON1 enzymatic activities in Mexican-American mothers and children with different genotypes and haplotypes. Toxicol Appl Pharmacol.

19. Marks, A.R., **Harley, K.**, Bradman, A., Kogut, K., Barr, D.B., Johnson, C., Calderon, N., and Eskenazi, B. (2010). Organophosphate Pesticide Exposure and Attention in Young Mexican-American Children: The CHAMACOS Study. Environ Health Perspect, 118(12): p. 1768-74.

20. Rosas, L.G., **Harley, K.G.**, Guendelman, S., Fernald, L.C., Mejia, F., and Eskenazi, B. (2010). Maternal perception of child weight among Mexicans in California and Mexico. Matern Child Health J, 14(6): p. 886-94.

21. Weldon, R.H., Webster, M., **Harley, K.G.**, Bradman, A., Fenster, L., Davis, M.D., Hubbard, A., Barr, D.B., Holland, N., and Eskenazi, B. (2010). Serum Persistent Organic Pollutants and Duration of Lactation among Mexican-American Women. J Environ Public Health, doi: 10.1155/2010/861757 [Online: July 31, 2010]: p. 861757.

22. Bouchard, M.F., Chevrier, J., **Harley, K.G.**, Kogut, K., Vedar, M., Calderon, N., Trujillo, C., Johnson, C., Bradman, A., Barr, D.B., and Eskenazi, B. (2011). Prenatal exposure to organophosphate pesticides and IQ in 7-year-old children. Environ Health Perspect, 119(8): p. 1189-95.

23. Bradman, A., Castorina, R., Barr, D.B., Chevrier, J., Harnly, M.E., Eisen, E.A., McKone, T.E., **Harley, K.**, Holland, N., and Eskenazi, B. (2011). Determinants of

organophosphorus pesticide urinary metabolite levels in young children living in an agricultural community. Int J Environ Res Public Health, 8(4): p. 1061-83.

24. Castorina, R., Bradman, A., Sjodin, A., Fenster, L., Jones, R.S., **Harley, K.G.**, Eisen, E.A., and Eskenazi, B. (2011). Determinants of serum polybrominated diphenyl ether (PBDE) levels among pregnant women in the CHAMACOS cohort. Environ Sci Technol, 45(15): p. 6553-60.

25. Chevrier, J., **Harley, K.G.**, Bradman, A., Sjodin, A., and Eskenazi, B. (2011). Prenatal exposure to polybrominated diphenyl ether flame retardants and neonatal thyroid-stimulating hormone levels in the CHAMACOS study. Am J Epidemiol, 174(10): p. 1166-74.

26. Chevrier, J., **Harley, K.G.**, Kogut, K., Holland, N., Johnson, C., and Eskenazi, B. (2011). Maternal Thyroid Function during the Second Half of Pregnancy and Child Neurodevelopment at 6, 12, 24, and 60 Months of Age. J Thyroid Res, 2011: p. 426427.

27. **Harley, K.G.**, Chevrier, J., Schall, R.A., Sjodin, A., Bradman, A., and Eskenazi, B. (2011). Association of prenatal exposure to polybrominated diphenyl ethers and infant birth weight. Am J Epidemiol, 174(8): p. 885-92.

28. **Harley, K.G.**, Huen, K., Schall, R.A., Holland, N.T., Bradman, A., Barr, D.B., and Eskenazi, B. (2011). Association of organophosphate pesticide exposure and paraoxonase with birth outcome in Mexican-American women. PLoS One, 6(8): p. e23923.

29. Rosas, L.G., Guendelman, S., **Harley, K.**, Fernald, L.C., Neufeld, L., Mejia, F., and Eskenazi, B. (2011). Factors associated with overweight and obesity among children of Mexican descent: results of a binational study. J Immigr Minor Health, 13(1): p. 169-80.

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31. Ehrlich, S.F., Rosas, L.G., Ferrara, A., King, J.C., Abrams, B., **Harley, K.G.**, Hedderson, M.M., and Eskenazi, B. (2012). Pregnancy glucose levels in women without diabetes or gestational diabetes and childhood cardiometabolic risk at 7 years of age. J Pediatr, 161(6): p. 1016-21.

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54. Eskenazi, B., Kogut, K., Huen, K., **Harley, K.G.**, Bouchard, M., Bradman, A., Boyd-Barr, D., Johnson, C., and Holland, N. (2014). Organophosphate pesticide exposure, PON1, and neurodevelopment in school-age children from the CHAMACOS study. Environ Res, 134C: p. 149-157.

* Student paper

Exhibit G

Statement of Julie Herbstman

COLUMBIA CENTER
FOR CHILDREN'S
ENVIRONMENTAL
HEALTH

MAILMAN SCHOOL OF PUBLIC HEALTH
COLUMBIA UNIVERSITY

Statement for Julie Herbstman

June 11, 2014

I, Julie Herbstman, am writing this statement in support of the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. I am an environmental epidemiologist, currently holding the position of Assistant Professor in the Department of Environmental Health Sciences at the Columbia University Mailman School of Public Health. I completed a master's of science (ScM) and a doctoral degree (PhD) in environmental epidemiology from the Johns Hopkins Bloomberg School of Public Health. I completed a postdoctoral fellowship in environmental health at the Columbia Mailman School of Public Health before joining the faculty. At Columbia, I am affiliated with the Columbia Center for Children's Environmental Health, the Columbia Center for Environmental Health in Northern Manhattan, and the Cancer Epidemiology Program at the Herbert Irving Comprehensive Cancer Center at the Columbia University Medical Center.

2. Since 2002, I have been studying the impact of prenatal exposure to polybrominated diphenyl ethers (PBDE) on children's thyroid hormone levels and neurodevelopment, first at Hopkins and now at Columbia. In my research, I have collected umbilical cord blood and have worked with the Centers for Disease Control and Prevention (CDC) to measure PBDE components (congeners) associated with the penta-brominated diphenyl ether (penta-BDE) mixture. I have found that all the neonates in my research studies in Baltimore and in New York had detectable levels of at least one penta-BDE congener in their cord blood [1,2]. We found evidence suggesting that prenatal exposure to penta-BDE congeners may impact perinatal thyroid hormone levels [3]. We also found that children who were exposed prenatally to higher concentrations of penta-BDE congeners (relative to children in the study with lower exposure) scored significantly lower on cognitive tests, including such tests as full-scale, verbal, and performance intelligence quotient (IQ) at ages 4 and 7 [1].

3. Based on this evidence along with evidence provided by other researchers in the field, I conclude that generally, infants in the US are born with detectable concentrations of penta-BDE in their circulating blood. This occurs because the mothers are exposed to penta-BDE either before or during pregnancy, and these chemicals are then transferred to the neonates while *in utero*. Additional research has shown that children's exposure to penta-BDE continues through the ingestion of penta-BDE-containing breast milk [4] and household dust [5]. Research shows that it is likely that penta-BDE in dust is the result of penta-BDE added to consumer products like furniture, toys, and electronics, which subsequently migrates into the household environment. I can conclude from this that other organohalogen flame retardants found in additive form in household consumer products also have the potential to migrate, leading to human exposure, especially in children.

4. Based on my research and the research of other investigators in the field, there is ample evidence indicating that prenatal exposure to penta-BDEs is associated with lower scores on indices of both cognition (e.g., IQ) and behavior throughout childhood. Since PBDEs have been phased out of use in new consumer products, new

compounds have been used instead. Some of these compounds are also organohalogen flame retardants, meaning they are in the same chemical family as PBDEs and other flame retardants that have been banned or phased out (e.g., brominated tris).

5. I have carefully reviewed the statement from Dr. Terry Collins about the toxicity mechanisms of organohalogen flame retardants, and the hazard screen performed by Dr. David Eastmond's group on 85 non-polymeric organohalogen flame retardants. Based on the information in these statements and my research and experience as an environmental epidemiologist, my professional opinion is that there is reason to be concerned that the entire class of organohalogen flame retardants may cause injury or illness to humans, particularly to fetuses and young children. Therefore, I support regulations designed to prevent human exposure to these chemicals from consumer products.

Sincerely,

Julie Herbstman, Ph.D.

References

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5. Stapleton HM, Eagle S, Sjödin A, Webster TF. (2012) Serum PBDEs in a North Carolina toddler cohort: associations with handwipes, house dust, and socioeconomic variables. Environ Health Perspect 120(7): 1049-1054.

Julie Beth Herbstman

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New York, NY 10032
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TRAINING:

Columbia University, Mailman School of Public Health, New York, NY — 2006-2010
Postdoctoral Research Fellow
Columbia Center for Children's Environmental Health
Mentor: Dr. Frederica P. Perera, DrPH

Johns Hopkins University, Bloomberg School of Public Health, Baltimore, MD — 2007
PhD, Environmental Epidemiology (degree completed: June 2006)
Dissertation: "Prenatal Exposure to Polybrominated Diphenyl Ethers: Effect on Birth Weight, Gestational Age, and Thyroid Function"
Advisor: Dr. Lynn R. Goldman, MD MPH

Johns Hopkins University, School of Public Health, Baltimore, MD — 2002
ScM, Epidemiology
Thesis: "Respiratory Effects of Inhalation Exposure Among Workers During the Clean-Up Effort at the World Trade Center Disaster Site"
Advisor: Dr. Margo Schwab, PhD

Johns Hopkins University, School of Public Health, Baltimore, MD — 2001
Certificate in Risk Sciences and Public Policy

Tufts University, Medford, MA — 1998
B.A. (*cum laude*), Major: Comparative Religion; Minor: Engineering Science; Certificate in Community Health

FELLOWSHIPS AND AWARDS:

Career Development Award — 2012-2014
Center for Environmental Health in Northern Manhattan, Columbia University

K99-R00 "Pathway to Independence" Career Development Award (NIEHS) — 2009-2014
Sponsor (for K99 phase): Dr. Frederica Perera

National Cancer Institute Postdoctoral Fellowship — 2006-2009
Principal Investigator: Dr. Alfred Neugut

Center for a Livable Future Research Award — 2004, 2005
Principal Investigator: Dr. Lynn Goldman

Doctoral Fellowship in Environmental Public Health Tracking — 2004-2005
Principal Investigator: Dr. Thomas Burke

The Charlotte Ferenze Fellowship — 2004
Johns Hopkins Department of Epidemiology

Maternal Child Health – Epidemiology Fellowship in Applied Epidemiology 2003-2004
Principal Investigator: Dr. Pat O'Campo
National Cancer Institute Summer Fellowship 2001
Mentor: Dr. Montserrat Garcia-Closas

SCIENCE ADVISORY BOARD/REVIEW PANELS:

Columbia's Center for Environmental Health in Northern Manhattan,
Pilot grant review 2012
Einstein-Montefiore Institute for Clinical and Translational Research,
Mentored Clinical and Translational Research Career Development Awards review 2012
University of Michigan Environmental Health Science Core Center,
Pilot grant review 2012
Harvard School of Public Health NIEHS Center, Pilot grant review
NIEHS R13 Peer Review Panel October 2012
U.S. EPA Science Advisory Board Panel on Perchlorate 2012-2013
NIH, Infectious Disease, Reproductive Health, Asthma and Pulmonary Conditions Study Section (IRAP), *Ad Hoc* Member June 2013
New York Academy of Sciences, Scientific conferences review 2013
Canadian Institutes of Health Research, external reviewer. 2013
NIH, Neurological, Aging, Musculoskeleton, and Epidemiology Study Section (NAME), *Ad Hoc* Member October 2014
South African Medical Research Council (MRC), external reviewer. 2014

RESEARCH EXPERIENCE:

Assistant Professor 2010-present
Research Fellow/Scientist 2006-2010
Columbia Center for Children's Environmental Health
NIEHS Center for Environmental Health in Northern Manhattan
Herbert Irving Cancer Center Member
Department of Environmental Health Sciences
Columbia Mailman School of Public Health
New York, NY

Research Investigator 2006-present
Research Assistant 2003-2006
"Tracking Health Related to Environmental Exposures" (THREE) Study
Department of Environmental Health Sciences
Johns Hopkins Bloomberg School of Public Health
Baltimore, MD

Research Fellow 2003-2006
Johns Hopkins Center of Excellence in Environmental Health Tracking
Department of Health Policy and Management
Johns Hopkins Bloomberg School of Public Health
Baltimore, MD

Research Fellow 2001-2004
Johns Hopkins World Trade Center (WTC) Research Team
Department of Environmental Health Sciences
Johns Hopkins Bloomberg School of Public Health
Baltimore, MD

Research Intern, Environmental Epidemiology Branch 2001
Department of Cancer Epidemiology and Genetics
National Cancer Institute
Rockville, MD

Research Assistant 2000
North Dakota Children's Health Study
Department of Epidemiology
Johns Hopkins School of Public Health
Baltimore, MD

Research Assistant
Nurses' Health Study 1998-2000
Channing Laboratory
Brigham and Women's Hospital
Boston, MA

Research Intern 1998
Silent Spring Institute
Newton, MA

TEACHING EXPERIENCE:

Instructor, Postgraduate Course at the American Thoracic Society Meeting 2012, 2014
- The Epigenetics of Lung Disease (1 day)

Instructor, Workshop in Risk Assessment and Molecular Epidemiology 2010
Shanghai Fudan University
- Molecular Epidemiology (1 week)

Course Director/Instructor, Department of Environmental Health Sciences 2006-Present
Columbia Mailman School of Public Health
- Analysis of Environmental Data (2013, 2014), Course Director
- Molecular Epidemiology (2006-present), Lecturer
- Journal Club (2011), Lecturer

Teaching Assistant, Department of Epidemiology
Johns Hopkins Bloomberg School of Public Health
- Introduction to Epidemiology (2 years) 2001-2002
- Intermediate Epidemiology (2 years) 2004
- Quantitative Methods (4 years) 2002-2005
- Health Services Research (1 year) 2003

Johns Hopkins Krieger School of Arts and Sciences
- Introduction to Epidemiology (1 year) 2003

Instructor, Experimental College
Tufts University

- Freshman literature course (1 year) 1998

MENTORING/ADVISING (COLUMBIA UNIVERSITY, UNLESS NOTED):

Jelena Vujcic, MPH, Department of Epidemiology	2009
Susan Edwards, MPH, Department of Environmental Health Sciences	2009
Erin Paxson, MS, Department of Human Nutrition	2009
Jennifer Mall, MPH, Department of Environmental Health Sciences	2010
Steven Cook, MPH, Department of Environmental Health Sciences	2011
Rosie Martinez, MPH, Department of Environmental Health Sciences	2012-2014
Shoko Kubotera, MPH, Department of Environmental Health Sciences	2012-2014
Whitney Cowell, PhD candidate, Department of Environmental Health Sciences	2012-present
Kristin White, MPH, Department of Epidemiology	2012
Zaynah Abid, MPH, Yale School of Public Health	2012
Katherine Schleiss, MPH, Department of Epidemiology	2013
Madeleine Hopson, MPH, Department of Environmental Health Sciences	2013-present
Erin Eimutus, MPH, Department of Environmental Health Sciences	2014-present

SELECTED ORAL PRESENTATIONS:

Prenatal Programming and Toxicity (PPTox) IV: Environmental Stressors in Disease and Implications for Human Health. (*2014, Boston, MA*)
Title: Cell distribution prediction from DNA methylation data using a reference set derived from umbilical cord blood

Northeast Regional Chapter of the Society of Toxicology Annual Meeting: Toxicological Aspects of Epigenetics (*2014, Storrs, CT*)
Title: DNA methylation and the challenge of linking prenatal exposures to childhood health outcomes

Duke University Integrated Toxicology and Environmental Health Program Spring Symposium *(2013, Durham, NC)*
Title: Detecting Methylation Changes Associated with Prenatal Exposure to Air Pollutants

Third Symposium on Anesthesia and Neurodevelopment in Children *(2012, New York, NY)*
Title: Use of Epigenetic Analyses in Studies of Neurodevelopment

American Academy of Pediatrics Julius B. Richmond Center of Excellence Visiting Lectureship and Grand Rounds *(2012, Baton Rouge, LA)*
Title: Human Epigenetics of Air Pollution

NIEHS Core Centers Meeting: Young Investigator Presentation *(2012, Boston, MA)*
Title: Using Sibling Pairs to Identify PAH-related Methylation Differences

International Society for Environmental Epidemiology *(2011, Barcelona, Spain)*
Title: Prenatal Exposure to PBDEs and Child Behavior at 3-7 Years

12th Annual Brominated and Other Flame Retardants *(2011, Boston, MA)*
Title: PBDE Levels In Children Determined Longitudinally From Birth To Age 9

Dioxin 2010 *(2010, San Antonio, TX)*
Title: Prenatal Exposure to PBDEs and Neurodevelopment

Am. Assoc. of Cancer Research, Future of Molecular Epidemiology *(2010, Miami, FL)*
Title: Using sibling pairs to study the epigenetic effects of prenatal PAH exposure

International Society for Environmental Epidemiology *(2009 Dublin, Ireland)*
Title: Prenatal exposure to polycyclic aromatic hydrocarbons and CpG methylation

International Society for Environmental Epidemiology *(2008 Pasadena, CA)*
Title: Prenatal Exposure to PBDEs and Neurodevelopment

International Society for Environmental Epidemiology *(2007 Mexico City, MX)*
Title: PBDE Exposure, Maternal-Fetal Transfer and Birth Outcomes

American Public Health Association *(2005 Philadelphia, PA)*
Title: State Capacity to Address Non-Communicable Disease Clusters

Dioxin 2005 *(2005 Toronto, ON)*
Title: PCBs and PBDEs and Thyroid Hormone Levels in Umbilical Cord Blood in an Urban U.S. population: A Feasibility Study.

Johns Hopkins Center for a Livable Future Research Day *(2005 Baltimore, MD)*
Title: The Effect of Brominated Flame Retardants (PBDEs) on Thyroid Hormone Status, Birthweight and Gestational Age.

American Industrial Hygiene Association, Chesapeake Section *(2002 Baltimore, MD)*
Title: Respiratory Health of Rubble Removal Workers at the World Trade Center Disaster Site

International Society of Environmental Epidemiology *(2002 Vancouver, BC)*
Title: Respiratory Health of Rubble Removal Workers at the World Trade Center Disaster Site

Title: Comparison of Exposure Surrogates for Predicting Health Status among Rubble Removal Workers at the WTC Disaster Site.

RESEARCH INTERESTS:
Perinatal and developmental epidemiology, health effects of endocrine disrupting chemicals, neurodevelopment, environmental public health surveillance, cancer, and children's health

PEER-REVIEWED PUBLICATIONS:
Barr RG, **Herbstman J**, Speizer FE, Camargo CA Jr. Validation of self-reported chronic obstructive pulmonary disease in a cohort study of nurses. American Journal of Epidemiology. 2002 May 15;155(10):965-71. [PMID: 11994237]

Garcia-Closas M, **Herbstman J**, Schiffman M, Glass A, Dorgan JF. Relationship between serum hormone concentrations, reproductive history, alcohol consumption and genetic polymorphisms in pre-menopausal women. International Journal of Cancer. 2002 Nov 10;102(2):172-8. [PMID: 12385014]

Landrigan PJ, Lioy PJ, Thurston G, Berkowitz G, Chen LC, Chillrud SN, Gavett SH, Georgopoulos PG, Geyh AS, Levin S, Perera F, Rappaport SM, Small C; **NIEHS World Trade Center Working Group**. Health and environmental consequences of the World Trade Center disaster. Environmental Health Perspectives. 2004 May;112(6):731-9. [PMID: 15121517]

Herbstman J, Frank R, Schwab M, Williams DL, Samet J, Breysse P and Geyh A Respiratory effects of inhalation exposure among workers during the clean-up effort at the World Trade Center disaster site. Environmental Research. 2005 September; 99(1):85-92. [PMID: 16053932]

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Breysse P, Williams, DL, **Herbstman J**, Symons JM, Chillrud, S, Ross J, Henshaw S, Rees K, Watson M, Geyh A. Asbestos Exposures to Truck Drivers During World Trade Center Clean-Up Operations. Journal of Occupational and Environmental Hygiene. 2005 August;2(8):400-5. [PMID: 16009648]

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Perera FP and **Herbstman JB**. Emerging technology in molecular epidemiology: what epidemiologists need to know. Epidemiology, 2008 Mar;19(2):350-2. [PMID: 18277170]

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Wells EM, Jarrett JM, Lin YH, Caldwell KL, Hibbeln JR, Apelberg BJ, **Herbstman J**, et al. Body burdens and descriptors of mercury, lead, selenium and copper among Baltimore newborns, Environmental Research. 2011 Apr;111(3):411-7. [PMID: 21277575]

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Herbstman JB, Wang S, Perera FP, Lederman SA, Vishnevetsky J, Rundle AG, Hoepner LA, Qu L, Tang D. Predictors and consequences of global DNA methylation in cord blood and at three years. PLoS One. 2013 Sep 4;8(9). [PMID: 24023780]

Abid Z, Roy A, **Herbstman JB,** Ettinger AS. Urinary Polycyclic Aromatic Hydrocarbon Metabolites and Attention Deficit/Hyperactivity Disorder, Learning Disability, and Special Education in U.S. children Aged 6-15. J Environ Public Health. 2014; 2014:628508. [PMID: 24624143]

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Wells EM, Navas-Acien A, Apelberg BJ, **Herbstman JB**, Jarrett JM, Lin YH, Verdon CP, Ward C, Caldwell KL, Hibbeln JR, Halden RU, Witter FR, Goldman LR. Association of selenium and copper with lipids in umbilical cord blood. Journal of Developmental Origins of Health and Disease. 2014 Aug; 5(4):281-7.

Perera FP, Chang HW, Tang D, Roen EL, **Herbstman J**, Margolis A, Huang TJ, Miller RL, Wang S, Rauh V. Early-life exposure to polycyclic aromatic hydrocarbons and ADHD behavior problems. PLoS One. 2014 Nov 5;9 (11).

Hansmeier N, Chao TC, **Herbstman JB**, Goldman LR, Witter FR, Halden RU. Elucidating the Molecular Basis of Adverse Health Effects from Exposure to Anthropogenic Polyfluorinated Compounds Using Toxicoproteomic Approaches. J Proteome Res. 2014 Nov 11 *(in press)*.

Kundakovic M, Gudsnuk K, **Herbstman JB**, Tang D, Perera FP, Champagne FA. DNA methylation of BDNF as a biomarker of early-life adversity. Proc Natl Acad Sci USA. 2014 Nov 10 *(in press)*.

BOOK CHAPTERS:

Miller RL and **Herbstman JB**. Epigenetic mechanisms in asthma, In: Epigenetics Nutrition and Environmental Health. Wiley Publishers, 2009.

PEER-REVIEW ACTIVITIES: MANUSCRIPT REVIEWER

Chemosphere, Environmental Research, Environmental Health Perspectives, Environmental Science and Technology, Ecotoxicology and Environmental Safety, Environment International, Environmental Health, Pediatrics, Journal of Hazardous Materials, Emerging Health Threats, PLoS ONE, American Journal of Epidemiology, Epidemiology, PLoS Genetics, New England Journal of Medicine, Environmental and Molecular Mutagenesis, Epigenetics, Nature Communications.

Exhibit H

Statement of Susan Kasper

UNIVERSITY OF Cincinnati

Department of Environmental Health
University of Cincinnati
PO Box 670056
Cincinnati, OH 45267-0056

Kettering
160 Panzeca Way
Cincinnati, OH 45267-0056
513-558-5701

October 7, 2014

I, Susan Kasper, am writing this statement in support of the Petition to the CPSC to ban certain household products containing additive monomer organohalogen flame retardants.

1. I, Susan Kasper PhD, am an Associate Professor in the Department of Environmental Health at the University of Cincinnati, College of Medicine. I have a Ph.D. and a M.Sc. in Physiology/Endocrinology from the University of Manitoba, Canada. Please see my CV and list of publications attached.

2. Research in my laboratory has focused on the mechanisms by which cancers develop and progress to become therapy resistant. This includes the role of chemicals such as organohalogen flame retardants on cancer progression. Many organohalogen flame retardants are Persistent Organic Pollutants (POPs), indicating that they are resistant to degradation and capable of remaining in the environment for many years. Furthermore, they are readily absorbed in the food chain and stored in fatty tissues[1]. Most Americans, when tested, were found to have trace levels of flame retardants in multiple tissues, including adipose, liver, muscle, skin and blood[2]. Importantly, organohalogen flame retardants can interfere with normal hormonal function in that they act as "endocrine disrupting chemicals" (EDCs) to either mimic or inhibit the action of naturally occurring hormones[3,4]. Exposure to organohalogen flame retardants has been linked to developmental defects, altered neurologic function, infertility, and cancer (reviewed in Kopras et al., 2014)[5]. Indeed, exposures to EDCs during the critical time of growth and development can result in genetic modifications that are passed down to subsequent generations[6].

3. For the past few years, we have studied the endocrine disrupting activities of Firemaster® 550 (FM 550), a new-generation flame-retardant mixture and previously the second most commonly detected flame retardant in polyurethane foam in the United States[7]. FM 550 might now be the most commonly used flame retardant in polyurethane foam since the previously most common compound, TDCPP, has been listed as a carcinogen under California Proposition 65 and is therefore slowly being phased out.

4. FM 550 is a mixture of two organohalogens (2-ethylhexyl-2,3,4,5-tetrabromobenzoate or TBB and bis(2-ethylhezyl)-2,3,4,5-tetrabromophthalate or TBPH) and organophosphates (isotpropylated triphenylphosphate isomers or ITPs, and triphenyl phosphate or TPP). The organohalogen components TBB and TBPH have been found in indoor dust, outdoor air, marine mammal tissues, wastewater and sewage sludge[8,9,10,11,12,13,14]. Stapleton and coworkers determined that exposure to FM 550 components could be measured in tissues of pregnant rat dams and offspring. In pregnant dams, TBB increased serum thyroxine levels and reduced

hepatic carboxylesterase activity; in offspring, exposure to FM 550 in the mother's milk resulted in male cardiac hypertrophy, advanced female puberty, significant weight gain in both males and females, and altered exploratory behaviors[15,16]. These results demonstrate for the first time that at environmentally relevant levels, FM 550 affects multiple biological processes, including organ development and function, weight gain, and behavior.

5. In our lab we are studying the effects of FM 550 on prostate cancer stem cells (CSC). Prostate CSCs comprise less than 0.1% of the total number of tumor cells, but they are central to promoting tumor growth, metastasis, and the emergence of treatment-resistant disease[17,18]. Using prostate CSC-like cells derived from human patient biopsy specimens, our initial findings imply that three FM 550 components, namely ITP, TBPH and TBB, are capable of stimulating the rapid expansion of prostate cancer stem cells. Moreover, this response is similar to that observed in CSC-like cells treated with the antiandrogens Casodex and hydroxyflutamide. Therefore, FM 550 could act as an endocrine disrupting chemical to promote the expansion of CSCs. Since prostate CSCs are thought to be resistant to androgen deprivation therapy, expansion of this cell type by FM 550 activity could promote resistance to clinical treatment.

6. The observation that FM 550 exerts anti-androgenic-like activity in prostate cancer implies a high probability that FM 550 will also exert its anti-androgenic effects on non-cancerous processes. These include the development and function of the male reproductive system (prostate, seminal vesicles, penis, testes, epididymis), spermatogenesis, and male fertility[19] as well as normal ovary development in females[20].

7. The available data on organohalogen flame retardants indicates a high likelihood that other yet unstudied members of this class of chemicals are also endocrine disruptors, which means they can impair normal cell development, and thus cause substantial personal injury or substantial illness. Therefore, I support this petition to the CPSC to ban consumer products containing organohalogen flame retardants in additive form, where there is a high risk of human exposure.

Yours sincerely,

S. Kasper

Susan Kasper, Ph.D.
Associate Professor,
Environmental Health,
University of Cincinnati College of Medicine

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[14] Ali N, Harrad S, Goosey E, Neels H, Covaci A. "Novel" brominated flame retardants in Belgian and UK indoor dust: implications for human exposure. Chemosphere 2012;83:1360-5.

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CURRICULUM VITAE

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BIRTH PLACE: Winnipeg, MB, Canada

EDUCATIONAL BACKGROUND:

1972-74; 1976-78	B. Sc. Honours in Zoology University of Manitoba, Winnipeg, Manitoba, Canada
1974 – 75	Department of Forestry University of British Columbia, Vancouver, BC, Canada
1975 – 76	Bodenseehof School, Friedrichshafen, Germany
1978 – 81	M. Sc. in Physiology/Endocrinology Department of Physiology, Faculty of Medicine University of Manitoba, Winnipeg, Manitoba, Canada
1981 – 84	Ph.D. in Physiology/Endocrinology Department of Physiology, Faculty of Medicine University of Manitoba, Winnipeg, Manitoba, Canada
1984 – 86	Ph.D. Fellow Department of Physiology, Faculty of Medicine University of Manitoba, Winnipeg, Manitoba, Canada
1986-87	Postgraduate: Medical Research Council of Canada Postdoctoral Fellow Dana Farber Cancer Institute, Harvard Medical School, Boston, MA.
1987-89	Postgraduate: Medical Research Council of Canada Postdoctoral Fellow Department of Molecular Medicine, New England Medical Center Hospitals, Boston, MA.

ACADEMIC AND PROFESSIONAL POSITIONS:

2008-present	Associate Professor (tenured), Department of Environmental Health, College of Medicine, University of Cincinnati, Cincinnati, OH.
2001-08	Assistant Professor (tenure track), Department of Urologic Surgery, Vanderbilt University Medical Center, Nashville, TN.
2001-08	Assistant Professor, cross-appointment in the Department of Cancer Biology.

2001-08 Assistant Professor, cross-appointment in the Department of Cell and Developmental Biology

2001-08 Member, Vanderbilt Ingram Cancer Center

1996-01 Research Assistant Professor (non-tenured), Department of Urologic Surgery, Vanderbilt University Medical Center, Nashville, TN.

1989-96 Research Associate, Department of Physiology, University of Manitoba, Winnipeg, MB, Canada.

AWARDS:

2014 *Endocrinology* Outstanding Reviewer Award
2000 American Urological Association Gallery Best Poster Award
1998 Society for Basic Urologic Research Travel Award
1997 Society for Basic Urologic Research Travel Award
1997 Stowell-Orbison Award, USCAP Best Poster
1996 CaP CURE Award, *Co-Investigator* (PI: RJ Matusik RJ), "Progression of Prostate Cancer to Androgen Dependence: The Role of the Androgen Receptor and Tumour-Derived Transcription Factors." [1 of only 2 awarded in Canada]
1996 American Urological Association Gallery Best Poster Award
1995 American Urological Association Gallery Best Poster Award
1993 Society for Basic Urologic Research Award (for Outstanding Science)
1986-88 Medical Research Council of Canada Postdoctoral Fellowship Award
1985 Drewry Memorial Scholarship and Medal for best Ph.D. dissertation in the Academic Year of 1985, Faculty of Medicine, Univ. of Manitoba

PATENTS/LICENSES:

2007 HPET cancer stem cell lines (licensed to Pfizer Global Research and Development, La Jolla laboratories, San Diego, CA).

GRANTS:

Active:

2013-2018 National Institutes of Health, NCI, *Co-Investigator* (PI: Gail Prins) "Estrogen Receptors in Human Prostate Stem-Progenitor Cells", R01 CA172220

2014-2015 CEG Pilot Projects Program 2014, *Principal Investigator*, "Exposure to Flame Retardants and Prostate Cancer".

Pending Support

2014-2019 National Institutes of Health, *Co-Investigator* (PI: Susan Waltz), "The HGGL:Ron receptor tandem in prostate cancer".

2015-2020 National Institutes of Health, *Principal Investigator,* "Inertial Microfluidics for Isolating Clinically Predictive Circulating Tumor Cells".

2015-2020 Department of Defense, Synergistic Idea Development Award application, *Principle Investigator*, "Circulating tumor cell subpopulations in early stages of prostate cancer progression".

Completed:

2009-13	Department of Defense Prostate Cancer Research Program, *Principal Investigator*, "DJ-1 in the Development of Hormone Refractory Prostate Cancer", W81XWH-08-1-0370.
2009-13	Department of Defense Prostate Cancer Research Program, *Principal Investigator*, "The Function of AR-Negative Cancer Stem Cells in Prostate Cancer", W81XWH-08-1-0662.
2003-11	National Institutes of Health, NIDDK, *Principal Investigator*, "Development of Androgen-Independent Prostate Cancer", DK060957
2004-09	National Institutes of Health, NCI, *Co-Investigator* (PI: RJ Matusik), "A Transgenic Mouse Model for Prostate Cancer", CA076142-08
2003-08	National Institutes of Health, NIDDK, *Co-Investigator* (PI: RJ Matusik), "Control of Prostate-Specific Gene Expression DK055748-06
2003- 04	Vanderbilt Ingram Cancer Center, *Co-Investigator* (PI: RJ Matusik), "PPG Pilot Project on Prostate Cancer"
2002-07	National Institutes of Health, NIDDK, *Principal Investigator*, "Developmental Biology of the Normal Mouse Prostate", DK059142
2000-03	Department of Defense, *Co-Investigator* (PI: RJ Matusik RJ), "Growth Inhibitory and Stimulatory Signals in Prostate Cancer", DAMD 17-00-1-0105
1999-04	National Institutes of Health, NCI, *Co-Investigator* (PI: RJ Coffey), "Mouse Cancer Models Via TGFβ RII Loss", 5U01 CA84239
1997-98	NCI Cancer Center Support Grant, *Principal Investigator*, "Progression of Prostate Cancer to Androgen Independence: a Role for the Androgen Receptor, IP30 CA68485
1996-97	National Institutes of Health, NIDDK, *Principal Investigator* (Director: MC Orgebin-Crist), "Peptide Growth Factors in Male Genitourinary Development", HD05797-25

PROFESSIONAL SOCIETY MEMBERSHIPS:
American Association for the Advancement of the Sciences, American Society of Cell Biology, American Urological Association, the Endocrine Society, Society for Basic Urologic Research, Vanderbilt Urology Society.

COMMITTEE SERVICE:

EXTRAMURAL (National and International):

2014-present	Member, Planning Committee, Fall 2015 meeting, Society for Basic Urologic Research
2014	*Chair*, Abstract Committee, 2014 Fall Meeting, Society for Basic Urologic Research
2014-present	Member, Planning Committee, Spring 2015 meeting, Society for Basic Urologic Research
2010-11	Organizing Committee, World Congress Urological Research, Innsbruck, Austria, September 15-17, 2011
2010-11	Advisory Board, Gordon Research Conference on Hormone Action in Development and Cancer, Bryant University, Smithfield, RI, July 31-August 5, 2011
2011	Endocrine Society, Annual Meeting 2011, Abstracts Review Committee

2009-10	Organizing Committee, Fall Meeting, Society for Basic Urologic Research, Atlanta, GE, November 11-14, 2010
2008-09	Advisory Board, Gordon Research Conference on Hormone Action in Development and Cancer, Holderness School, Holderness, NH, July 26-31, 2009 2008 American Urology Association Conference, Abstracts Review Committee
2007-09	*Chair*, ByLaws Committee, Society for Basic Urologic Research
2004-07	*Chair*, Membership Committee, Society for Basic Urologic Research
2001-03	Executive Board, Society for Basic Urologic Research
1997-2008	Nashville Symphony Chorus, Soprano II
1995-96	*Chair*, Eden Health Care Services
1994	Vice Chair, Eden Health Care Services
1993	Secretary, Eden Mental Health Centre Hospital Board
1990-96	Board of Directors, Eden Health Care Services including Eden Mental Health Centre Hospital, Linden Place, Recovery of Hope counseling services, Enns Court Supported Housing Apartments, Segue Vocational Program.

INTRAMURAL:

2014-15	*Coordinator*, Department of Environmental Health Wednesday Seminar Series; Fall and Spring series.
2012-present	Appointment, Reappointment, Promotion, and Tenure (ARPT) committee, Dept. of Environmental Health, UC
2012	Department of Environmental Health Wednesday Seminar spring series; co-organizer
2011-present	Institutional Biosafety Committee, University of Cincinnati
2005-08	Executive Committee, HBCU Partnership grant, Department of Defense, Prostate Cancer Research Grant, Vanderbilt and Meharry Universities
2005-08	Institutional Biosafety Committee, Vanderbilt University
2004-08	American Cancer Society Pilot Project Review Committee, Vanderbilt Ingram Cancer Center
2003	The Pilot and Feasibility Committee of the Vanderbilt Diabetes Center
2000-08	The Vanderbilt Prostate Cancer Center, Member
1998-01	Institutional Animal Care and Use Committee, Vanderbilt University

PROFESSIONAL SERVICE and ACTIVITIES:

Journal Reviewer (*ad Hoc*): *American Journal of Pathology; Cancer; Cancer Letters; Cancer Research; Cancer Epidemiology Biomarkers and Prevention; Carcinogenesis; Cell Death and Differentiation; Clinical Cancer Research; Current Gene Therapy; Developmental Biology; Differentiation; Endocrine-Related Cancer, Endocrinology; Endocrine-Related Cancer; Future Oncology; Gynecologic Oncology; Histology and Histopathology; International Journal of Cancer; Investigative Urology; Journal of Biological Chemistry; Journal of Mass Spectrometry; The Journal of Steroid Biochemistry and Molecular Biology; Journal of Urology; Molecular Biology of the Cell; Molecular Cancer, Molecular Cancer Therapeutics; Molecular Carcinogenesis; Molecular and Cellular Biology; Molecular Endocrinology; Nature; Nature Communications; Nature Medicine; Nature Reviews Urology; Oncogene; PLOS ONE; Reproductive Toxicology; Science; Stem Cells; Stem Cell Reviews; Steroid Biochemistry & Molecular Biology; The Prostate; Translational Andrology and Urology; Transgenic Research; Urology; Urologic Oncology: Seminars and Original Investigations*

Editorial Boards:

2012-present *Endocrinology*
2012-present *The Prostate*

Grant Review Panels and Study Sections:

2014	NCI Omnibus (R03 and R21) SEP ZCA1 SRB-V(O1) (June 26-27)
2013	Prostate Cancer UK, Pilot Award, PA13-028 (August 27; external reviewer)
2013	Innovative Molecular Analysis Technologies, IMAT (August, *ad hoc*)
2013	NCI Review Meeting, Molecular Analysis Technologies, RFA-CA-13-002 (July, *ad hoc*)
2013	Prostate Cancer UK (Spring; external reviewer)
2013	Innovative Molecular Analysis Technologies, IMAT (February, *ad hoc*)
2012	Austrian Science Fund, Vienna, Austria, Biological and Medical Sciences (October)
2011	NCI, RFA-CA-11-010, "Cancer Target Discovery and Development (CTDD) Network (U01) (November, *ad hoc*)
2011	Innovative Molecular Analysis Technologies, IMAT (March, *ad hoc*)
2010	Department of Defense, PCRP PRE-END peer review panel (April 8)
2009	Innovative Molecular Analysis Technologies, IMAT (November, *ad hoc*)
2009	ARRA Grand Opportunities Grant Review, NCI Molecular Target Discovery and Development Centers Pilot Program (August, *ad hoc*)
2009	Innovative Molecular Analysis Technologies, IMAT (June, *ad hoc*)
2009	American Cancer Society Ohio Division Supported Research (May, *ad hoc*)
2009	Innovative Molecular Analysis Technologies, IMAT (March, *ad hoc*)
2009	British Prostate Cancer Charity (January)
2008	British Prostate Cancer Charity (January)
2007	Department of Defense, Prostate Cancer Research Program PCT-1
2007	Israel Science Foundation, Life Sciences & Medicine
2006	Molecular Oncogenesis Study Section (*ad hoc*)
2006	North Carolina Biotechnology Center Multidisciplinary Research Grants Program
2005-07	Molecular, Cellular, and Developmental Neuroscience Study Section
2005	NIH Special Emphasis Panel: Cell Selective Research Tools and Methods for Studies of the Genitourinary Tract (June)
2005	Australian NHMRC Grant Review Panel 3A, Endocrinology and Reproduction
2004	NIH Special Emphasis Panel: Cell Selective Research Tools and Methods for Studies of the Genitourinary Tract (October).
2004	Urologic and Kidney Development and Genitourinary Disease Study Section (October, *ad hoc*)
2004	Renal and Urological Sciences Integrated Review Group, (October, *ad hoc*)
2004	NIH Special Emphasis Panel: Cell Selective Research Tools and Methods for Studies of the Genitourinary Tract (June)
2004	Urologic and Kidney Development and Genitourinary Disease Study Section (June, *ad hoc*)
2004	Renal and Urological Sciences Integrated Review Group (June, *ad hoc*)
2004	Department of Defense, Clinical and Experimental Therapeutics # 3
2004	Urologic and Kidney Development and Genitourinary Disease Study Section (March, *ad hoc*)
2004	Renal and Urological Sciences Integrated Review Group (March, *ad hoc*)
2003	Endocrinology Study Section (*ad hoc*)
2003	Reproductive Endocrinology Study Section (October, *ad hoc*)
2003	Reproductive Endocrinology Study Section (June, *ad hoc*)
2003	NIDDK Special Emphasis Panel: Androgen Receptor and Prostate Cancer
2003	Department of Defense, Clinical and Experimental Therapeutics # 3.
2002	Urologic and Kidney Development and Genitourinary Disease Study Section (*ad hoc*)
2002	Renal and Urological Sciences Integrated Review Group (*ad hoc*)
2001	Department of Defense, Cell Biology # 3

1999	Department of Defense, External Reviewer
1998	Fonds pour la Formation de Cherchers et l'Aide à la Recherche, Canada

Scientific Session/Symposium Moderator:

2011	GRC Hormone Action in Development & Cancer, Hormonal Regulation Of Development & Cancer, Bryant University, Smithfield, RI, July 31, 2011: Keynote Lectures: Hormonal and Dietary Control of Metabolism
2010	Society for Basic Urological Research, Atlanta GA, November 12, 2010: Aging, Obesity, and Co-Morbidities: Immunologic Impacts on Urologic Function
2010	Annual Endocrine Meeting, San Diego CA, June 21, 2010: Tumor and Normal Stem Cells in Breast and Prostate
2010	6th Annual National Symposium on Prostate Cancer, Clark Atlanta University, Atlanta GA, March 16, 2010: Steroid Receptors in Prostate Cancer
2009	GRC Hormone Action in Development & Cancer, Hormonal Regulation Of Development & Cancer, Holderness NH, July 29, 2009: Common Signaling Pathways: Development Pathways Gone Awry in Cancer
2008	Society for Basic Urological Research: Epigenetics and Genitourinary Disorders
2007	DOD Innovative Minds in Prostate Cancer Today (IMPaCT) conference: Stem Cells

TEACHING:

2014	CCHMC/UC: Introduction to Functional Genomics (GNTD8001C and CS7097C in CoM and CEAS; Course Directors: Jarek Meller and Robert Brackenbury). Lecturer – "AR: a key regulator of normal and abnormal prostate growth".
2013	CCHMC/UC: Introduction to Functional Genomics Introduction to Functional Genomics (GNTD8001C and CS7097C in CoM and CEAS; Course Directors: Jarek Meller and Robert Brackenbury). Lecturer – "Estrogen Receptor – Structure and Function".
2013	UC: Environmental Genetics & Molecular Toxicology(EGMT)Course: Lecturer For 2 Courses Sections - Stem cells; Male and Female Reproductive Toxicology.
2011	UC: Environmental Genetics & Molecular Toxicology (EGMT) Course: Course Coordinator
2010	UC: Environmental Genetics & Molecular Toxicology (EGMT) Course: Lecturer- Stem cells.
2009	UC: Environmental Genetics & Molecular Toxicology (EGMT) Course: Lecturer - Stem cells.
2007	VU: Current Topics in Cancer Biology: Cancer and Metastasis: Course Coordinator and Lecturer
1995-96	UM Faculty of Medicine: Medicine I Endocrinology and Metabolism:Lecturer/tutorials
1990-96	UM Course in Medical Physiology: Endocrinology: Lecturer
1979-81	University of Manitoba Special Pre-medical Studies Program: Tutor

LABORATORY TRAINEES AND STUDENT PROGRAMS:

PhD Thesis Supervisor:

2002-07	Jennifer Erin Tillman (Advisor: Susan Kasper, PhD, Dept. of Urologic Surgery, VUMC)
2002-07	Ritwik Ghosh (DOD Predoctoral Training Award recipient) (Advisor: Susan Kasper, PhD, Dept. of Urologic Surgery, VUMC)

Doctoral Dissertation Committee:

2014-present	Nicholas Brown (Advisor: Susan Waltz, PhD, Dept of Cancer and Cell Biology, UC)
2013-present	Logan Fulford (Advisor: Tanya Kalin, MD, PhD, Department of Pediatrics, UC)
2013-present	Evan Frank (Advisor: Jagjit Yadav, PhD, EH Division of Environmental Genetics and Molecular Toxicology, UC)
2013-present	Abby Johnson (Advisor: Susan Waltz, PhD, Dept of Cancer and Cell Biology, UC)
2012-present	Qin Wang (Advisor: Alvaro Puga, PhD, EH Division of Environmental Genetics and Molecular Toxicology, UC)
2011-present	Andrew Paluch (Advisor: Susan Waltz, PhD, Dept of Cancer and Cell Biology, UC)

2010-present	Eunice Varughese (Advisor: Jagjit Yadav, PhD, EH Division of Environmental Genetics and Molecular Toxicology, UC)
2010-present	Nivedita Nivedita (Advisor: Ian Papautsky, PhD, BioMicroSystems Lab, School of Electronic and Computing Systems, UC)
2010-2012	Jian Zhou (Advisor: Ian Papautsky, PhD, BioMicroSystems Lab, School of Electronic and Computing Systems, UC)
2007-09	Maria Abreu, Department of Cancer Biology, VU
2007-09	Jie Wang, Department of Pathology, VU
2005-08	Ashwath Jayagopal, Department of Biomedical Engineering, VU

UC Training Grants/graduate student mentor:

2009-2012	Brian Wortham (graduate student, EH Gene-Environment Interactions Training Program, UC)
2009-2011	Marina Galvez, Ph.D. (EH T32 training program, UC)
2009-2011	Rebekah Karns (graduate student, EH Division of Epidemiology/Biostatistics, UC)

UC Young Faculty Mentor:

2009-present	Tianying Wu, MD, PhD, ScM (Assistant Professor, EH Division of Epidemiology and Biostatistics, UC)

Vanderbilt Integrated Graduate Program Qualifying Exam Committee (IGP):

2008	Carrie Whiting (PhD)
2007	Maria Abreu (PhD)
2006	Jie Wang (PhD)
2004	Yue He (PhD)
2003	Mingfang Ao (PhD)
2002	Ildiko Csiki (MD, PhD)
2002	Li Yang (PhD)

Vanderbilt Initiative for Maximizing Student Diversity (IMSD) Program (Faculty Advisor/Mentor):

2005-2006	Gerren Ector
2002-2006	Tamela Hunt

Vanderbilt Introduction to Biomedical Research Program (Faculty Advisor/Mentor):

2003	Julia Kristina Wood (medical student)

Undergraduate courses/summer training:

2014	Emma Eschker (Niles North High School, Chicago, IL, Susie Posnock, teacher)
2013	Sloane Harris and Meghan Cholak (Walnut Hills High School, Science Project Competition, Renee Mahaffey Harris, Correspondent)
2011-12	Preetom Borah (Sycamore High School, Capstone Project research project, Beth Quinones, Science Teacher)
2011-12	Nicholas Aube (Sycamore High School, Capstone Project research project, Beth Quinones, Science Teacher)
2010	William Hunt (Biology, Summer Undergraduate Research Fellow (SURF), Office of Research and Graduate Education, UC)
2010	James Cross (B. Sc Biology undergraduate student/technician, UC)
2009	James Cross (B. Sc Biology Summer Undergraduate Research Fellow (SURF), Office of Research and Graduate Education, UC)
2009	John Hegman (Biomedical Engineering undergraduate student/technician, UC)
2006	Carrie Johnson (Summer Internship, Belmont University, Nashville, TN)

2005	Carrie Johnson (Summer Internship, Belmont University, Nashville, TN)
2005-2006	Carrie Johnson (Biology Course Project, Belmont University, Nashville, TN)
2004	Sheree Carney (Vanderbilt Minority Summer Research Program)
2003	Ashwin Sastry (Undergraduate summer student)
2002	Yash A. Choksi (Undergraduate summer student)

Postdoctoral Fellows:

2010-12	Premkumar Vummidi Giridhar, PhD
2007-08	Seungchan Yang, PhD
2006-08	Mohammed Atiqur Rahman, PhD
2005	Shwetank Sharma, PhD
2004	Zhang Han PhD
2003-07	Guangyu Gu, MD
2001-03	Tiina Pikänen-Arsiola, PhD

Research Scientists:

2009-2013	Karin Williams, PhD

Other Trainees:

2013	Veena Potluri, MD
2013-2014	Mei-Ling Bermudez (PhD rotation student)
2014	Andrew Vonhandorf (PhD rotation student)

Research Residents:

2008	Michelle E. Koski, MD

Medical Students:

2013	Karan Motiani, Department of Urology, UC. Research rotation. [Dr. Motiani's abstract was the only submissions from the UC Departments of Urology and Environmental Health accepted. Importantly, it was selected for a prestigious podium presentation for research excellence.]
2007-2011	Thesis Advisor, Thomas Reinhold MD, Universität Witten/Herdecke Witten, Germany [Dr. Reinhold's thesis earned him a *cum laude* degree]
2006-07	Thomas Reinhold (Universität Witten / Herdecke Witten, Germany: Medical Student rotation)

Research Awards to Trainees:

2011-2012 I served as project director and mentor to a team of two Sycamore High School students, Preetom (Ruku) Borah and Nicholas Aube, on their Capstone research Project research.
- Ruku and Nick won a "Superior" rating for their Capstone Research Project, "IGF-1 and its Effects on Human Breast Cancer Cells" at Sycamore High School.
- They were winners in the Southwest Ohio District Science & Engineering Expo competition held at UC on Saturday, March 10, 2012.
- At the OH State Science Fair on Saturday, May 5, 2012, they won a "Superior" rating with a perfect score of 50/50 from both judges. They also won the following awards for their research on: "IGF-1 and its Effects on Human Breast Cancer Cells":
1) Interdisciplinary Research Award, sponsored by Sigma Xi Scientific Research Society,
2) Veterinary Medicine Award, sponsored by the Ohio Veterinary Medical Association,
3) University of Akron Scholarship.

2006 Jennifer Erin Tillman, PhD student, Travel Award, Society for Basic Urologic Research

2006 Ritwik Ghosh, PhD student, DOD Predoctoral Training Award

2005 Guangyu Gu, MD, Travel Award, Society for Basic Urologic Research
2003 Tiina Pikänen-Arsiola, PhD, Travel Award, Society for Basic Urologic Research

INVITED LECTURES:

National and International Meetings:

Clark Atlanta University 10th Annual National Symposium on Prostate Cancer, Atlanta GA, March 17, 2014: "Inhibition of Stathmin1 Accelerates the Metastatic Process".

The 10th World Congress on Urological Research, Society for Basic Urologic Research Fall Symposium, Nashville TN, November 21-24, 2013 (substitute speaker for Dr. Gail Prins who could not attend), Plenary Session IV: Stem Cells are Part of the Urologic Tissue Heterogeneity and Therapeutic Solutions: "Cancer Stem Cell Self-renewal and Differentiation".

Underwriters Laboratories – Flame Retardants and Health Summit/Furniture Flammability and Human Health, Atlanta GA, April 16, 2013: "Flame Retardants as Endocrine Disrupting Chemicals that Promote Prostate Cancer".

Clark Atlanta University 9th Annual National Symposium on Prostate Cancer, Atlanta, GA, March 19, 2013: "Mechanisms Which Preserve the Prostate Cancer Stem Cell Phenotype".

Endocrine Society Annual Meeting, Houston, TX, June 23, 2012: "Notch-Androgen Receptor Axis in Prostate Cancer Stem Cells".

Clark Atlanta University 8th Annual National Symposium on Prostate Cancer, Atlanta, GA, March 19, 2012: "Cancer Stem Cell Strategies for Promoting Androgen Resistance".

Society for Basic Urologic Research Fall Symposium, Las Vegas, NE, November 10-13, 2011, Session: Genetic, Epigenetic and Stem Cell Determinants of Development and Disease. "Stem Cell Strategies for Escaping Differentiation".

American Society of Andrology 34th Annual Meeting, Philadelphia, PA, April 5, 2009: "Prostate Stem Cells: Friend or Foe".

Clark Atlanta University 5th Annual National Symposium on Prostate Cancer, Atlanta, GA, March 17, 2009: "Androgen Receptor Function in Hormone-Sensitive and Castrate-Resistant Prostate Cancer

Reproductive Tract Biology Gordon Research Conference (GRC), Andover, NH, August 3-8, 2008: "Regeneration of Human Prostate Tumors from Prostate Cells with Cancer Stem Cell Characteristics".

Endocrine Society Annual Meeting, San Francisco, CA, June 16, 2008: "Stem Cells in Prostate Cancer Initiation & Progression".

Prostate Cancer Research Foundation Forum (United Kingdom), Toronto, Ontario, Canada, June 13, 2008: "Isolation and characterization of cancer stem cells from human prostate tissues".

Society for Basic Urological Research Spring Session, Orlando, FL, May 17, 2008: "Prostate Cancer and Cancer Stem Cells".

Gordon Research Conference on Hormone Action in Development & Cancer, New London, NH, July 15-20, 2007: "Regeneration of Human Prostate Tumors from Prostate Cells with Cancer Stem Cell Characteristics".

Clark Atlanta University 2nd Annual National Symposium on Prostate Cancer, Atlanta, GA, March 31, 2006: "Cancer Stem Cells and the Androgen Receptor in Prostate Cancer".

American Urological Association, Research Conference, Houston, TX, August 1, 1999: "BPH Animal Models - An Overview".

Roswell Park Cancer Institute Workshop: Prostate Cancer, Prouts Neck, ME, October 24, 1999.

Society for Basic Urologic Research/ European Society for Urologic Oncology and Endocrinology Joint Symposium, The Second World Congress on Urological Research, Pacific Grove, CA, December 10-14, 1997: "Gene Therapy Vectors for Prostate Cancer."

Visiting Professor Lectureships:

Green Science Policy Flame Retardant Dilemma Symposium, San Francisco CA, February 14, 2014: "Do Flame Retardants Impact Men's Hormones?"

Prostate Cancer Foundation, 1250 Fourth Street Santa Monica, CA 90401, August 31, 2012. "Inhibition of Stathmin1 Accelerates the Metastatic Process"

Clark Atlanta University CCRTD/RCMI Program, November 10, 2010: "Mechanisms Required to Maintain Epithelial Cell Architecture and Function."

East Tennessee State University, Department of Biochemistry, Johnson City, TN, October 20, 2009: "Beating the Androgen Receptor at Its Own Game".

University of Illinois at Chicago Cancer Center, Chicago, IL, June 17, 2009: "Cancer Stem Cells – Disrupting the Status Quo".

University of Manitoba, Department of Physiology, Winnipeg, MB, Canada, May 7, 2009: "The Androgen Receptor, Cancer Stem Cells and Prostate Tumorigenesis".

Kimmel Cancer Center, Department of Cancer Biology, Philadelphia, PA, October 23, 2008: "In search of the Prostate Stem Cell".

University of Rochester, Department of Pathology, Rochester, NY, August 27, 2008: "Dissecting Androgen Receptor Function in the Prostate".

University of Cincinnati, Department of Environmental Health, Kettering Lab Complex, Cincinnati, OH, July 10, 2008: "Ideas Stemming from Primary Prostate Cell Culture".

Pfizer Global Research and Development, La Jolla laboratories, San Diego, CA, June 18, 2008: "Ideas Stemming from Primary Cell Culture".

University of Cincinnati, Department of Environmental Health, Kettering Lab Complex, Cincinnati, OH, April 23, 2008: "Stem Cells – the Root of Prostate Cancer?"

Boston Medical Center, Section of Endocrinology, Diabetes & Nutrition, Boston, MA, February 12, 2008: "Androgen Receptor Functions in Prostate Development and Disease."

John Hopkins University, Department of Urology, Baltimore, MD, January 17, 2008: "Stem Cells: the Key to Prostate Cancer?"

University of Miami Seminar Series, Miami, FL, December 1, 2005: "Mechanisms Leading to the Development of Hormone Resistant Prostate Cancer".
Wake Forest University Medical Center, Department of Cancer Biology, Winston-Salem, NC, August 15, 2005: "Prostate Tumorigenesis: Insights from Androgen Receptor Studies and Primary Cell Culture Models".

University of Massachusetts Medical School, Department of Surgery/Urology Research, Worcester MA, May 10, 2005: "Development of Androgen-Independent Prostate Cancer".

The University of Texas Health Science Center at San Antonio, Institute of Biotechnology, Department of Molecular Medicine, San Antonio, TX, September 7, 2004: "Prostate Cancer Progression: Escaping Androgen Control".

University of South Florida, College of Medicine, Department of Pathology, Tampa, FL, June 1, 2001: "Modeling Prostate Cancer in LPB-Tag mice: a Lady's Perspective".

University of Massachusetts Medical School, Department of Surgery, Worcester, MA, November 8, 1999.

Tufts University, Department of Biology, Boston, MA, November 9, 1998.

Eastern Virginia Medical School, Department of Microbiology and Immunology, Norfolk, VA, June 19, 1998.

New England Medical Center and Tufts University School of Medicine, Division of Endocrinology, Diabetes, Metabolism and Molecular Medicine, Boston, MA, November 3, 1998.

UC Lectureships:

Cincinnati Prostate Cancer Information Group, Feb 27, 2013: "How do prostate cancer cells become metastatic and why do they migrate to bone?"

GEITP Seminar Series, Jan 15, 2013: "Inhibition of Stathmin1 Accelerates the Metastatic Process".

UC Chemical Engineering Program, Graduate Seminar Series, October 12, 2013: "Separating Fragile Prostate Cancer Stem Cells and Circulating Tumor Cells".

Division of Urology, Urology Oncology Meeting, May 11, 2012: "Stem Cell/CSC Strategies for Promoting Androgen Resistance".

GEITP Seminar Series, February 7, 2012: "Confocal Microscopy".

Division of Urology, Urology Oncology Meeting, April 15, 2011: "Cancer stem cells: Why are they clinically important?"

Cincinnati Children's Hospital Medical Center, Endoderm Club, April 5, 2011: "Using Cancer Stem Cells to Map Normal Prostate Development".

Division of Urology, Urology Oncology Meeting, April 14, 2009: "Androgen Receptor and Prostate Cancer Stem Cells".

Department of Cancer Cell Biology Seminar Series, March 26, 2009: "The Androgen Receptor, Stem Cells and Prostate Tumorigenesis".

Cincinnati Cancer Consortium Leaders Meeting, March 3. 2009: "Androgen Receptor, Stem Cells and Prostate Cancer".

GEITP Seminar Series, February 24, 2009: "In Search of the Prostate Stem Cell".

Vanderbilt Lectureships:

Center for Stem Cell Biology Seminar, September 11, 2008: "Prostate Stem Cell Models".

Surgical Oncology Research Seminar, April 18, 2008: "Cancer Stem Cells: the Key to Prostate Cancer?"

Signal Transduction and Cell Proliferation Program Seminar, November 15, 2005: "Development of hormonal resistance in prostate cancer: Insights from androgen receptor and primary cell culture studies".

32th Annual Vanderbilt Urology Society Visiting Professorship and Rhamy-Shelley Lecture, November 13, 2003: "Update in Prostate Cancer Research".

Surgical Research Conference, September 13, 2002: "Prostate Cancer Progression: Schemes for Escaping Androgen Control".

Vanderbilt Ingram Cancer Center Cancer, Biology Seminar Series, September 11, 2002: "Molecular Mechanisms of Prostate Cancer Progression."

28th Annual Vanderbilt Urology Society Visiting Professorship and Rhamy-Shelley Lecture, November 11, 1999: ""BPH Animal Models: An Overview".

Surgical Research Conference, April 18, 1997.

Center for Reproductive Biology Research, April 8, 1997.

PUBLICATIONS:

Total Publications: 66; h-Index: 27; Total Citations: 2171; Research Gate (RG) score: 36.54

PEER-REVIEWED JOURNAL ARTICLES:

1. **Kasper S**, Worsley IG, Rowe JM, Shiu RPC, and Friesen HG, 1982. Chondrocyte growth factor from the human pituitary gland. J Biol Chem 257:5226-5230.
2. Rowe JM, **Kasper S**, and Shiu RPC, 1986. Purification and characterization of a human mammary tumor-derived growth factor. Cancer Res 46:1408-1412.
3. **Kasper S**, and Friesen HG, 1986. Human pituitary tissue secretes a potent growth factor for chondrocyte proliferation. J Clin Endocrinol Metab 62:70-76.
4. Fink JS, Verhave M, **Kasper S**, Tsukada T, Mandel G, and Goodman RH, 1989. The CGTCA sequence motif is essential for biological activity of the vasoactive intestinal peptide gene cAMP regulated enhancer. Proc Natl Acad Sci USA 85:6662-6666.

5. **Kasper S**, Popescu RA, Torsello A, Vrontakis ME, Ikejiani C, and Friesen HG, 1992. Tissue-specific regulation of vasoactive intestinal peptide messenger ribonucleic acid levels by estrogen in the rat. Endocrinology 130:1796-1801
6. Leite V, Vrontakis ME, **Kasper S**, and Friesen HG, 1993. Bromocriptine inhibits galanin gene expression in the rat pituitary gland. Mol Cell Neuroscience 4:418-423.
7. **Kasper S**, Rennie PS, Bruchovsky N, Sheppard PC, Cheng H, Lin L, Snoek R, and Matusik RJ, 1994. Cooperative binding of the androgen receptor to two DNA sequences is required for androgen induction of the probasin gene. J Biol Chem 269:31763-31769.
8. Snoek R, Rennie PS, **Kasper S**, Matusik RJ and Bruchovsky N, 1996. Induction of cell-free, *in vitro* transcription by recombinant androgen receptor peptides. J Steroid Biochem Mol Biol 59 (3-4): 243-250.
9. Yan Y, Sheppard PC, **Kasper S**, Lin L, Hoare S, Kapoor A, Dodd JG, Duckworth ML, and Matusik RJ, 1997. Large fragment of the probasin promoter targets high levels of transgene expression to the prostate of transgenic mice. The Prostate 32(2):129-139.
10. Metts JC, Kotkin L, **Kasper S**, Shyr Y, Adams MC, and Brock JW, 1997. Genital malformations and coexistent urinary tract or spinal anomalies in patients with imperforate anus. J Urology 158:1298-1300.
11. Bai G, **Kasper S**, Matusik RJ, Rennie PS, Moshier JA, and Krongrad A, 1998. Androgen regulation of the human ornithine decarboxylase promoter in prostate cancer cells. J of Androl, 19(2): 127-135.
12. Lareyre JJ, Mattei M-G, **Kasper S**, Ong DE, Matusik RJ and Orgebin-Crist M-C, 1998. Genomic organization and chromosomal localization of the murine epididymal retinoic acid binding protein (mE-RABP) gene. Mol Reprod Dev, 50, 387-395.
13. **Kasper S**, Sheppard PC, Yan Y, Pettigrew N, Borowsky AD, Prins GS, Dodd JG, Duckworth ML and Matusik RJ, 1998. Development, progression, and androgen-dependence of prostate tumors in probasin-large T antigen transgenic mice: A model for prostate cancer. Lab Invest 78:i-xv (Erratum, June 1998).
14. Lareyre JJ, Zheng WL, Zhao GQ, **Kasper S**, Newcomer ME, Matusik RJ, Ong DE and Orgebin-Crist MC, 1998. Molecular cloning and hormonal regulation of a murine epididymal retinoic acid-binding protein messenger ribonucleic acid. Endocrinology, 139 (6), 2971-2981.
15. Snoek R, Bruchovsky N, **Kasper S**, Matusik RJ, Gleave M, Sato N, Mawji NR, Rennie PS, 1998. Differential transactivation by the androgen receptor in prostate cancer cells. The Prostate, 36, 256-263.
16. Lareyre JJ, Mattei M-G, **Kasper S**, Newcomer ME, Ong DE, Matusik RJ and Orgebin-Crist M-C, 1998. Structure and putative function of a murine epididymal retinoic acid-binding protein (mE-RABP). J of Reprod Fertil Suppl 53:59-65.
17. Lareyre JJ, Thomas TZ, Zheng W-L, **Kasper S**, Ong DE, Matusik RJ, and Orgebin-Crist M-C, 1999. A 5 kilobase pair promoter fragment of the murine epididymal retinoic acid-binding protein gene drives the tissue-specific, cell-specific, and androgen-regulated expression of a foreign gene in the epididymis of transgenic mice. J Biol Chem 274(12): 8282-8290.
18. **Kasper S**, Rennie PS, Bruchovsky, Lin L, Cheng H, Snoek R, Dahlman-Wright K, Gustafsson J-A, Shiu, RPC, Sheppard PC, Matusik RJ, 1999. Selective activation of the probasin androgen-responsive region by steroid hormones. J Mol Endocrinology 22:313-325.
19. Shappell SB, Boeglin WE, Olson SJ, **Kasper S**, Brash AR, 1999. 15-Lipoxygenase-2 (15-LOX-2) is expressed in benign prostatic epithelium and reduced in prostate adenocarcinoma. Am J Pathol 155(1):235-245.
20. Brash AR, Jisaka M, Boeglin WE, Chang MS, Keeney DS, Nanney LB, **Kasper S**, Matusik RJ, Olson SJ, Shappell S.B, 1999. Investigation of a second 15S-lipoxygenase in humans and its expression in epithelial tissues. Adv Exp Med Biol 469:83-89.
21. Zhang J-F, Thomas TZ, **Kasper S**, Matusik RJ, 2000. A small composite probasin promoter confers high levels of prostate-specific gene expression through regulation by androgens and glucocorticoids *in vitro* and *in vivo*. Endocrinology 141(12):4698-4710.

22. Lareyre J-J, Reid K, Nelson C, **Kasper S**, Rennie PS, Orgebin-Crist M-C, Matusik RJ, 2000. Characterization of an androgen-specific response region within the 5' flanking region of the murine epididymal retinoic acid binding protein gene. Biol Reprod 63:1881-1892.
23. Lareyre J-J, Winfrey VP, **Kasper S**, Ong DE, Matusik RJ, Olson GE, and Orgebin-Crist M-C, 2001. Gene duplication gives rise to a new 17 kDa lipocalin that shows epididymal region-specific expression and testicular factors(s) regulation. Endocrinology 142:1296-1308.
24. Masumori N, Thomas TZ, Chaurand P, Case T, Paul M, **Kasper S**, Caprioli R, Tsukamoto T, Shappell S, Matusik RJ, 2001. A probasin-large T antigen transgenic mouse line develops prostate adenoand neuroendocrine-carcinoma having metastatic potential. Cancer Res 61:2239-2249.
25. Andriani F, Nan B, Ju Y, Li X, Weigel NL, McPhaul MJ, **Kasper S**, Kagawa S, Fang B, Matusik RJ, Denner L, Marcelli M, 2001. The third generation probasin promoter ARR_2PB drives bax overexpression and apoptosis in androgen receptor positive prostate cancer cells in a dihydrotestosterone-dependent way. J Natl Cancer Inst 93:1314-24.
26. Chaurand P, DaGue BB, Ma S, **Kasper S**, Caprioli RM, 2001. Strain-based sequence variations and structure analysis of murine prostate specific spermine binding protein using mass spectrometry. Biochem 40:9725-33.
27. Zhang Y, Yu J,Unni E, Shao TC, Nan B, Snaboon T, **Kasper S**, Andriani F, Denner L, Marcelli M, 2002. Monoand poly-gene therapy for the treatment of experimental prostate cancers by use of apoptotic genes Bax and Bad driven by the prostate-specific promoter ARR2PB. Human Gene Therapy 13:2051-64.
28. Tu WH, Thomas TZ, Masumori N, Bhowmick NA, Gorska AE, Shyr Y, **Kasper S**, Case T, Roberts RL, Shappell SB, Moses HL and Matusik RL, 2003. The loss of TGF-beta signaling promotes prostate cancer metastasis. Neoplasia 5:267-77.
29. Zhang J, Gao N, **Kasper S**, Reid K, Nelson C, Matusik RJ, 2004. An androgen dependent upstream enhancer is essential for high levels of probasin gene expression. Endocrinology 145:134-48.
30. Masumori N, Tsuchiya K, Tu W, Lee C, **Kasper S**, Tsukamoto T, Shappell S, Matusik RJ, 2004. An allograft model of androgen independent prostatic neuroendocrine carcinoma derived from a large probasin promoter-T antigen transgenic mouse line. J Urol 171:439-442.
31. Jin RJ, Wang Y, Masumori N, Ishii K, Tsukamoto T, Shappell SB, Hayward SW, **Kasper S**, Matusik RJ, 2004. NE-10 neuroendocrine cancer promotes the LNCaP xenograft growth in castrated mice. Cancer Res 64:5489-5495.
32. Shao TC, Li H, **Kasper S**, Matusik RJ, Ittmann M, Cunningham GR, 2006. Comparison of the Growth-Promoting Effects of Testosterone and 7-α-Methyl-19-Nor-Testosterone (MENT) on the Prostate and Levator Ani Muscle of LPB-Tag Transgenic Mice. The Prostate, 66(4):369-76.
33. Pitkänen-Arsiola T, Tillman JE, Gu G, Yuan JL, Roberts RL, Wantroba M, Coetzee GA, Cookson MS, and **Kasper S**, 2006. Androgen and Antiandrogen Treatment Modulate Androgen Receptor Activity and DJ-1 Stability. The Prostate 66:1177-93.
34. Wang Y, **Kasper S**, Yuan J, Jin RJ, Zhang J, Ishii K, Wills ML, Hayward SW, Matusik RJ, 2006. Androgen-dependent prostate epithelial cell selection by targeting ARR(2)PBneo to the LPB-Tag model of prostate cancer. Lab Invest. 2006 Oct;86(10):1074-88.
35. Gipp J, Gu G, Crylen C, **Kasper S**, Bushman W, 2007. Hedgehog Pathway Activity in the LADY Prostate Tumor Model. Molecular Cancer 6:19-26.
36. Tillman EJ, Yuan J, Gu G, Fazli L, Ghosh R, Flynt AS, Gleave M, Rennie PS, and **Kasper S**, 2007. DJ-1 binds androgen receptor directly and mediates its activity in hormonally treated prostate cancer cells. Cancer Res 67:4630-4637.
37. Gu G, Yuan J, Wills ML and **Kasper S**, 2007. Prostate cancer cells with stem cell characteristics reconstitute the original human tumor in vivo. Cancer Res, 67:4807-4815.
38. Ghosh R, Gu G, Tillman EJ, Yuan J, Wang YQ, Friedman D, Fazli L, Rennie PS, and **Kasper S**, 2007. Increased expression and differential phosphorylation of stathmin may promote prostate cancer progression. The Prostate 67:1038-1052.

39. Chaurand P, Rahman MA, Hunt T, Mobley JA, Gu G, Caprioli1 RM and **Kasper S**, 2008. Monitoring mouse prostate development by profiling and imaging mass spectrometry. Mol Cell Proteomics 7:411-23.
40. Zhang J-F, Gao N, DeGraff D, Yu X, Sun Q, Case T, **Kasper S**, Matusik, RJ, 2010. Characterization of cis elements of the probasin promoter necessary for prostate-specific expression. Prostate 70:934-51.
41. Liu J, Pascal LE, Isharwal S, Metzger D, Ramos Garcia R, Pilch J, Kasper S, Williams K, Basse PH, Nelson JB, Chambon P, Wang Z, 2011. Regenerated luminal epithelial cells are derived from preexisting luminal epithelial cells in adult mouse prostate. Mol Endocrinol. 25:1849-57.
42. Williams K, Ghosh R, Vummidi Giridhar P, Gu G, Case T, Belcher SM and **Kasper S**, 2012. Inhibition of Stathmin1 Accelerates the Metastatic Process. Cancer Res:72:5407-17. PMID: 22915755
43. Kendig EL, Buesing DR, Christie SM, Cookman CJ, Gear RB, Hugo ER, **Kasper S**, Kendziorski JA, Ungi KR, Williams K, Belcher SM. 2012. Estrogen-like disruptive effects of dietary exposure to bisphenol A or 17α-ethinyl estradiol in CD1 mice. Int J Toxicol 31:537-50. PMID: 23160314
44. Zhou J, Giridhar PV, **Kasper S**, Papautsky I, 2013. Modulation of aspect ratio for complete separation in an inertial microfluidic channel. Lab Chip 13:1919-29. PMID: 23529341
45. Cai Y, Balli D, Ustiyan V, Fulford L, Hiller A, Misetic V, Zhang Y, Paluch AM, Waltz SE, **Kasper S**, Kalin TV, 2013. Foxm1 expression in prostate epithelial cells is essential for prostate carcinogenesis. J Biol Chem. 288:22527-41. PMID: 23775078
46. Zhou J, **Kasper S**, Papautsky I, 2013. Enhanced size-dependent trapping of particles using microvortices. Microfluid Nanofluid 1007/s10404-013-1176-y. PMID: 24187531
47. Zhou J, Vummidi Giridhar P, **Kasper S**, Papautsky I, 2014. Modulation of rotation-induced lift for cell filtration in a low aspect ratio microchannel. Biomicrofluidics 8, 044112; doi: 10.1063/1.4891599.

INVITED REVIEWS/EDITORIALS:

1. **Kasper S**, Matusik RJ: Rat Probasin, 2000. Structure and function of an outlier lipocalin. (Review) Biochim Biophys Acta 18(1-2):249-258.
2. **Kasper S**, Tu W, Roberts RL, Shappell SB, 2003. Transgenic mouse models for prostate cancer: Identification of an androgen-dependent promoter and creation and characterization of the LPB-tag model. Methods Mol Med 81:113-47.
3. **Kasper S** and Smith JA, 2004. Genetically Modified Mice and Their Use in Developing Therapeutic Strategies. J Urol 172:12-19.
4. **Kasper S**, 2005. Survey of Genetically Engineered Mouse Models for Prostate Cancer: Analyzing the Molecular Basis of Prostate Cancer Development, Progression and Metastasis. J Cell Biochem 94:279-297.
5. **Kasper S** and Cookson MS, 2006. Mechanisms leading to the development of hormone resistant prostate cancer. Urologic Clinics of North America 33:201-210.
6. **Kasper S**, 2007. Characterizing the Prostate Stem Cell. J Urol 178:375.
7. **Kasper S**, 2007. Mechanisms that Promote Androgen Receptor-mediated Recurrence of Prostate Cancer. J Urol 178:1288.
8. **Kasper S**, 2008. Stem cells: The Root of Prostate Cancer? J Cell Physiol 216:332-336.
9. **Kasper S**, 2008. Exploring the Origins of the Normal Prostate and Prostate Cancer Stem Cell. Stem Cell Rev 4:193-201.

10. **Kasper S**, 2009. Identification, characterization, and biological relevance of prostate cancer stem cells from clinical specimens. Urol Oncol 27:301-3.
PMID: 19414117

11. Williams K, Motiani K, Vummidi Giridhar P, **Kasper S**, 2013. CD44 integrates signaling in normal stem cell, cancer stem cell and (pre)metastatic niches. Exp Biol Med 238:324-38.
PMID: 23598979

12. Kopras E, Potluri V, Bermudez M-L, Williams K, Belcher S, **Kasper S**, 2014. Actions of endocrine disrupting chemicals on stem/progenitor cells during development and disease. Endocrine Related Cancer, 21:T1-T12. doi: 10.1530/ERC-13-0360.

BOOK CHAPTERS:

1. Friesen HG, Dean HJ, and **Kasper S**, 1985. A perspective on growth hormone and growth. In: Human Growth Hormone (Raiti, S., ed) Pergamon Press, Plenum Publ. Co.
2. **Kasper S**, and Friesen HG, 1986. Growth factors: a selected review. In: Growth Hormone (Tolis G., and Ludecke, D.K. eds) Raven Press, NY.
3. Goodman RH, Verhave M, **Kasper S**, Tsukada T, Mandel G, and Fink JS, 1988. Regulation of expression of the human pre-pro VIP gene. In: Perspectives in Neuroendocrinology. (Wass, J. and Scanlon M., eds.). Springer-Verlag.
4. Cattini PA, Nachtigal MW, Ludwig SM, Klassen ME, **Kasper S**, and Nickel BA, 1992. Implantation and transfection procedure: use of gene transfer to examine expression and regulation of human placental hormone. In: Neuroendocrine Research Methods. (Greenstein, B.D., ed.).
5. Matusik RJ, Masumori M, Thomas TZ, Case T, Paul M, **Kasper S**, Shappell SB, 2000. Transgenic mouse models of prostate cancer. In: Transgenics in Endocrinology, ed. By MM Matzuk, CW Brown, and TR Kumar. The Humana Press Inc. (Totowa, NJ) pp 399-423.
6. Shappell SB., Masumori M, Thomas TZ, Case T, Paul M, **Kasper S**, Matusik RJ, 2004. Transgenic mouse models of prostate carcinoma: Anatomic, Histopathologic, and molecular considerations. In: Prostate Cancer: Scientific and Clinical Aspects of Bridging the Gap, PD Abel and E-N Lalani (eds), Imperial College Press (London), pp 245-319.
7. Williams K, Vummidi Giridhar P, **Kasper S**, 2013. CD44 integrates signaling in stem cell microenvironments. CRC Press, Dittmar T & Zänker KS, Eds. In: Role of Cancer Stem Cells in Cancer Biology and Therapy, pp129-150.

Exhibit I

Statement of Donald Lucas

BERKELEY LAB
ENVIRONMENTAL ENERGY
TECHNOLOGIES DIVISION

Sept. 11, 2014

I, Donald Lucas, am writing this statement in support of the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. I am a scientist at the Lawrence Berkeley National Laboratory (LBNL) and a Professional Researcher in the School of Public Health at the University of California, Berkeley (UCB). I officially retired in 2011, but I continue to perform research in the areas of combustion byproducts at LBNL, UCB, and the Energy and Resources Group at UCB. Before retiring I was a Principal Investigator in the Combustion Group of the Environmental Energy Technologies Division (EETD), and was a Deputy Director for EETD and the Environment, Health, and Safety Division. I am on the Executive Committee for the International Congress on Toxic Combustion Byproducts and their Health Effects, and received their Adel Sarofim Award in 2013. I also serve as a consultant to the Green Science Policy Institute. I received a B.S. in Chemistry from the Illinois Institute of Technology in 1972 and a Ph.D. in Physical Chemistry from the University of California, Berkeley in 1977. I have attached a copy of my curriculum vitae and a list of my scientific publications.

2. Based on my expertise, it is my opinion that, in the case of fires, organohalogen flame retardants used in plastic, foam, fabrics, and other products in residences can lead to the formation of increased amounts of toxic combustion byproducts. It is also my opinion that, as currently used, organohalogen flame retardants do not provide fire safety benefits that justify their use (Talley, 1995; Mehta, 2012; Blais and Carpenter, 2013; Tao, 2005; BEARHFTI, 2002; Babrauskas, 1983; Schuman and Hartzell, 1987). Other experts I collaborate with have described the human and environmental health effects associated with organohalogen flame retardants and their combustion byproducts, so my statements below will be limited to the formation of products of combustion.

3. Organohalogen flame retardants are used in products and assemblies such as electronic enclosures, furniture foam, building insulation, and other items, but they do not make the products flameproof. If a large enough ignition source is involved, flaming combustion of fire-retarded items can occur; for smaller ignition sources, smoldering combustion may happen.

4. Most fire deaths and injuries result from inhalation of smoke containing narcotic/asphyxiant and/or irritant combustion byproducts such as toxic gases and particulates (Hall 2011; Stec and Hull, 2010). These combustion byproducts may be directly toxic or cause such irritation that they impair vision and breathing, ultimately resulting in incapacitation. In addition to the combustion products of immediate concern for survival in a fire, other harmful by-products including halogenated dioxins and furans (generally referred to as dioxins) can cause chronic health effects in those exposed to the fires, contaminate the air, soil, and water long-term, and spread from the

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fire site when burned materials are removed.

5. Though in some sense every fire is different, a few factors most strongly influence toxic product yield. These factors include material composition, such as the presence or absence of organohalogen flame retardants (Stec and Hull, 2010). The incorporation of organohalogen flame retardants into the material composition can increase the generation of combustion byproducts of concern for both acute and chronic fire toxicity, for reasons described in detail below.

6. Fire effluents from the combustion of materials containing organohalogen flame retardants can be **more acutely toxic** for the following reasons:

i. Greater amounts of irritant gases, such as hydrogen chloride (HCl) or hydrogen bromide (HBr) combustion products, and particulate matter of varying size and toxicity can be produced (Stec and Hull, 2010). In fact, these irritant gases are the active fire retardant species, which act by preventing the complete oxidation of the fuel to carbon dioxide and water. HCl and HBr can cause incapacitation, reducing ability to escape a fire. If inhaled, these can also penetrate deep into the lung and injure tissue. If a fire occurs where large amounts of materials with added organohalogen flame retardants burn, significant amount of HCl or HBr will be produced, since HCl and HBr are the thermodynamically favored products for organohalogen flame retardants. For example, furniture foam with chlorinated flame retardants can produce 10 grams of HCl per kg of foam burned for every 1% by mass of chlorine it contains (the amount of halogenated fire retardants in foam varies, but it is commonly used at levels up to 5% (Allen et al., 2008). While the actual concentration depends on the room size and ventilation rate, it should be noted that the American Conference of Governmental Industrial Hygienists (ACGIH) ceiling limit for HCl is 2 ppm, and that in a small room (50 m^3) with little ventilation, 100 ppm of HCl can be produced by 1 kg of burning foam.

ii. Greater amounts of asphyxiant/narcotic gases that are combustion byproducts, such as carbon monoxide and hydrogen cyanide, can be produced, leading to loss of consciousness and ultimately death if people are exposed to high levels or for long amounts of time (Braun et al., 1987; Levin et al., 1985; Purser, 1990, Krasny et al., 2001).

iii. Greater amount of soot and smoke can be produced, which obscures visibility and impedes escape. The action of chlorine and bromine radicals from organohalogen flame retardants can prevent the complete oxidation of the hydrocarbons present in most fires, resulting in higher yields of partial combustion products, which are apparent as greater amounts of soot and smoke (Stec and Hull, 2010).

7. In addition to increasing the amount of acutely toxic gases and particles produced, the presence of organohalogen flame retardants in products during fires can increase the amounts of persistent organic pollutants produced by combustion processes, thus **increasing the chronic toxicity of fires**.

8. In particular, incomplete combustion of products containing organohalogen flame retardants leads to the formation of halogenated dioxins and furans, substances that are considered amongst

the most toxic chemicals known (Ebert and Bahadir, 2003; Babrauskas et al., 1988; Weber and Kuch, 2003).

9. Based on my research and knowledge of fire toxicity, I support regulations that prevent the use of organohalogen flame retardants in the four categories of consumer products covered in this petition.

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Education:

UC, Berkeley	Ph.D.	1977	Chemistry
Illinois Institute of Technology	B.S.	1972	Chemistry (with Honors)

Professional Experience

Management

2007- 2011	Deputy Director, Environmental, Health and Safety Division, LBNL
2005- 2007	Assistant Division Director, Environmental Energy Technologies Division Member, EET Division Council
2000- 2009	Safety Review Committee, LBNL (Chair 2005 – 2009)
2003- 2007	Program Director, High Performance Commercial Building Systems
2002- 2004	Deputy Director, Berkeley Superfund Basic Research Program
2000- 2007	Chair, Safety Committee, Environmental Energy Technologies Division
2003 -2005	Chair, Laser Safety Committee, LBNL
2000- 2005	Safety Manager, Environmental Energy Technologies Division

Research and Teaching

1980- present	Scientist, Lawrence Berkeley National Laboratory (Environmental Energy Technologies Division – rehired retiree)
1982 – present	Professional Researcher and Visiting Scholar, University of California, Berkeley (Environmental Health Sciences, Mechanical Engineering)
1994 - present	Affiliate, Energy and Resources Group, UC Berkeley
2011 – 2014	Visiting Lecturer, East China University of Science and Technology, Shanghai, China
1988, 1990	Lecturer, University of California, Berkeley (Chemistry) Instructor, University of California, Berkeley (Mechanical Engineering) Visiting Professor, Indiana University (Chemistry) Research Associate, Indiana University (Chemistry) Teaching and Research Assistant, University of California, Berkeley (Chemistry)

Recent Committees and Activities

Finance Committee Chair, The Combustion Institute
35th International Symposium on Combustion, Local Organizing Committee Member
External Advisor, LSU Superfund Program
California AB 127 Working Group
LBNL HSS Steering Committee
LBNL DOE 142.3 Implementation Plan Project Director
LBNL EHS Training Group Head
Idaho National Laboratory Review Committee for Laser Safety (2006)
LBNL Ergonomics Pilot Program Committee (2003-2005)
Scientific Peer Reviewer, California EPA

Multimedia Working Group, California EPA
DOE Laser Program Review Panel (2003)
Executive Board and Treasurer of the US Sections of the Combustion Institute
Executive Committee and Treasurer, Western States Section/Combustion Institute
International Congress on Toxic Combustion Byproducts: Executive Committee and Awards Committee Chair
Organizing Committee, Quad Universities Superfund – EPA Conference
Publications Committee, The Combustion Institute
Organizing Committee, 2nd Joint Meeting of the U.S. Sections of the Combustion Institute
EPA Peer Review Panels Reviewer
Health Effects Institute Advisory Panel
Technical Advisor, California Institute for Energy Efficiency
Member: American Chemical Society, Sigma Xi, The Combustion Institute
Volunteer for various LBNL CSEE programs.

Service as Reviewer:

U.S. DOE
Environmental Science and Technology
Combustion Science and Technology
California EPA
International Journal of Chemical Kinetics
National Science Foundation
California Air Resources Board
Combustion and Flame
Applied Optics
U.S. EPA
Health Effects Institute
The Combustion Institute
Applied Spectroscopy
Universitywide Energy Research Group
California Energy Commission
California Institute for Energy Efficiency
Journal of Physical Chemistry

Service as Consultant:

ChevronTexaco
Texaco
Western Independent Refiners Association
UC Riverside
WESTAR
Aarons Air Services
Expert witness in legal proceedings
Green Science Policy Institute

Extramural Funding:

U.S. EPA
DOE
California Air Resources Board
NIEHS
UERG
Western States Petroleum Association

Awards

Dr. Donald Lucas and Dr. Catherine P. Koshland shared the Adel Sarofim Award in May, 2013, presented by the International Congress on Toxic Combustion Byproducts and their Health Effects.

Invited Talks (2003 – present):

Lucas, D. (2014). The complex role of chlorinated hydrocarbons in combustion. ACS National Meeting, Dallas, TX, Mar. 18, 2014.

Lucas, D (2011) Measuring combustion products: Plumbing parts to engineered nanaoparticles. LSU Chemistry Dept., Baton Rouge, LA, Feb. 2, 2011.

Lucas, D (2011). Toxic combustion emissions: Measuring them and determining their health effects. East China University of Science & Technology (ECUST), June 2, 2011.

Lucas, D (2011) Combustion and health effects: Basic research to public policy. Chinese University of Hong Kong, Hong Kong, China, June 13, 2011.

Lucas, D (2011) Nanomaterials as environmental sensors. EPA Region 9, Sept. 21, 2011, San Francisco, CA

Lucas, D (2011) Nanomaterials as environmental sensors. SRP/EPA Region 9 seminar series. Oct. 3, 2011 (web presentation)

UC Riverside, Department of Mechanical Engineering, Riverside, CA Nov., 2009.

Renewable Energy Sources – New Fuels, New Issues. California Industrial Hygiene Council, San Diego, CA, Dec., 2008; San Francisco, CA, Dec., 2009

Berkeley Nanotechnology Forum, UC Berkeley, CA, April, 2008.

Environmental Health, Energy, and Transportation: Bringing Health to the Fuel Mixture. Institute of Medicine, The National Academies, Washington, DC, Dec., 2007.

Nanoparticles from Combution Sources and their Toxicity. 38th Environmental Mutagen Society, Atlanta, Ga. Oct., 2007.

"Non-Burning Issues" of Combustion Fundamentals. 5th Meeting of the U.S. Sections of the Combustion Institute, San Diego, CA, Mar., 2007.

Moving Forward in Partnership to Protect Health. Superfund Basic Research Program, Berkeley, CA, May 5, 2006.

ERG100 Lectures, 2004, 2005, 2008 UC Berkeley

Excimer Laser Fragmentation Fluorescence Spectroscopy. Gordon Research Conference on Laser Diagnostics in Combustion, Oxford, England, August, 2003.

Patents

James JZ, Crosby, JS, Lucas D, Koshland CP. Localized Surface Plasmon Resonance Mercury Detection System and Methods. U.S. Application Nos. 61/585,542 and 61/587,546. January 10, 2013 (filed). The International Patent Application has been accorded serial number PCT/US2013/021066.

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3. D. Lucas (1977). Fast Reactions, Free Radicals, and Molecular Complexes Studied by the Matrix Isolation Technique. Ph.D. Thesis, University of California, Berkeley.

4. L. J. Allamandola, D. Lucas, and G. C. Pimentel (1978). Synchronized Flash Photolysis and Pulse Deposition in Matrix Isolation Experiments. *Rev. Sci. Instrum.* **49** (7), 913.
5. D. Lucas and G. C. Pimentel (1979). Reaction Between NO and O_3 in Solid Nitrogen. *J. Phys. Chem.* **83** (18), 2311.
6. D. Lucas and G. E. Ewing (1981). Spontaneous Desorption of Vibrationally Excited Molecules Physically Adsorbed on Surfaces. *Chem. Phys.* **58**, 385.
7. D. Lucas and N. J. Brown (1982). Characterization of the Selective Reduction of NO by NH_3 Addition. *Combust. Flame* **47**, 219.
8. D. Lucas, L. J. Allamandola, and G. C. Pimentel (1982). Matrix Isolation Infrared Spectra of Hydrogen Halide and Halogen Complexes with Nitrosyl Halides. *Croat. Chem. Acta* **55**, 121.
9. D. Lucas, A. S. Newton, and N. J. Brown (1982). The Measurement of Ammonia in Lean Combustion Exhausts. *Combust. Sci. Technol.* **29**, 309.
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Exhibit J

Statement of Sharyle Patton

Commonweal Biomonitoring Resource Center
CBRC, 451 Mesa Road, PO Box 316, Bolinas, CA 94924
PH: 415.779-1010, FAX: 415 868.2230, www.commonweal.org

September 17, 2014

I, Sharyle Patton, am writing this statement in support of the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. I am the director of the Commonweal Environmental Health Program in Bolinas, California, which takes a science-based approach to the challenge of reducing anthropogenic environmental contaminants. I also direct the Commonweal Biomonitoring Resource Center, and have worked with government agencies and community groups nationally and internationally to design and implement biomonitoring projects to inform improved chemicals regulation, focus chemicals research, and raise public awareness. Additionally, I am director of special projects for the Collaborative on Health and Environment (CHE), a Commonweal-sponsored network that seeks to raise the level of awareness about possible linkages between environmental threat and health outcomes. I was previously the northern co-chair of the International Persistant Organic Pollutants (POPs) Elimination Network, a network of over 350 international non-governmental organizations that worked successfully towards the UN Treaty on POPs, signed in May 2001. Please see my biographical sketch attached.

2. For the past 8 years, I have been involved with numerous biomonitoring studies, including a study in collaboration with the Center for Disease Control (CDC) and California Public Health Department to measure levels of perchlorate in humans, water and produce in Southern California, a study that measured levels of neurotoxicants in a group of individuals heading up national groups concerned with learning and developmental disabilities, and a methods development study in collaboration with the International Association of Firefighters that tested 35 firefighters in 15 states for levels of combustion bioproducts and flame retardants. I am currently a founding member of the Women Firefighter Biomonitoring Collaborative, (WFBC), a team of scientists and firefighter groups and advocacy groups which has been awarded a three year grant from the California Breast Cancer Research Foundation to assess women firefighters' exposure to chemicals linked to breast cancer, including carcinogens and endocrine disruptors such as combustion products and diesel exhaust, flame retardants, and perfluorinated chemicals. I am Co-chair of the Women Firefighter Biomonitoring Collaborative's) communication, education, and policy team, and have recently co-written a paper discussing effecting biomonitoring study results communication[1].

3. Firefighters are exposed on the job, particularly during fire cleanup and overhaul, to organohalogen flame retardants contained in consumer products, and to their toxic

combustion products. The latter include dioxins and furans [2], which are likely contributors to the observed high levels of cancer (such as myeloma, lymphoma, and testicular and bladder cancers) in acting and retired firefighters[3].

4. Several studies have found that firefighters have higher levels of organohalogen flame retardants and dioxins and furans than the average population. In collaboration with the University of California Irvine's Center for Occupational and Environmental Health and a Southern California fire department, Biomonitoring California carried out a study of environmental chemical exposures in 101 firefighters in Southern California in 2010-2011, known as the Firefighter Occupational Exposures (FOX) Project[4]. The study detected five PBDE (polybrominated diphenyl ether) congeners in over 90% of the study population, indicating widespread exposure. Two of these highly detected congeners, BDE-47 and BDE-99, are the most abundant congeners used in the commercial flame retardant mixture pentaBDE, which was added to foam inside upholstered furniture in California for many years. A 2013 study by Shaw *et al.*[5] also measured the blood levels of several flame retardants, including the organohalogen flame retardants PBDEs, in 12 firefighters following a fire event. Study participants had elevated concentrations of PBDEs, particularly the PBDE-209 congener. The authors suggested that this high concentration of PBDE-209 may be due to inhalation of deca-BDE-containing particulate in smoke and dust that is released from burning consumer products such as televisions. Shaw *et al.*[6] also found distinctive patterns of dioxin and furan congeners in the blood of these 12 firefighters, suggesting occupational exposure.

5. Since 2002, 56 percent of firefighters in the International Association of Fire Fighters Cancer and Occupational Disease Database who have died in the line of duty have died of occupation cancers (unpublished confidential data). This is the largest health-related issue facing the fire fighting profession. Firefighters have higher incidence of several forms of cancer, which may be at least in part related to their exposure to organohalogen flame retardants and their combustion products such as halogenated dioxins and furans[7]. A recent NIOSH study[8], in collaboration with the National Cancer Institute and the Department of Public Health Sciences at the University of California at Davis, analyzed cancers and cancer deaths through 2009 among 29,993 firefighters from the Chicago, Philadelphia and San Francisco fire departments who were employed since 1950, and found higher rates of respiratory, digestive and urinary systems cancers compared to the general population. Bates *et al.*[9] found that California firefighters are disproportionately susceptible to testicular cancer, melanoma, brain cancer, or esophageal cancer. Ma *et al.*[10] found that Florida firefighters may get bladder, testicular, or thyroid cancer. Baris *et al.*[11] found that Philadelphia firefighters had increased mortality from colon cancer, kidney cancer, non-Hodgkin's lymphoma, or multiple myeloma. A 2006 study by Youakim[12] found firefighters with long-term service had an increased risk for colon cancer, kidney cancer, brain cancer, leukemia, and bladder

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cancer. Kang *et al.*[13] found increased incidence of colon and brain cancer in Massachusetts firefighters. LeMasters *et al.*[14] reviewed 32 published studies and concluded that, overall, the risk of multiple myelomas, non-Hodgkin's lymphoma, testicular cancer, and prostate cancer for firefighters was notable. As firefighters are not required to regularly handle industrial chemicals, a probable reason for elevated incidences of such cancers is due to occupational exposure of firefighters to carcinogens such as certain organohalogen flame retardants, dioxins and furans, polycyclic aromatic hydrocarbons (PAHs) and others.

6. Firefighters save lives, but they are more likely to get sick or be killed on the job than the average Americans[15]. Organohalongen flame retardants and their combustion products are some of the potentially carcinogenic compounds that firefighters become exposed to on the job at higher levels than the general population. As such, deaths could potentially be avoided by banning, or at least restricting, the use of the entire class of organohalogen flame retardants in household products. Given that organohalogen flame retardants in furniture, mattresses, children's products and electronics casings as currently used do not stop fires, but increase the risk of cancer for firefighters, I see no justification for their use, and fully support the accompanying petition.

Yours sincerely,

Sharyle Patton

Sharyle Patton

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Sharyle Patton is director of the Commonweal Biomonitoring Resource Center, a program that helps communities of concern learn more about the public health tool of biomonitoring. She also is director of Special Projects for the Collaborative on Health and Environment, a Commonweal-sponsored network that seeks to raise the level of awareness about possible linkages between environmental threat and health outcomes.

Patton was a co-founder and served as the Northern Co-Chair of the International Persistent Organic Pollutants (POPs) Network, a network of over 500 public-interest groups around the globe who are active in UN negotiations dealing with toxic chemical regulation. Working closely with governments, this network participated in creating the Stockholm Convention, a legally binding UN treaty that bans or severely restricts the use of POPs chemicals. The Convention entered into force in May 2004.

Patton serves as advisor for the California Health Tracking Program, a CDC-funded project to develop infrastructure and processes for tracking chemical hazards, pathways of exposure and health outcomes in California.

In 1995, 1996, and 1997, Patton was the public sector representative on the Unites States Delegation to the UN Commission on Sustainable Development. Patton was also a public sector representative on the United States Delegation to the UN Summit, Habitat II, as well as on the US Delegation to Rio Plus Five. Patton was active as an NGO representative at the UN summits on women's issues in Cairo and Beijing, supporting women's reproductive rights and the right of women to live in environments conducive to the highest possible standard of good health.

Patton currently serves on the Advisory Group for human milk monitoring, World Health Organization, and the steering group for the World Alliance for Breastfeeding Advocacy. Patton is also a board member of the Barbara Smith Fund and The Endocrine Disrupter Exchange (TEDX).

Exhibit K

Statement of Ruthann Rudel

SILENT SPRING INSTITUTE

RESEARCHING THE ENVIRONMENT AND WOMEN'S HEALTH

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I, Ruthann Rudel, am writing this statement to provide information relevant to the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. I, Ruthann Rudel, am Director of Research at the Silent Spring Institute, and Adjunct Research Associate in the Brown University Department of Pathology and Laboratory Medicine. I have a B.A. in chemistry and neuroscience from Oberlin College, and an M.S. in environmental management and policy from Tufts University. I have served on the US National Toxicology Program Board of Scientific Counselors and the Regulatory Affairs and Legislative Assistance Committee of the Society of Toxicology, and have participated in numerous environmental regulatory reviews for the US EPA, Health Canada, Toxicology Excellence for Risk Assessment, and others. I have attached my CV and list of publications.

2. For almost 20 years, I have been co-leading Silent Spring Institute's exposure and toxicology research programs focusing on endocrine active chemicals and on the mechanisms by which chemicals may influence breast cancer risk. I also direct Silent Spring Institute's Household Exposure Study, which was described by Environmental Science & Technology as the "most comprehensive analysis to date" of exposures in homes. I have expanded the initial study to include indoor and outdoor air, house dust, urine, blood, and self-reported exposure data from 170 participants in California and Massachusetts, leading to over 30 highly-cited peer-reviewed exposure-related papers.

3. Our 2003 Household Exposure Study was the first to test US homes for the flame retardant PentaBDE (a commercial mixture of polybrominated diphenyl ethers (PBDE)), which was then used as flame retardant in furniture foam. We found that levels of PBDEs in US homes were ten times higher than in Europe. In 2006, we discovered that, due to unique furniture flammability standards, exposures to PentaBDE congeners (BDE 47, 99 and 100) were 4 to 10 times higher in California than in the rest of the US, and two orders of magnitude higher than in Germany and the UK. Californians also had nearly twice as high blood levels of PBDEs (sum of BDE-28, -47, -99, -100, -153, and -154 congeners) compared to other US residents[1]. These results show that flammability standards influence exposures and risks[2].

5. In 2011, we tested again the same 16 California homes from the 2006 study, to understand exposure to a wider range of flame retardants. This time we screened for 49 flame retardants (organohalogens and organophosphates), chosen due to evidence for their widespread use and potential harmful health effects.

6. We found that the current levels of exposure to the organohalogen flame retardants are often above health based guidelines[3]. House dust concentrations of six chemicals, including the carcinogens TCEP (Tris (2-chloroethyl) phosphate) and TDCPP (chlorinated "Tris"), were higher than EPA health risk guidelines in at least one home, and levels in 13 of 16 homes exceeded at least one health guideline level. TCEP and TDCPP (both listed as carcinogens under California's Proposition 65) were found at levels of up to 0.01% in dust, higher than previously reported in the US. Our study was also the first to detect TDBPP (brominated "Tris") in house dust, in 75% of the homes studied.

7. Our 2011 study also showed that exposure to flame retardants from house dust had changed since 2006, after the phase out of PentaBDE and OctaBDE. PentaBDE levels decreased in homes that added new furniture, electronics, and flooring. Similarly, households that reported purchasing new electronics had lower levels of TBBPA in 2011 compared to 2006. Instead, households that added new furniture and other flame retardant products between 2006 and 2011 had higher levels of tris(1-chloro-2-propyl) phosphate (TCPP), suggesting its use as PentaBDE replacement[4].

8. Our 2003, 2006 and 2011 study results prove that, if added to consumer products in additive form (i.e. not chemically-bound to the material), organohalogen flame retardant chemicals migrate out of products and get into dust. This house dust is thought to be a major source of flame retardants in people's bodies, especially in children[5].

9. In particular, I wish to point out that our 2011 study indicated that banning individual flame retardants is ineffective because manufacturers tend to replace them with other chemicals with similar structures and hazards, including chemicals with uncharacterized toxicity. Some of the chemicals found in homes at the highest levels are carcinogenic, and are structurally similar to banned chemicals. Many of the chemicals detected in households show evidence of hormone disruption. The attached table from the Silent Spring study by Dodson et al. (2012)[6] summarizes the known health concerns and the data gaps for some of the high production volume flame retardants we found in homes.

10. Based on these findings, my professional opinion is that, in order to reduce people's exposure to hazardous chemicals in homes, it is best to use inherently non-flammable materials or smolder-resistant flammable materials. Continued use of non-polymeric additive organohalogen flame retardants would lead to continued exposure and may cause adverse health effects, particularly to vulnerable populations.

Sincerely,

Ruthann Rudel

Ruthann Rudel, MS
Director of Research, Silent Spring Institute

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Table SI4. Summary of flame retardant uses and health effects

Flame Retardant Class	**Uses**	**Health Concerns**[a]
Polybrominated diphenyl ethers (PBDEs)		
PentaBDE CAS 32534-81-9 *Includes congeners BDE 28, BDE 47, BDE 66, BDE 85, BDE 99, BDE 100, BDE 153, and BDE 154*	Additive flame retardant in polyurethane foams[7] Phased out in US in 2004 10-50 million pounds produced in 2002 in US	EPA Action Plan Chemical Dose-dependent decrease of T4, increased liver weight and P450 induction after 4 days of oral administration of DE-71 to 28 d.o. female rats. [8] Decrease of T4 and T3, increase of TSH, hypothyroid indicators, increased liver to body weight ratio, increased P450 induction, decrease in seminal vesicle and ventral prostate weights and delayed preputial separation in males, delayed vaginal opening in females; males more sensitive in this screening battery for EPA ED Screening Program using gavage of DE-71 on young Wistar rats[9] BDE-99: gestational exposure associated with hyperactivity and permanently impaired spermatogenesis in male rats[10] Decreased birth weight and birth length in humans associated with BDE 47, BDE 99, and BDE 100 levels in mothers' breast milk[11] Children with higher concentrations of BDE 47, BDE 99, and BDE 100 in cord blood scored lower on tests of mental and physical development at 12-48 and 72 months[12] In adult male sport fish consumers, serum levels of BDE 47, BDE 99, BDE 100, and BDE 153 were positively related to T4 and inversely related to T3 and TSH. Men over the 95th percentile of PBDE levels were more likely to have thyroglobulin antibodies[13] Serum concentrations of BDE 28, BDE 47, BDE 99, BDE 100, and BDE 153 in pregnant women were inversely associated with TSH levels; no relationship was found with T4.[14] Serum levels of BDE 47, BDE 99, and BDE 100 were positively associated with T4 in pregnant women in their third trimester[15] Endocrine disruption through androgen, progesterone, estrogen, T4 receptor agonism and antagonism in vitro[16] Decreased attention, motor skills, and IQ in children associated with mothers' PBDE blood serum concentrations during pregnancy; decreased attention and IQ in children (age 7) associated with PBDE serum concentrations[17]
OctaBDE CAS 32536-52-0 *Includes congeners BDE 183,*	Additive flame retardant in polymers for plastic housings and office equipment[7] Phased out in US in 2004	EPA Action Plan Chemical Dose-dependent decrease of T4, increased liver weight and P450 induction after 4 days of oral administration of DE-79 to 28 d.o. female rats[8]

Flame Retardant Class	Uses	Health Concerns[a]
BDE196, BDE 197, and BDE 203	1-10 million pounds produced in 2002 in US	Neonatal mice gavaged BDE 203 resulted in increased CaMKII and synaptophysin in the hippocampus[18]
DecaBDE CAS 1163-19-5 *Includes congener BDE 209*	Additive flame retardant in electrical and electronic equipment, textiles and fabric backings; accounts for 80% of total PBDE production[7] Volunteer phase-out in US by 2014 50-100 million pounds produced in 2006 in US	EPA Action Plan Chemical Impaired reproductive function to male mice exposed in utero[19] Neonatal exposure to mice effects neurobehavioral effects, including locomotion, rearing, and habituation activity; effects worsened with age.[20] Neonatal exposure to mice effects sensorimotor responses and locomotor activity, and reduction of thyroxine levels[21] Decreased birth weight and birth length in humans associated with BDE 209 levels in mothers' breast milk[11] Leukemia and liver, spleen, and thyroid tumors and cancers in oral high doses over 2 years to male rats[22]
Firemaster® 550 *2-ethylhexyl-2,3,4,5-tetrabromobenzoate (EH-TBB)* CAS 183658-27-7 *bis(2-ethyhexyl)-3,4,5,6-tetrabromophthalate (BEH-TBEP)* CAS 26040-51-7 *tri-phenyl phosphate (TPHP)* CAS 115-86-6	Replacement for PentaBDE in foams BEH-TBEP: 1-10 million pounds produced in 2006 in US TPHP: 10-50 million pounds produced in 2006 in US	FM® 550: DNA damage in liver tissue of fathead minnows after oral exposure.[23] Increased thyroxine, body weight in offspring, early puberty in female offspring, difficultly in glucose regulation in female offspring and thickened walls in the left ventricle in male offspring. [24] BEH-TBEP structurally similar to DEHP, a reproductive and developmental toxicant and listed carcinogen on CA's Proposition 65 List[25, 26] Hypothyroidism, decrease T3, hepatotoxicity in pregnant rats, and increased multinucleated germ cells in fetal testis following two days of oral dosing of TBMEHP, a metabolite of TBPH [27] TPHP: increased prolactin levels, reduced sperm concentration in men[28] *Lack of cancer, and 2 generation reproductive, and developmental studies*[29]
hexabromocyclododecanes (HBCYDs) CAS: 3194-55-6 *Includes alpha, beta, and gamma-hexabromocyclododecane*	Additive flame retardant in thermoplastic (moldable) polymers and styrene resins[7] Used in building insulation, upholstery textiles and electrical equipment housing[30] 10-50 million pounds produced in 2006 in US	EPA 2010 Action Plan to review potential reproductive, developmental and neurological effects[31] Listed as Substance of Very High Concern (SVHC) under REACH Hyperactive activity, reduced habituation, learning and memory impairment in neonatal mice with oral exposures[32] Non-monotonic dose response curve observed for TSH levels in adult mice and their offspring, decreased ovarian follicles in second generation female mice, decreases in the

Flame Retardant Class	Uses	Health Concerns[a]
		viability index of F2 pups[33] Thyroid hormone disruption in animals and in vitro models[34] Endocrine disruption through androgen, progesterone, estrogen, T4 receptor agonism and antagonism in vitro[16] Dopamine and GABA uptake inhibition due to effects on membrane potential in rat brain cells[35]
tetrabromobisphenol A (TBBPA) CAS: 79-94-7	Most widely used flame retardant; reactive in circuit boards; additive flame retardant in polymers[7] 100-500 million pounds produced in 2006 in US	Endocrine disruption through T3, T4 agonism and estradiol inhibition in vitro.[16] Strong T4 agonism.[36] CD25 inhibition in female mice.[37] Decreased T4, increased testis and pituitary weight in orally exposed rats, increased testis weight, testosterone, female gonadal weight in second generation[38] Dopamine and GABA uptake inhibition due to effects on membrane potential in rat brain cells[35] *Lack of health studies*
Other brominated flame retardants (BFRs)		
tetrabromobisphenol A-bis(2,3-dibromopropylether) (TBBPA-BDBPE) CAS: 21850-44-2	Additive flame retardant in plastics, including pipes, water barriers, kitchen hoods and electronics[39] 1-10 million pounds produced in 2006 in US	Endocrine disruption through T4 agonism and estradiol inhibition in vitro[16] Mutagenic in salmonella; structural similarities to TDBPP, a classified carcinogen [40] *Lack of health studies*
hexabromobenzene (HBB) CAS: 87-82-1	Additive flame retardant in paper, wood, textiles, electronic and plastics; not used in Europe[39]	Disruption of heme formation in female rats following gavaged HBB over 28 days[41] Increased liver:body ratio and increased carboxylesterase in rats subchronically fed HBB[42] *Lack of health studies*
1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE) CAS: 37853-59-1	Replacement for OctaBDE[39] 1-10 million pounds produced in 2006 in US	Its metabolite is a endocrine disruptor through androgen, progesterone, estrogen, T4 receptor agonism and antagonism in vitro[16] Behavioral, gastrointestinal, and respiratory changes, and dermatitis following high dose inhalation in rats. Dermal exposure to rabbits led to metabolic changes[43]

Flame Retardant Class	Uses	Health Concerns[a]
		No chronic animal studies[43]
decabromodiphenylethane (DBDPE) CAS: 84852-53-9	Alternative to DecaBDE[39] 10-50 million pounds produced in 2006 in US	Reduced EROD activity in fish hepatocytes; acutely toxic to water fleas; reduced hatching rates of zebra fish eggs and increased mortality of hatched larvae[44] Structurally similar to BDE 209[39] *Lack of health studies*
Halogenated organophosphate flame retardants (OPFRs)		
tris(2-chloroethyl)phosphate (TCEP) CAS: 115-96-8	Used in polyurethane foams, plastics, polyester resins, and textiles[45, 46] Banned from children's products in NY in 2011[47] Up to 1 million pounds produced in 2006 in US	Listed as carcinogen on CA's Proposition 65 List in 1992 Listed as Substance of Very High Concern (SVHC) and persistent, bioaccumulative, and toxic (PBT) as a reproductive toxicant under REACH[48] Impaired memory in rats, cholinesterase inhibition in hen brains.[49] Neurotoxicity due to altered cellular neurodifferentiation in vitro.[50] Decreased cognitive function correlated with TCEP in house dust in boys and girls age 5-9[48]
tris(1-chloro-2-propyl)phosphate (TCIPP) CAS: 13674-84-5	Used in polyurethane foams[45] 10-50 million pounds produced in 2006 in US	Structurally similar to TCEP[51] *Lack of health studies*
tris(1,3-dichloro-isopropyl)phosphate (TDCIPP) CAS: 13674-87-8	Used in polyurethane foams, plastics, and textiles[45, 46] Removed from children's clothing in the late 1970s in the US[52] 10-50 million pounds produced in 2006 in US	Listed as carcinogen on CA's Proposition 65 List in 2011 Increased liver carcinomas and kidney, testicular, and brain tumors in male and female rats[49] Associated with Sick Building Syndrome in men and women[53] Endocrine disruption through decrease in thyroxine, increase in prolactin, and decrease in androgens in men[28] Neurotoxicity due to altered cellular neurodifferentiation and inhibited DNA synthesis in vitro[50]
tris-(2,3-dibromopropyl)phosphate (TDBPP)	Used in polyurethane foams[45] Banned in 1977 for use in children's clothing[54]	Listed as carcinogen on CA's Proposition 65 List in 1988; classified as IARC 2A carcinogen

Flame Retardant Class	Uses	Health Concerns[a]
CAS: 126-72-7		
Non-halogenated OPFRs		
tri-ethyl-phosphate (TEP) CAS: 78-40-0	Used for plasticizing properties and in antifoam agents and lacquers[45, 46] 1-10 million pounds produced in 2006 in US	Brain colinesterase inhibition and reduced righting reflex in rats following injection of TEP[55] *Lack of health studies*
tri-iso-butyl-phosphate (TIBP) CAS: 126-71-6	Used for plasticizing properties and in antifoam agents and lacquers[45, 46]	*Lack of health studies*
Tri-n-butyl-phosphate (TNBP) CAS: 126-73-8	Used for plasticizing properties and as lubricants in hydraulic fluids[45] 1-10 million pounds produced in 2006 in US	A dose-related increase in the incidence and severity of urinary bladder tumors was found in male and female rats receiving TnBP in the diet for 2 years[56] Associated with Sick Building Syndrome in men and women[53] *Lack of health studies*
tri-(2-butoxyethyl)-phosphate (TBOEP) CAS: 78-51-3	Also used in floor wax, lacquers, and rubber and plastic stoppers[45, 46] 1-10 million pounds produced in 2006 in US	Decreased red cell acetylcholinesterase, ataxia, tremors, and increased liver weight in rats gavaged TBEP for 18 weeks[57] *Lack of health studies*
tri-(2-ethylhexyl)-phosphate (TEHP) CAS: 78-42-2	Used in clothing, as a plasticizer, and as a solvent [58]	Increase in lymphomas, liver, pituitary tumors in mice orally exposed to high doses of TEHP in diet for 2 years[59] *Lack of health studies*
tri-cresyl-phosphate (TMPP) CAS: 1330-78-5	Used as flame retardant plasticizers and as lubricants in hydraulic fluid [45] 1-10 million pounds produced in 2006 in US	Reproductive and developmental toxicity due to dose-dependent increase in abnormal sperm morphology in male rats and increased pup mortality following in utero exposure[60] Toxicity to central nervous system due to neuropathy of the sciatic nerve[60] *Lack of health studies*
Dechlorane-plus (DDC-CO) CAS: 13560-89-9	• Flame retardant in electronics[61] 1-10 million pounds produced in 2006 in US	Increased liver weight, increased lung weight and macrophages in alveoli in rats, decreased liver and ovarian weight in rabbits[62] Shares structural similarities with dieldrin, chlordane, heptachlor, endrin, and endosulfan[63]

Flame Retardant Class	Uses	Health Concerns[a]
		Lack of health studies

[a] From laboratory or animal studies unless otherwise indicated

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Harvard Extension School and New England Epidemiology Institute, 1993-1995, graduate courses in epidemiology, statistics

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Research Associate, Department of Pathology and Laboratory Medicine, The Warren Alpert Medical School of Brown University, 2007-present

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Senior Research Assistant, Neuroscience Laboratories, Tufts University Medical School, Boston, MA, 1986-1989
Editor, World Information Systems, Cambridge, MA, 1989-1990
Environmental Toxicologist, Gradient Corporation, Cambridge, MA, 1990-1995
Director of Research, Senior Scientist, Toxicology and Environmental Health Risk Assessment, Silent Spring Institute, 1995-present (Silent Spring Institute is a nonprofit research organization dedicated to studying the environment and women's health.)

OTHER APPOINTMENTS

Ad hoc Manuscript Reviewer, *Environmental Science & Technology, Toxicological Sciences, Environmental Health Perspectives, Environmental Research,* and others, 1997-present
Invited Reviewer, Toxicology Excellence for Risk Assessment, Cincinnati, OH, 1998-present
Reviewer, US EPA/NIEHS STAR grants, 1999
Invited Reviewer, Cornell University Program on Breast Cancer and Environmental Risk Factors, 1999-2002

Advisor, Breast Cancer Fund, Breast Cancer Action, Massachusetts Breast Cancer Coalition, Massachusetts Alliance for a Healthy Tomorrow, California Breast Cancer Research Program, and others, 1999-present

Consultant, risk assessment reviewer, Health Canada, 1997-2009

Science Advisory Board Member, Massachusetts Toxics Use Reduction Act implementation, 2000-2001

Developer, Co-Chair, Society of Toxicology annual meeting symposium, *Breast Cancer: Issues in Screening and Testing of Potential Human Carcinogens,* 2001

Chair, Member, Society of Toxicology Regulatory Affairs and Legislative Assistance Committee, 2004-2006

Expert Panelist, California Breast Cancer and Chemicals Policy Project, 2009

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Guest lecturer at Tufts University, Harvard School of Public Health, and Suffolk University, 2005-present

PUBLICATIONS LIST

ORIGINAL PUBLICATIONS IN PEER-REVIEWED JOURNALS

1. Talamo, B.R., **R.A. Rudel**, K.S. Kosik, V.M. Lee, S. Neff, L. Adelman, and J.S. Kauer. 1989. Pathological changes in olfactory neurons in patients with Alzheimer's disease. *Nature* 337:736-739.

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5. Brody, J.G., and R.A. **Rudel**. 2003. Environmental pollutants and breast cancer. *Environmental Health Perspectives* 111(8):1007-1019.

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Morello-Frosch, R., P. Brown, J.G. Brody, R.G. Altman, R.A. **Rudel**, A. Zota, and C. Perez. 2011. Experts, ethics, and environmental justice: Communicating and contesting results from personal exposure science. In *Technoscience and Environmental Justice: Expert Cultures in a Grassroots Movement,* eds. G. Ottinger and B.R. Cohen. Cambridge, MA: MIT Press.

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OTHER NON-PEER-REVIEWED PUBLICATIONS

Letters

Rudel, R.A., J.G. Brody, and J.D. Spengler. 2001. Identification of selected hormonally active agents and animal mammary carcinogens in commercial and residential air and dust samples [Response]. *Journal of Air and Waste Management Association* 51:1388-90.

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Schaider, L.A., R.A. **Rudel**, J.M. Ackerman, and J.G. Brody. (2010) Correspondence re: Using residential history and groundwater modeling to examine drinking water exposure and breast cancer by Lisa Gallagher et al., *Environmental Health Perspectives*, published online 1 September 2010.

Rudel, R.A, J.M. Ackerman, and R.E. Dodson. 2011. Dietary intervention and DEHP reduction: Rudel et al. respond. *Environmental Health Perspectives* 119:a380-a381. doi:10.1289/ehp.1103852R

Rudel, R.A. and L.J. Perovich. 2012. Accurate risk-based chemical screening relies on robust exposure estimates. *Toxicological Sciences*, doi:10.1093/toxsci/kfs143.

PUBLICATIONS SUBMITTED

Dodson, R.E., Van den Eede, N, Covaci, A, Perovich,LJ, Brody, JG., **Rudel, RA.** (Under review) Urinary biomonitoring of phosphate flame retardants: Levels in California adults and recommendations for future studies

INVITED PRESENTATIONS

1. **Rudel**, R.A. 1995. Modeling *in vivo* estrogenic potency. Invited talk. Workshop on hormones, hormone metabolism, and breast cancer. National Cancer Institute's National Action Plan on Breast Cancer, September, New Orleans, LA.

2. **Rudel**, R.A. 2001. Residential exposure to EDCs in the context of a breast cancer study. e.hormone 2001, October 18-20, Tulane University, New Orleans, LA.

3. Brody, JG, RA **Rudel**. 2002. Environmental pollutants and breast cancer: using GIS and environmental sampling in the Cape Cod Breast Cancer and Environment Study. Presented at the

National Institute of Environmental Health Sciences (NIEHS), June 10, 2002, Research Triangle Park, North Carolina.

4. **Rudel**, R.A. 2002. Household exposure to hormonally active agents and animal mammary carcinogens in indoor air, dust, and residents' urine on Cape Cod, MA. Invited talk sponsored by the EPA conference Risk Management for Endocrine Disrupting Compounds, January, Cincinnati, OH.

5. **Rudel**, R.A. 2003. Air, dust, and urinary markers of phthalates. NIEHS Workshop on Human Health Effects of Phthalate Exposure. March 26-27, Research Triangle Park, NC.

6. Brody, JG, RA **Rudel**. 2005. Community-initiated breast cancer and environment studies and the Precautionary Principle. Presented to the Collaborative on Health and the Environment Cancer Working Group, June 1.

7. Brody, JG, RA **Rudel**. 2007. Endocrine disruptors and breast cancer: The Cape Cod Study and beyond. Presented at the Superfund Basic Research Program Seminar, Brown University, April 20, Providence, Rhode Island.

8. Brody, JG, RA **Rudel**. 2007. Breast cancer and the environment: Science review with Silent Spring Institute. Presented to the Collaborative on Health and the Environment Partnership Call, June 19.

9. **Rudel**, RA. 2009. Key issues and data needs for considering mammary gland effects in chemical risk assessment. Presented at the Mammary Gland Evaluation and Risk Assessment Workshop, November 16-17, Oakland, CA.

10. Brody, J.G., R. Morello-Frosch, P. Brown, R.A. **Rudel**, S. Dunagan. Is It Safe? Reporting Personal Exposures When Health Effects are Uncertain. Presented at the Keystone Science Lecture Series sponsored by the NIEHS Division of Extramural Research and Training (DERT), December 1, 2009, Research Triangle Park, North Carolina.

11. **Rudel**, R.A. 2010. Toxicology Can Advance Breast Cancer Prevention by Informing Chemicals Policies and Epidemiologic Study Design. Institute of Medicine Committee on Breast Cancer and the Environment. July 7, 2010, San Francisco, CA

12. **Rudel**, RA., R. Dodson. 2011. SVOCs in indoor air, dust, and personal care products. Presented at the SVOCs in the Indoor Environment: Mechanistic Insights to Support Sustainable Product Design, Safe Use and Improved Public Health Workshop sponsored by the Indoor Air Institute, January 5-7, 2011, EPA, Research Triangle Park, North Carolina.

13. **Rudel**, RA. 2011. "Is It Safe?": New Ethics for Reporting Personal Exposures to Environmental Chemicals. Presented at the Biomonitoring California Workshop: Understanding and Interpreting Biomonitoring Results, March 17, 2011, Oakland, California.

14. Brody, J.G., **R. Rudel**. Household Cancer Hazards Interview. Julie and Ruthann interviewed with Dr. Lynn Goldman on NPR's On Point (Tom Ashbrook) regarding the Product Testing Study, March 13, 2012.

15. **Rudel**, RA. 2013. Chemicals and Breast Cancer: Building on National Initiatives for Chemical Safety Screening. Presented at Chemical Testing in the 21st Century: Opportunities and Challenges, January 24, 2013, Environmental Defense Fund, Washington DC.

16. **Rudel**, RA. 2013. Chemicals Testing Workgroup Panel. California Breast Cancer Research Program's "From Research to Action: Two Decades of Change" symposium, May 17-18, 2013, Costa Mesa, CA.
17. **Rudel**, R.A. 2013. How are the critical relationships between chemical bioavailability, activity, and adversity established within an AOP in a way that protects the most sensitive subpopulations? Panel speaker at Adverse Outcome Pathways: From Research to Regulation. September 3-4, 2014, Bethesda, MD.
18. **Rudel**, R.A. Toxicology for Breast Cancer Prevention. Risk Assessment Specialty Section (RASS) and Mixtures Specialty Section (MSS) Webinar. September 10, 2014.

SELECTED ABSTRACTS

1. **Rudel**, R.A., and B.D. Beck. 1993. Risk assessment for indoor air: Evaluating risks to susceptible populations. *Methods of Risk Assessment for Indoor Environment*. B. Seifert, ed. NATO/CCMS Pilot Study of Indoor Air Quality and European Collaborative Action. "Indoor Air Quality and its Impact on Man (Formerly Cost Project613)." Report on a joint workshop, held October 15-17, 1991 in Kloster Banz, Federal Republic of Germany.

2. **Rudel**, R.A., and B.D. Beck. 1994. Variability in international criteria for chemical toxicity: Comparison of the methods and criteria developed by the U.S. EPA, the WHO, and the RIVM. Presented at the Society for Risk Analysis Annual Meeting, December, Baltimore, MD.

3. Melly, S.J., S.R. Swedis, R.A. **Rudel**, Y.T. Joyce, and J.G. Brody. 1996. Environmental factors in breast cancer: Enhancing an ecological epidemiology study through the use of a geographic information system. Joint Annual Meeting of the Society for Risk Analysis and the International Society for Exposure Assessment. New Orleans, LA.

4. Melly, S.J., R.A. **Rudel**, A.M. Soto, C. Sonnenschein, M. Fernandez, and J.G. Brody. 1996. Potential exposure to estrogenic chemicals via drinking water from a vulnerable aquifer: Pairing chemical analysis with a bioassay. Joint Annual Meeting of the Society for Risk Analysis and the International Society for Exposure Assessment. New Orleans, LA.

5. Brody, J.G., A. Aschengrau, and R.A. **Rudel**. 1997. Occupational history module of the breast cancer core questionnaire. American Public Health Association Annual Meeting. Indianapolis, IN.

6. **Rudel**, R.A. 1998. Estrogenic components in wastewater, septage, and groundwater: A comparison between chemical analysis and results from an MCF-7 cell proliferation bioassay. Presented at the NIEHS/EPA Endocrine Disruptor Grantees Annual Meeting, October, Research Triangle Park, NC.

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8. Camann, D.E., J.S. Colt, S.L. Teitelbaum, R.A. **Rudel**, R.M. Hart, and M.D. Gammon. 2000. Pesticide and PAH distributions in house dust from seven areas of USA. Society of Environmental Toxicology and Chemistry 21st Annual Meeting, Nashville, TN.

9. **Rudel**, R.A., D. Camann, P.W. Geno, N. Ho, M. Ortiz, A. Yau, J.D. Spengler, J. Vallarino, and J.G. Brody. 2000. Identification of animal mammary carcinogens and hormonally active chemicals in residential air and dust samples. International Society for Exposure Analysis Meeting. Monterey, CA.

10. Brody, JG, SJ Melly, RA **Rudel**, NI Maxwell. 2000. GIS exposure assessment for pesticides and drinking water in the Cape Cod Breast Cancer and Environment Study. Annual Conference of International Society for Environmental Epidemiology (ISEE)/International Society of Exposure Analysis (ISEA). Epidemiology 11(4):S102.

11. **Rudel**, R.A. and B. Davis. 2001. Breast cancer: Issues in screening and testing of potential human carcinogens. Symposium for 2001 Society of Toxicology Annual Meeting, March 29, San Francisco, CA.

12. O'Leary, ES, CH Swartz, JG Brody, RA **Rudel**. 2001. GIS in exposure assessment for pesticides in the Cape Cod Breast Cancer and Environment Study and the Long Island Breast Cancer Study Project. Presented at the American Public Health Association Meeting. October 24, Atlanta, Georgia.

13. **Rudel**, RA, D Barr, JG Brody. 2001. Characterizing exposure to a wide range of chemicals of interest for breast cancer research: Indoor air and dust and urinary measure for pesticides, endocrine disruptors, and animal mammary carcinogens. Presented at the American Public Health Association Meeting, October 24, Atlanta, Georgia.

14. **Rudel**, RA, JG Brody, D Camann, A Yau, JD Spengler, J Vallarino. 2001. Characterization of residential exposures to a wide range of endocrine-active compounds in the context of a breast cancer epidemiologic study. Presented at e.hormone 2001: The Cutting Edge of Endocrine Disruptor Research, Tulane University. October 20, New Orleans, Louisiana.

15. **Rudel**, RA. 2002. Residential indoor air and dust measurements of phthalates and other EDCs. Effective Risk Management of Endocrine Disrupting Chemicals, U.S. Environmental Protection Agency. January 29–30, Cincinnati, Ohio.

16. Brody, JG, RA **Rudel**. 2002. Environmental pollutants and breast cancer: using GIS and environmental sampling in the Cape Cod Breast Cancer and Environment Study. Presented at National Institute's Environmental Health Sciences meeting. June 10, Research Triangle Park, North Carolina.

17. Brody, JG, CH Swartz, T Kennedy, RA **Rudel**. 2002. Historical pesticide exposure assessment using a geographic information system and self-report in a breast cancer study. Annual Conference of International Society for Environmental Epidemiology (ISEE)/International Society of Exposure Analysis (ISEA). Epidemiology 13(4):S209.

18. **Rudel**, RA, CH Swartz, JG Brody, DM Camann, A Yau, M Zuniga, JD Spengler. 2002. Residential indoor air and dust measures for pesticides, alkylphenols, phthalates, and other endocrine disruptors. Annual Conference of International Society for Environmental Epidemiology (ISEE)/International Society of Exposure Analysis (ISEA). Epidemiology 13(4):S198.

19. Brody, JG, R Polk, AM Menting, CH Swartz, RA **Rudel**. 2002. Beyond "I don't know": responsible and effective strategies to communicate results of exposure assessment for endocrine disruptors to study participants and communities in a breast cancer study. Annual Conference of International Society for Environmental Epidemiology (ISEE)/ International Society of Exposure Analysis (ISEA). Epidemiology 13(4):S253.

20. Swartz, CH, RA **Rudel**, JR Kachajian, JG Brody. 2002. Indicators of wastewater and land use impacts on public drinking water: Historical reconstruction of exposure on Cape Cod, MA. Annual Conference of International Society for Environmental Epidemiology (ISEE)/ International Society of Exposure Analysis (ISEA). Epidemiology 13(4):S191.

21. **Rudel**, R.A. 2003. Phthalates in indoor air, housedust, and urine. Invited talk. NIEHS Workshop on Human Health Effects of Phthalate Exposure. March 26-27, 2003, Research Triangle Park, NC.

22. McKelvey, W, RA **Rudel**, V Cortessis, JG Brody. 2003. Is there an association between cryptorchidism or hypospadias in a son and a mother's risk of breast cancer? Presented at the 36th Annual Meeting of the Society for Epidemiologic Research; June 11–14, Atlanta, Georgia. American Journal of Epidemiology 157(suppl 11): S39.

23. Brody, JG, RA **Rudel**, R Morello-Frosch, P Brown, A Napolis, RG Altman, C Osimo, C Perez, L Seryak, A Just. 2006 Environmental justice and breast cancer advocacy: Household exposure to endocrine disrupting compounds. 134th Annual Meeting of the American Public Health Association, November, Boston, Massachusetts.

24. Attfield, K, T Kennedy, A Just, S Gray, R **Rudel**, JG Brody. 2006. Developing computer mapping tools for public access to environmental health information. 134th Annual Meeting of the American Public Health Association, November, Boston, Massachusetts.

25. Morello-Frosch, R, JG Brody, M Frye, P Brown, RG Altman, RA **Rudel**, C Perez. 2006. Right-to-know, the right-to-act, and the right not-to-know: Ethical and scientific dilemmas of reporting data in biomonitoring and environmental exposure studies. 134th Annual Meeting of the American Public Health Association, November, Boston, Massachusetts.

26. Standley, LJ, RA **Rudel**, CH Swartz, KR Attfield, JG Brody. 2006. Contamination of surface ponds on Cape Cod, MA, by EDCs and pharmaceuticals from septic-contaminated groundwater. North

American Meeting of the Society for Environmental Toxicology and Chemistry, November, Montreal, Canada.

27. Zota, AR, RA **Rudel**, RA Morello-Frosch, DE Camann, JG Brody. 2007. Regional variation in levels of indoor polybrominated diphenyl ethers may reflect differences in fire safety regulations for consumer products. 17th Annual Conference of the International Society of Exposure Analysis. Research Triangle Park, North Carolina.

28. Zota, AR, RA **Rudel**, RA Morello-Frosch, JG Brody. 2008. Elevated house dust and serum concentrations of PBDEs in California: Unintended consequences of furniture flammability standards? ISEE-ISES Joint Annual Conference on Exposure and Health in a Global Environment. Pasadena, California.

29. Morello-Frosch, RA, AR Zota, RA **Rudel**, C Perez, J Tovar, P Brown, R Dodson, JG Brody. 2008. Community-based participatory exposure assessment in an environmental justice community: preliminary results and communication. ISEE-ISES Joint Annual Conference on Exposure and Health in a Global Environment. Pasadena, California.

30. **Rudel** RA, RE Dodson, E Newton, AR Zota, JG Brody. 2008. Correlations between urinary phthalate metabolites and phthalates, estrogenic compounds 4-Butyl phenol, and some pesticides in home indoor air and house dust. ISEE-ISES Joint Annual Conference on Exposure and Health in a Global Environment. Pasadena, California.

31. Dodson RE, RA **Rudel**, E Newton, JG Brody. 2008. Urinary Pesticide Concentrations and Their Relationship to Air and Dust Concentrations and Household Predictors. ISEE-ISES Joint Annual Conference on Exposure and Health in a Global Environment. Pasadena, California.

32. Dodson RE, LJ Standley, JG Brody, RA **Rudel**. 2008. Development of an Evidence-based Intervention Study to Reduce Exposures to Contaminants in Consumer Products. ISEE-ISES Joint Annual Conference on Exposure and Health in a Global Environment. Pasadena, California.

33. Brody JG, RG Altman, R Morello-Frosch, P Brown, C Adams, RA **Rudel**. 2008. Reporting Individual-level Exposure Measurements to Participants in Intervention Studies for Emerging Contaminants. ISEE-ISES Joint Annual Conference on Exposure and Health in a Global Environment. Pasadena, California.

34. Dodson RE, KR Attfield, RA **Rudel**. 2009. Green buildings and indoor air quality: Lessons learned from household exposure studies. Healthy Buildings 2009 Conference and Exhibition. Syracuse, New York.

35. Zota AR, G Adamkiewicz, JD Spengler, R Morello-Frosch, JG Brody, RA **Rudel**. 2009. Cumulative Exposures to Thyroid Hormone Disrupting Compounds (PCBs and PBDEs) in Residential House Dust. Annual Conference of the International Society of Exposure Science (ISES). Minneapolis, Minnesota.

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41. Dodson, R.E., J.G. Brody, R.A. **Rudel**. Household Exposures in an Urban Environmental Justice Community. Urban Environmental Pollution Conference 2010. Boston, Massachusetts.

42. Dodson, R.E., L.J. Perovich, M. Nishioka, J.D. Spengler, J. Vallarino, R.A. **Rudel**. Long-term integrated sampling of SVOCs in indoor air: Measurement of emerging compounds using novel active and passive sampling methods. International Society of Exposure Science/International Society of Environmental Epidemiology (ISES/ISEE) 2010. Seoul, South Korea.

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44. Adamkiewicz, G, R Dodson, A Zota, L Perovich, J Brody, R **Rudel**, J Spengler. 2010. Semi-volatile Organic Compounds Distributions in Residential Dust Samples From 5 US Communities: Key Lessons for Improving Residential Exposure Assessment. Joint Conference of International Society of Exposure Science & International Society for Environmental Epidemiology. Seoul, Korea. Epidemiology. 22(1):S160-S161, January 2011. doi: 10.1097/01.ede.0000392166.33641.22.

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guideline studies and risk assessment. Society of Toxicology Annual Meeting 2011. March 6-10, 2011. Washington, D.C.

47. Schaider, L.A., R.A. **Rudel**, J.M. Ackerman, S.C. Dunagan, J.G. Brody. 2011. Pharmaceuticals, Perfluorinated Compounds and Other Organic Wastewater Compounds in Private Drinking Water Wells on Cape Cod, Massachusetts. 32nd Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC) North America. November 13-17, 2011, Boston, Massachusetts.

48. Dodson, R., M. Nishioka, L. Standley, L. Perovich, J. Brody, R. **Rudel**. 2011. What Do We Know About What Is in Personal Care Products?. 32nd Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC) North America. November 13-17, 2011, Boston, Massachusetts.

49. Dodson, R., L. Perovich, J. Brody, R. **Rudel**. 2011. Relationship Between House Dust and Indoor Air Concentrations: Applying Partitioning Theory to Empirical Data. 32nd Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC) North America. November 13-17, 2011, Boston, Massachusetts.

50. **Rudel** RA, J. Ackerman, K. Attfield, R. Dodson, JG Brody. New exposure biomarkers for breast cancer epidemiology. ISES 2012. Seattle, WA.

51. Dodson R.E., K. Rodgers, A. Covaci, N. Van den Eede, A. Ionas, A. Dirtu, L. Perovich, J. Brody, R. **Rudel**. 2012. Health Risks from Flame Retardants in California House Dust. Environment and Health-Bridging South, North, East and West Conference of ISEE, ISES, and ISIAQ. August 19-23, 2013, Basel, Switzerland.

52. **Rudel** RA, JA Ackerman, C Vulpe. 2013. *In Vitro* Predictive Toxicology for Breast Cancer. Society of Toxicology Annual Meeting 2013. March 10-14, 2013. San Antonio, Texas.

53. Van den Eede N, RE Dodson, RA **Rudel**, LJ Perovich, H Neels, A Covaci. Urinary Concentration of Phosphate Flame Retardants and Plasticiser Metabolites and Relationships with Indoor Dust Levels. Brominated Flame Retardants Conference. 2013.

54. Pan, S., C. Yuan, A. Tagmount, R. **Rudel**, C. Vulpe, D. Leitman. 2013. Cross-Talk Between HER2 Agonists and Xenoestrogens Lead to a Synergistic Proliferation of Breast Cancer Cells. California Breast Cancer Research Symposium. May 17-18, 2013, Costa Mesa, California.

55. Dodson, RE, KM Rodgers, A Covaci, N Van den Eede, AC Ionas, AC Dirtu, LJ Perovich, JG Brody, RA **Rudel**. 2013. Health Risks From Flame Retardants In California Homes. Sixth International Symposium On Flame Retardants. April 7-10, 2013, San Francisco, California.

56. **Rudel**, R., J. Ackerman, C. Vulpe. 2013. Chemical Screening to Identify Potential Breast Carcinogens Using Human Breast Cell Cultures: Genotoxicity. California Breast Cancer Research Symposium. May 17-18, 2013, Costa Mesa, California.

57. Zarate, O, J Brody, P Brown, L Sweeney, M Ramirez-Andreotta R. **Rudel**. 2013. "Open Data" Practices for Environmental Health Studies. Environmental Health Disparities and Environmental Justice Meeting. July 29-31, 2013, Research Triangle Park, North Carolina.

58. Dodson, RE, RA **Rudel**. 2013. Indoor exposure to SVOCs from consumer products and building materials: Empirical data validates air-dust partitioning models and informs measurement strategies. 2013 Conference of the International Society of Environmental Epidemiology (ISEE), the International Society of Exposure Science (ISES), and the International Society of Indoor Air Quality and Climate (ISIAQ). August 19–23, 2013, Basel, Switzerland.

59. Dodson, RE, K Rodgers, A Covaci, N Van den Eede, A Ionas, A Dirtu, L Perovich, J Brody, RA **Rudel**. 2013. Health Risks of Flame Retardants in California House Dust. 2013 Conference of the International Society of Environmental Epidemiology (ISEE), the International Society of Exposure Science (ISES), and the International Society of Indoor Air Quality and Climate (ISIAQ). August 19–23, 2013, Basel, Switzerland.

60. Ackerman J., R **Rudel**, C. Vulpe. 2014. High-Content Screening of Genotoxicity in Breast and Liver Cells. FutureTox II: In Vitro Data and In Silico Models for Predictive Toxicology. January 16-17, 2014, Chapel Hill, North Carolina

GRANTS

1. California Breast Cancer Research Program 2013 - 2016 $833,945
   Women Firefighters Biomonitoring Collaborative

2. National Institutes of Health: 1R01ES021726-01 2012 - 2017 $1,785,672
   Data Sharing and Privacy Protection in Digital-Age Environmental Health Studies

3. US Department of Housing and Urban Development: MAHH000512 (PI)
   2012 - 2015 $699,786
   Impact of Green Renovations on asthma and IEQ in public housing: The role of phthalates, glycol ethers, flame retardants, perfluorinated compounds and PCBs

4. California Breast Cancer Research Program 2011 - 2014 $256,194
   Chemicals and Breast Cancer: Building on National Initiatives for Chemical Safety Screening

5. Avon Foundation 2011 - 2014 $175,000
   Methods and resources for cohort studies of breast cancer and environmental chemicals;

6. American Chemistry Council 2011 – 2012 $120,000
   Interpretation of Biomonitoring Data from a Dietary Intervention Study

7. Mount Desert Island Biological Laboratory 2010 – 2011
   Exposure Ontology and HES data on the Web

8. Avon Foundation (Co-I) 2010 - 2011 $150,000

Methods and resources for cohort studies of breast cancer and environmental chemicals; Massachusetts Health and Environment Information System

9. National Institute of Environmental Health Sciences: 1RO1ES017514-01A1
2009 - 2014 $2,830,157
Ethical and Legal Challenges in Communicating Individual Biomonitoring and Personal Exposure Results to Study Participants: Guidance for Researchers and Institutional Review Boards (5 years)

10. MA Environmental Trust (Co-I) 2009-2010 $45,000
Emerging Contaminants in Public and Private Drinking Water Wells

11. Centers for Disease Control: 1RO1EH000632-01 (Co-I) 2009 - 2010 $333,000
Women's Health and the Environment: Breast Cancer Prevention Research

1. Passport Foundation/Breast Cancer Fund (Co-I) 2009 – 2010 $10,000
BPA Migration and Consumption in a Pilot Sample of US Families

13. Brown University/NIEHS (Co-I) 2009 – 2010 $10,000
Brominated Flame Retardants

14. Avon Foundation (Co-I) 2009 - 2010 $200,000
Methods and resources for cohort studies of breast cancer and environmental chemicals; Massachusetts Health and Environment Information System

15. Barnstable Assembly of Delegates (Co-I) 2009 – 2010 $24,000
EDC's in Public Drinking Water on Cape Cod

16. New York Community Trust (Co-I) 2009 - 2010 $75,000
Pollution at Home: Exposures in a Fence-line Environmental Justice Community

17. California Breast Cancer Research Program (PI) 2009 $25,000
Conference on the Effects of Chemicals on Mammary Glands

18. National Institute of Environmental Health Sciences (PI) 2009 $32,000
Conference on the Effects of Chemicals on Mammary Glands

19. US Environmental Protection Agency (PI) 2009 $17,354
Conference on the Effects of Chemicals on Mammary Glands

20. NSF/University of California – Berkeley: SES-0822724 (Co-I)
2008 - 2011 $94,395.66
Toxic Ignorance and the New Right-to-Know: The Implications of Biomonitoring for Regulatory Science

21. Centers for Disease Control: 1H75EH000377-01 (Co-I) 2008 - 2009 $118,886

Women's Health and the Environment: Breast Cancer Prevention Research

22.	National Institute of Environmental Health Sciences: 3R25ES013258-04S2 (Co-I) Linking Breast Cancer Advocacy and Environmental Justice Supplement 2	2008 - 2009	$139,805
23.	Avon Foundation (Co-I) Breast Cancer and Environmental Chemicals	2008 - 2009	$175,000
24.	Commonwealth of Massachusetts Breast Cancer Prevention Research: Household Exposure	2008 - 2009	$20,000
25.	New York Community Trust (Co-I) California Household Exposure Study Data Analysis	2007 - 2008	$75,000
26.	Commonwealth of Massachusetts Breast Cancer and the Environment on Cape Cod	2007 - 2008	$107,500
27.	Commonwealth of Massachusetts (UMASS Lowell) (Co-I) Breast Cancer Prevention Research: Household Exposure	2007 - 2008	$175,000
28.	MA Environmental Trust (Co-I) EDC's in Ponds on Cape Cod (FY2008 grant)	2007 - 2008	$25,000
29.	Avon Foundation (Co-I) Breast Cancer and Environmental Chemicals	2007 - 2008	$175,000
30.	HES Goldman (Co-I) Exposure Reduction for Endocrine Disruptors in Homes	2006 – 2009	$400,000
31.	Department of Defense (Co-I) Nanotech Method to Identify EDC's in Septic Waste	2006 – 2008	$93,108
32.	Babylon Breast Cancer Coalition (Co-I) EDC's in Cape Cod Groundwater and Drinking Water	2006 – 2007	$7,500
33.	MA Environmental Trust (Co-I) Groundwater and Drinking Water	2006 - 2007	$25,000
34.	Hurricane Voices (Co-I) Household Exposure Study	2006 - 2007	$45,000
35.	Jane's Trust Environmental Factors in Breast Cancer	2006 - 2007	$100,000
36.	Avon Foundation (Co-I)	2006 - 2007	$100,000

Breast Cancer and Environmental Chemicals

37.	Commonwealth of Massachusetts Cape Cod Household Exposure Study	2006 - 2007	$107,500
38.	National Science Foundation: SES-0450837 (Co-I) "Research Right-to-Know": Ethics and Values in Communicating Environmental Health Study Results to Individuals and Communities	2005 - 2008	$299,999
39.	Beldon Fund Environmental factors and women's health	2005 - 2007	$150,000
40.	Centers for Disease Control: R01DP000218-01 (Co-I) Impact of Environmental Pollutants on Breast Cancer and Women's Health	2005 - 2006	$347,200
41.	Avon Foundation Environmental factors and breast cancer	2005 - 2006	$75,000
42.	MA Department of Public Health (Co-I) Cape Household Exposure Study follow-up	2005 - 2006	$107,500
43.	MA Environmental Trust (Co-I) Groundwater and Drinking Water	2005 - 2006	$25,000
44.	National Institute of Environmental Health Sciences: 1R25ES013258 (Co-I) Linking Breast Cancer Advocacy and Env. Justice (4 yrs)	2004 - 2008	$932,104
45.	Susan G. Komen for the Cure (Co-I) Breast Cancer and the Environment Science Review	2004 - 2008	$611,273
46.	Agua Fund (Co-I) EDCs in Cape Cod Groundwater and Drinking Water	2004 - 2006	$25,000
47.	National Cancer Institute: 5R03CA103478-2 Risk Factors for Ductal Carcinoma In Situ (DCIS)	2004 - 2006	$140,000
48.	National Library of Medicine: 1G08LM008415 Public Access to Environmental Health Information	2004 - 2006	$130,199
49.	Hurricane Voices (Co-I) Household Exposure Study of EDCs	2004 - 2005	$60,000
50.	Avon Foundation Environmental factors and breast cancer	2004 - 2005	$50,000

51. MA Environmental Trust (FY05 grant) (Co-I) Groundwater and Drinking Water	2004 - 2005	$25,000
52. Heinz Endowments Environmental factors and breast cancer	2004 - 2004	$50,000
53. Jane's Trust Environmental factors and women's health	2003 - 2004	$281,980
54. Beldon Fund Environmental factors and women's health	2003	$75,000
55. MA Environmental Trust 2003 grant – Wells (Co-I) EDCs in Cape Cod Water	2003	$25,000
56. MA Environmental Trust 2002 grant (Co-I) EDCs in Cape Cod Water	2002	$25,000
57. Susan G. Komen Breast Cancer Foundation Cape Cod Breast Cancer and Environment Study data analysis	2001 - 2002	$160,000
58. Anonymous foundation Environmental factors and women's health	2000-2005	$606,072
59. Tides Foundation (Co-I) EDCs in Cape Cod Groundwater and Drinking Water	2000 - 2001	$115,000
60. Jessie B. Cox Charitable Trust Environmental factors and women's health	1998-2002	$194,000
61. Dolphin Trust (Soil, Atlas, Wells, and Septic) (Co-I) EDCs in Cape Cod Groundwater and Drinking Water	1998 - 2001	$86,700
62. Komen Massachusetts Affiliate Outreach and education	1996 - 2003	$312,000
63. Massachusetts Department of Public Health (Co-I) Cape Cod Breast Cancer and Environment Study	1994 - 2003	$7,300,000

Exhibit L

Statement of Ted Schettler

October 14, 2014

I, Ted Schettler, am writing this statement in support of the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. I, Ted Schettler MD, MPH am a physician and the Science Director of the Science and Environmental Health Network. I also serve as Science Director of the Collaborative on Health and Environment (CHE) and am a science advisor to the Health Care Without Harm (HCWH) campaign. I have a medical degree from Case Western Reserve University and a Masters in Public Health from Harvard University. I am co-author of "Generations at Risk: Reproductive Health and the Environment"; "In Harm's Way: Toxic Threats to Child Development"; and "Environmental Threats to Healthy Aging." I am also the author of "The Ecology of Breast Cancer: The Promise of Prevention and the Hope for Healing". I have published a number of articles in peer-reviewed scientific journals. I served on the U. S. Environmental Protection Agency's (EPA) Endocrine Disruptor Screening and Testing Advisory Committee (EDSTAC) and the National Academy of Sciences' committee on defining concerns associated with products of animal biotechnology.

2. In collaboration with organizations in the US and internationally, I have addressed many aspects of the relationship between environmental exposures and human health. I am an active contributor to HCWH's international campaign on improving the environmental performance of healthcare institutions. HCWH has had great success in helping to reduce the emissions of dioxin and mercury from health care institutional materials management practices, and we are working to reduce the use of organohalogen flame retardants in materials and products purchased by those institutions.

3. Organohalogen flame retardants are of considerable concern because of their persistence, toxicity, tendency of many to bioaccumulate, and long-range transport. Many of these chemicals have been incorporated into consumer products and are being released from them into indoor and outdoor environments, resulting in exposures to humans and wildlife.[1] In general, halogenated organic molecules (i) are more resistant to metabolic break down, (ii) cross biologic membranes more readily, and (iii) gain access to cells and tissues more readily than non-halogenated compounds. Because of this, virtually all halogenated flame retardants have adverse impacts when they interact with cells and

tissues of living organisms. Virtually all organohalogen flame retardants studied for their toxic properties have health effects at varying levels of exposure, including adverse impacts on brain development in children,[2] adverse impacts on reproduction,[3] endocrine disruption,[4] immune suppression,[5,6] and/or cancer.

4. Widespread human and wildlife exposures to flame retardants are well documented. Humans are exposed to organohalogen flame retardants mainly through inhalation or ingestion of dust particles containing these chemicals[7] and ingestion of food that has been contaminated with these chemicals[8]. Fetuses are exposed to these chemicals by transplacental transport, and infants are also exposed through ingestion of contaminated breast milk.

5. As a physician, I am particularly concerned about the health effects of organohalogen flame retardants on developing children. In 2010, in invited testimony before the U.S. Senate Committee on Environment and Public Works[9], I described windows of vulnerability and unique susceptibility to hazardous environmental exposures during *in utero* development, infancy, and childhood. Those exposures may result in adverse health outcomes with lifelong consequences. For example, ample scientific evidence confirms the unique susceptibility of the developing brain to chemical exposures that can disrupt one or more of a number of biologic processes that must proceed in an orderly fashion as brain architecture and chemistry are established throughout pregnancy, infancy, and childhood.[10] Studies have shown that exposure to polybrominated diphenyl ethers during critical windows of brain development can result in adverse impacts on multiple measures of brain function in childhood, including impaired learning and memory.[11,12] As replacement organohalogen flame retardants are slowly tested, their toxicity, too, becomes increasingly clear.

6. This combination of circumstances – biologically active compounds, increased resistance to biologic degradation, ready access to biologic tissues, and widespread exposure – justifies evaluation of organohalogen flame retardants as a class and replacement with safer alternatives.

Yours sincerely,

Ted Schettler, MD MPH

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[2] Herbstman JB, Sjödin A, Kurzon M, Lederman SA, Jones RS, Rauh V, Needham LL, Tang D, Niedzwiecki M, Wang RY, Perera F. Prenatal exposure to PBDEs and neurodevelopment. *Environ Health Perspect*. 2010 May;118(5):712-9. doi: 10.1289/ehp.0901340.

[3] Birnbaum LS, Staskal DF. Brominated flame retardants: cause for concern? *Environ Health Perspect*. 2004 Jan;112(1):9-17.

[4] Legler J, Brouwer A. Are brominated flame retardants endocrine disruptors? *Environ Int.* 2003 Sep;29(6):879 85.

[5] Darnerud PO, Eriksen GS, Jóhannesson T, Larsen PB, Viluksela M. Polybrominated diphenyl ethers: occurrence, dietary exposure, and toxicology. *Environ Health Perspect.* 2001 Mar;109 Suppl 1:49-68.

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[9] Hearing on EPA's Efforts to Protect Children's Health. Testimony of Ted Schettler MD, MPH. March 17, 2010
http://www.epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=b1cf9367-64b7-4884-b06a-2719e2709f2c

[10] Ibid

[11] Eriksson P, Jakobsson E, Fredriksson A. Brominated flame retardants: a novel class of developmental neurotoxicants in our environment? *Environ Health Perspect.* 2001 Sep;109(9):903-8.

[12] Viberg H, Fredriksson A, Jakobsson E, Orn U, Eriksson P. Neurobehavioral derangements in adult mice receiving decabrominated diphenyl ether (PBDE 209) during a defined period of neonatal brain development. *Toxicol Sci.* 2003 Nov;76(1):112-20. Epub 2003 Aug 12.

CURRICULUM VITAE

Theodore H. Schettler, M.D., M.P.H.

Education:

Carleton College - B.A., 1963
University of Minnesota
Case-Western Reserve University - M.D., 1968
Internship - Internal Medicine - University Hospitals - Cleveland, Ohio
Harvard School of Public Health - MPH, 1994
Occupational and environmental health

Clinical Medical Practice:

1969-71 - U.S. Navy / 3rd Marine Division - Viet Nam, Okinawa, Japan, San Francisco

1971-79 - Emergency Medicine - Dept. of Emergency Medicine; Windham Community Memorial Hospital; Willimantic, Ct.

1979-90 - Chief of Emergency Services; Penobscot Bay Medical Center; Rockland, Me. Established and directed the department of emergency medicine. Provided both clinical and administrative services as department director

1987-93 - Medical Director; Health Connections – an occupational health program established in 1987 as a subsidiary of its parent corporation, Northeast Health.

1994 – June, 2006 – Dept. of Internal Medicine; Boston Medical Center. Staff physician - East Boston Neighborhood Health Center; E. Boston, MA

Non-clinical positions:

1999 – present - Science director, Science and Environmental Health Network

2008—present—Science director. Collaborative on Health and Environment

Science advisor—Health Care Without Harm

Physicians For Social Responsibility (PSR)
- Steering Committee - Greater Boston PSR (co-chair, 2000, 2001)
- Environment Committee - National PSR (1995, 1996)
2000- 2006—Co-Chair - Committee on Human Health and the Environment - New England

Administrative:
1979-89 - Medical Director - Mid-Coast Emergency Medical Services, Inc.
1979-90 - Chief of Emergency Services - Penobscot Bay Medical Center (PBMC)
1982-85 - Secretary of Medical Staff (PBMC)
1986 - Vice President of Medical Staff (PBMC)
1986 - Chairman, Credentials and Peer Review Committee (PBMC)
1982-86 - Member, Executive Committee of Medical Staff (PBMC)

Boards and committees:

1987-90 - Member, Medical Staff Development Plan Committee (PBMC)

1989-90 - Member, Board of Trustees, Northeast Health

1989 - Member of Subcommittee on Emergency Medicine - Maine Medical Mutual Insurance Co. - charged with developing standards for medical management of selected clinical conditions in emergency medicine

1995 -96 - Member of the Federal Facility Environmental Restoration Dialogue Committee - (US EPA)

1996-1998 - Endocrine Disruptor Screening and Testing Advisory Committee (US EPA)

1997 - 2003 - Special committee on occupational and environmental health. Massachusetts Medical Society; member and consultant

1997-2000 – Advisory Board – Women's Cancer Resource Center; Minneapolis, MN

1999-2000 - Board of Directors – Clean Water Action; Boston, MA

1999-2000 - Member – Environmental Leadership Committee – American Hospital Association and US EPA

2001- 2003: Professional Advisory Board – Learning Disabilities Association of America

2001 – National Academy of Sciences Sub-Committee on Defining Science-based Concerns Associated with Animal Biotechnology

2001, 2002, 2003 – Endocrine Disruptor Methods Validation Subcommittee (US EPA)

2008-present—Science Advisory Board; Environmental Health Initiative; American Association of Intellectual and Developmental Disabilities (formerly American Association for the Mentally Retarded)

2009-2013—Board of directors. Pesticide Action Network North America

2010-present—Science Advisory Panel. The Breast Cancer Fund.

2012-present—Advisory council; California Breast Cancer Research Program

2014—Science advisory board. Women's Voices for the Earth

Select Publications

Schettler, T.H. Reverberations of Militarism: Toxic Contamination, the Environment, and Health. Medicine and Global Survival, 2(1), 7-18, (1995).

Co-author: *An Environmental and Health Impact Report on Known and Potentially Contaminated Sites at Former U.S. Military Bases in the Philippines.* 1995.

Schettler T, Solomon G, Burns P, Valenti M. Generations at Risk: How Environmental Toxins May Affect Reproductive Health in Massachusetts. August, 1996.

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Schettler T. Manganese in gasoline: A case study of the need for precautionary action. In: Protecting Public Health and the Environment: Implementing the Precautionary Principle. Ed: Raffensperger C, Tickner J. Island Press Washington DC. July, 1999.

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Schettler T. Corn and corn-derived products: Sources of endocrine disruptors. Environ Health Perspect 111(13): A691, 2003.

Schettler T. The Ethics of Environmentally Responsible Health Care; Pierce J, Jameton A. Book Review. Environ Health Perspect 112(8):A382, 2004.

Mekdeci B, Schettler T. Birth defects and the environment. http://www.protectingourhealth.org/newscience/birthdefects/2004-0501birthdefectspreview.htm Accessed July, 2004.

Schettler T. Endometriosis. http://www.protectingourhealth.org/newscience/endometriosis/2003-04peerreviewendometreosis.htm Accessed July, 2004.

Schettler T. Infertility and related reproductive disorders. http://www.protectingourhealth.org/newscience/infertility/2003-04peerreviewinfertility.htm Accessed July, 2004.

Schettler T. Developmental disabilities-impairment of children's brain development and function: the role of environmental factors. http://www.protectingourhealth.org/newscience/learning/2003-02peerreviewlearningbehavior.htm Accessed July, 2004.

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Honors and Awards

1968—Alpha Omega Alpha - Case-Western Reserve University
1990—Presidential Leadership Award - 1990 - Mid-Coast Emergency Services Council, Inc.
1998—Broad Street Pump Award - 1998 - Physicians for Social Responsibility
2000 - Will Solimene Award for Excellence in Medical Writing, American Medical Writers Association
2009—Science hero award. The Breast Cancer Fund.
2011—Environmental Health Hero Award; CleanMed

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thscv

Exhibit M

Statement of Roland Weber

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U.S. Consumer Product Safety Commission

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Schwäbisch Gmünd, den

24.09.2014

To Whom It May Concern:

I, Roland Weber, am writing this statement in support of the Petition to the CPSC to regulate four categories of household products containing non-polymeric additive organohalogen flame retardants.

1. I am an independent consultant working mainly for UN Organizations for the implementation of the Stockholm Convention on global elimination of persistent organic pollutants (POPs). I am also a visiting Professor at Tsinghua University, China. I received my Masters in Chemistry (1993) and my Ph.D. (1996) from the University of Tuebingen, Germany. My Ph.D. thesis was entitled "Synthesis, Analysis, Toxicology and Occurrence of fluorinated and chlorinated-fluorinated Dioxins, Dibenzofurans and Biphenyls". Since then I have carried out research, and since 2003 also consulting, in the field of dioxins/furans and other unintentionally and intentionally produced POPs. I have attached a copy of my curriculum vitae and a list of my scientific publications on halogenated dioxins, furans and other unintentionally formed POPs.

2. Polyhalogenated dibenzo-p-dioxins und dibenzofurans (dioxins and furans) are structurally-similar groups of chemicals containing benzene rings and halogens (chlorine or bromine). They have no industrial use, but are unintentional by-products of incomplete combustion and of various industrial processes, including the manufacture of some chemicals.

3. Dioxins and furans are likely human carcinogens and have been linked - at very low doses - to a wide range of other adverse health effects, including immune suppression, enzyme induction, thyroid hormone and vitamin A perturbations, antiestrogenicity, teratogenicity, and neurobehavioral deficits (US EPA, Van den Berg et al. 2013, WHO 1998). Additionally, they are highly persistent and bioaccumulative. They all have similar structures and a common mechanism of action, which accounts for their similar biological effects. The harmful effects of chlorinated dioxins and furans have been recognized by the Stockholm Convention, which recommends reducing and/or eliminating the unintentional releases of these chemicals. Brominated dioxins and furans are not currently regulated by any international authority, but have similar toxicities to their chlorinated counterparts (Van den Berg et al. 2013).

4. Dioxins and furans are unintentional byproducts of the production of halogenated aromatic compounds (i.e. compounds containing halogens and benzene rings), a group that includes many of the commonly used organohalogen flame retardants. As a result, they occur as impurities in commercial organohalogen flame retardants. For instance, brominated dioxins and furans have been found as contaminants in commercial brominated flame retardants, such as polybrominated diphenyl ethers (PBDEs),

decabromobiphenyl, 1,2-bis(tribromophenoxy)ethane, tetrabromobisphenol A (TBBPA), and bromophenols (WHO 1998, Ren et al. 2011).

5. Levels of dioxin and furan contamination in some organohalogen flame retardants increase during a product's life span, suggesting that dioxins and furans can form during the normal use of products containing these organohalogen flame retardants. For instance, additive organohalogenated flame retardant decaBDE in plastics such as those used in TV casings have been shown to form brominated furans when exposed to sunlight during normal use (Kajiwara et al. 2008). Similarly, polybrominated dibenzofurans (PBDFs) can be formed in treated textiles (Kajiwara et al. 2013). Thus, normal usage of household products containing organohalogen flame retardants that are dioxin precursors is potentially a major source of dioxins and furans found in indoor air and dust (Suzuki et al. 2010; Tue et al. 2013).

6. House and office dust originating from normal wear and tear of common household products such as polyurethane foam, TV sets, computers and other electronic and electrical equipment or textiles containing organohalogen flame retardants that are dioxin precursors is a source of direct human exposure to polybrominated dibenzodioxins (PBDDs) and PBDFs (Brorstrom-Lunden et al. 2010; Suzuki et al. 2010; Tue et al. 2013). Levels measured in Japanese house dust were sufficient to contribute to a major share of daily dioxin toxic equivalencies (TEQ)-exposure for toddlers (Suzuki et al. 2007).

7. All chlorinated and brominated aromatic compounds (i.e. compounds containing benzene rings) are dioxin/furan precursors

under thermal treatments below 850°C, which includes accidental household fires (Weber & Kuch 2003, Weber 2007). Furthermore, any chlorine/bromine present in consumer products during their low temperature combustion can lead to the formation of dioxin and furans (McKay 2002, Ikeguchi & Tanaka 2001; Weber et al. 2002, Weber & Kuch 2003). Thus, the presence of any organohalogen flame retardants in consumer products during accidental household fires can lead to the formation of dioxins and furans (Weber & Kuch 2003). This increases the risk of harm to humans, particularly to firefighters who are exposed to these chemicals on the job.

8. In summary, dioxins and furans (i) have been found as impurities in organohalogen flame retardants in consumer products, (ii) can form from certain aromatic organohalogen flame retardants during the normal use of household products containing them, and (iii) can form from all organhalogen flame retardants when products containing them burn during household fires. The EPA, the WHO and Stockholm Convention have determined that some of these dioxins and furans present serious health risks.

9. Therefore, my professional opinion is that the use of organohalogen flame retardant chemicals in the four categories of household products covered by this petition should be stopped, as the human health risks associated with dioxin and furan impurities or their unintentional formation due to organohalogen flame retardants are severe. I am happy to answer any questions, and provide further documentation as needed.

Yours sincerely,

Roland E. Weber, Ph.D. R. Weber

International Consultant for Persistent Organic Pollutants

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Ren M., Peng P., Cai Y., Chen D., Zhou L., Chen P., Hu J. (2011) PBDD/F impurities in some commercial deca-BDE. Environ. Pollut. 159, 1375-1380.

Suzuki G., Someya M., Takahashi S., Tanabe S., Sakai S., Takigami H. (2010) Dioxin-like activity in Japanese indoor dusts evaluated by means of in vitro bioassay and instrumental analysis: brominated dibenzofurans are an important contributor. Environ. Sci. Technol. 44(21), 8330-8336.

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Van den Berg M., Denison M. S., Birnbaum L. S., DeVito M. J., Fiedler H., Falandysz J., Rose M., Schrenk D., Safe S., Tohyama C., Tritscher A., Tysklind M., Peterson R.E. (2013) Polybrominated Dibenzo-p-Dioxins, Dibenzofurans, and Biphenyls: Inclusion in the Toxicity Equivalency Factor Concept for Dioxin-Like Compounds. Toxicol. Sci. 133, 197-208.

Weber R., Kuch B., Ohno T., Sakurai T. (2002) De novo synthesis of mixed brominated-chlorinated PXDD/PXDF. Organohalogen Compd. 56, 181-184.

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Weber R. (2007) Relevance of PCDD/PCDF Formation for the Evaluation of POPs Destruction Technologies - Review on Current Status and Assessment Gaps. Chemosphere 67, 109-117.

World Health Organization (WHO) (1998) Polybrominated dibenzo-p-dioxins and dibenzofurans. Environ Health Criteria 205 [Geneva].

Yu X., Zennegg M., Engwall M., Rotander A., Larsson M., Wong M. H., Weber R. (2008) E-waste recycling heavily contaminates a Chinese city with chlorinated, brominated and mixed-halogenated dioxins. Organohalogen Compd. 70, 813-817.

Zennegg M., Xiezhi Y., Hung W. M., Weber R. (2009) Fingerprints of chlorinated, brominated and mixed halogenated dioxins at two e-waste recycling sites in Guiyu/China. Organohalogen Compd. 71, 2263-2267.

Curriculum Vitae Dr. Roland E. Weber

Family Name:	Weber, Dr.
Given Names:	Roland Erich
Profession:	Chemist; Environmental consultant
Nationality:	German
Date and place of birth:	5. January 1967 in Laupheim (Germany)
Marital Status:	Married; two children
Address:	Dr. Roland Weber POPs Environmental Consulting Lindenfirststrasse 23, D-73527 Schwäbisch Gmünd, Germany roland.weber10@gmail.com; +49-7171-189-809; +49-174-712-5593

Key expertise and interests

- Persistent Organic Pollutants (POPs) including newly listed POPs under the Stockholm Convention and related national implementation plans.
- Research and research strategies on chlorinated, brominated and fluorinated POPs/PTS
- Inventories and action plans for PCDD/PCDF (Dioxins) and other unintentionally produced POPs (Stockholm Convention implementation).
- Best Available Technologies (BAT) and Best Environmental Practice (BEP) for reduction of PCDD/PCDF and other unintentionally produced Persistent Organic Pollutants (UPOPs).
- Chemicals and Sustainable Production & Consumption. Substitution of critical chemicals.
- Destruction of POPs (combustion and non-combustion technologies) and formation of Dioxins (PCDD/PCDF) and other pollutants.
- POPs contaminated sites (Editor POPs contaminated site series in ESPR)

Education:

03/1994 - 03/1996	PhD, Thesis "Synthesis, Analysis, Toxicology and Occurrence of fluorinated and chlorinated-fluorinated Dioxins, Dibenzofurans and Biphenyls" (University Tübingen; Institute of Organic Chemistry, Supervisor Prof. Dr. H. Hagenmaier)
10/1993 - 05/1996	Study of "Public law for scientists and engineers" at the University of Hagen. (Equivalent to bachelor degree)
10/1988 - 01/1994	Master (diploma) in chemistry (University of Tübingen/Germany)

Employment career:

Since 01/2003	Independent international consultant (POPs Environmental Consulting)
Since 01/2010	Visiting Professor; Department of Environmental.Engineering, POPs Center, Tsinghua University, China (Stockholm Convention Center)
Since 07/2006	Visiting Professor at the MTM Research Center, University Oerebro/Sweden
05/97-12/2002	Employee in IHI Co. Ltd. (Yokohama, Japan, www.ihi.co.jp/index-e.html) (Management dioxin laboratory, R & D Dioxin reduction and POPs destruction)
03/96-04/1997	Post doc at the University Tübingen (Formation mechanisms of PCDD/PCDF)

Consultancies for governmental bodies and UN organisations:

Since 08/2013	Publication "Alternatives to POPs chemicals" (for SC Secretariat)
Since 03/2013	Member of the SwitchMed Expert Group for "Switching to more sustainable consumption and production in the Mediterranean" (for CP/RAC Spain)
Since 02/2013	IPOP Project Dioxin reduction from open burning in the Philippines (for World Bank; Subcontract to Witteveenbos)
Since 11/2012	Updating SC National Implementation Plans (Mongolia, Turkey, Philippines, Indonesia, Sudan, Tanzania) (for UNIDO)
Since 10/2012	R&D project "Environmental contamination of Dioxin and PCB and interlink to food contamination" (for German Environmental Ministry/ Agency)
Since 09/2011	Consultancy on international chemical management (for GIZ)
04/2012 – 04/2013	Monitoring of new listed POPs in articles and products. Support for the Basel and Stockholm Convention Centre China (for BRS Conv. Secretariat and GIZ)
12/2011 – 07/2012	Pilot country workshops for updating Stockholm Convention NIPs for newly listed POPs (Algeria, China, India, Nigeria, Serbia) (for SC Secretariat)
12/2011-12/2012	Consultancy for updating the SC Dioxin Toolkit (for SC Secretariat)
07/2011-08/2012	Lead author/co-author of Guidelines for supporting the implementation of newly listed POPs in the Stockholm Convention (for UNITAR & UNIDO)
07/2011-03/2012	Developing chemical criteria for Ecolabel and Green Public Procurement (For the European Commission Joint Research Center IPTS Seville)
07/2011-10/2011	FSP development for POPs management in Egypt (for WB; with Tauw)
05/2011-12/2011	1st pilot project on inventory of newly listed POPs Nigeria (for SC Secretariat)
04/2011-01/2013	Dioxin/Furan inventory and NIP development Zimbabwe (for UNEP)
11/2010	Invited expert at POPs Reviewing Committee meeting (for SC Secretariat)
01/2010-10/2010	Technical paper on PBDEs newly listed in the Convention (for SC Secretariat with Alan Watson; UNEP/POPS/POPRC.6-2, UNEP/POPS/POPRC.6/INF/6)
09/2010	Summary report on the questionnaire survey on new POPs PBDE and PFOS from parties and observers (for Stockholm Convention Secretariat & POPRC)
03/2009-04/2011	Hazardous chemical/waste management Egypt (EU Twinning project, for GIZ)
03/2009 – 06/2011	Dioxin/Furan inventory and NIP development Suriname (for UNDP)
10/2009-12/2009	Integrating Pollution Prev. and Control and Stockholm Convention (UNIDO)
02/2009	Refining of National Implementation Plan for UPOPs Serbia (for UNEP)
09/2008 – 03/2009	EU Life project on hazardous waste management Turkey (for GTZ)
10/2008	Refining of National Implementation Plan for UPOPs Montenegro (for UNEP)
2007/2008	Dioxin/Furan Inventory Turkey; support finalising the NIP (for UNIDO)
2007/2008	Dioxin/Furan Inventory Vietnam; BAT/BEP project development for UPOPs reduction Vietnam (MSP for UNIDO)
08/2005 - 02/2006	Stockholm Convention BAT/BEP and NIP consultancy Sudan (for UNDP)
Since 2004	Dioxin/Furan Inventories and NIP support for Montenegro, Serbia, Sudan, Suriname, Turkey, Uganda, Vietnam & Zimbabwe (Stockholm Convention consultancy UNDP, UNEP, UNIDO for respective environmental ministries).
2003	Minimisation strategies for PCDD/PCDF emission from waste incineration. Chemical Risk Assessment (Risk Management Handbook, AIST, Japan)
2002	Regulations and status of hospital waste management in Germany (For Japan Waste Management Experts; Co-operation with German Env. Agency (UBA))
1997-1998	Evaluation historical input of PCDD/F in Japan (Prof. Sakai, NIES, Japan)

Research and Research Cooperations:

Since 2011 (ongoing)	Formation of dioxin-like compounds from Chlorpyrifos (Osaka University).
Since 2009 (ongoing)	PBDE, other BFRs and PBDD/F in E-waste (cooperation Basel Convention Center Nigeria; Fraunhofer Institute Germany; Umea University/Sweden).
Since 2005 (ongoing)	Research/documentation of global POPs contaminated sites (selected partners)
2000-2012	Historical PCDD/F inputs and their source implication in Queensland, Australia (National Centre for Environmental Toxicology, Queensland, Australia).
2008/2009	Assessment of chlorinated and brominated Dioxin pollution of an e-waste village in Guiyu/China (with Prof. Ming Wong, Baptist University, Honkong).
2007/2008	Assessment of PFOS/PFOA sources for contamination of a German river system and drinking water reservoir (BUND, Germany).
2004-2007	Research on PCDD/PCDF formation in thermal processes in dependence on inorganic matrices (Czech Academy of Science, Prague, Czech Republic).
2002 – 2003	Forest fires as a potential PCDD/F source in Queensland, Australia (National Research Centre for Environmental Toxicology, Queensland, Australia).
1997-1999	Evaluation historical input of PCDD/F in Japan (Kyoto University; Japan).
1993-1996	Evaluation of the relevance of fluorinated and fluorinated-chlorinated dibenzodioxins and dibenzofurans in technical processes and assessment of their toxicity (with Institute of Toxicology, Univ. Tübingen; Prof. Schrenk).
1993-1994	Development of the trace analysis for fluorinated Dioxin and Furans.

Further Activities in the international community of POPs/PTS research

Member of the UNEP PCDD/PCDF Toolkit group (since 2006) and now BAT/BEP (since 2012).

Chair of the session "Remediation Methods and Control Techniques" DIOXIN 2004.

Chair of session "Contaminated sites – cases, remediation, risk and policy" & related at DIOXIN Conference Series 2006 - 2013 (26^{th} to 33^{th} International Symposium on Halogenated POPs).

International advisory board ISWA final sink Conference (2013); ISWA World 2016

Editor Board Environmental Science Pollution Research (ESPR)

Member of the ISO Group analysis brominated flame retardants (ISO/TC 146/SC 6/WG 22)

Member VDI (Community of German Engineers) development analytical standard for POPs.

Reviewer for scientific journals: ES&T, ESPR, Chemosphere, Environmental Pollution, Environmental International, Hazardous Materials, Waste Management and others.

Experience in industry and co-operation with industry (including R&D):

Since 2004	Consulting on long term monitoring of PCDD/PCDF and other UPOPs with AMESA System (Environnement SA, Germany)
2004/2005	Consulting on destruction of POPs (Prantner GmbH Verfahrenstechnik, Reutlingen, Germany) http://www.prantner.de/index.html
1997-2006	BAT/BEP strategies for municipal waste incinerators and hazardous waste incinerators in respect to PCDD/PCDF and other UPOPs emission reduction (IHI Co., Ltd. Yokohama and Tokyo, Japan) http://www.ihi.co.jp/en/index.html
1999-2003	Research & development work on formation and destruction of POPs (PCB, PCDD/F, PCP, PCBz) in technical processes (IHI Co., Ltd. Yokohama, Japan).

1998-2002	Development and improvement of catalytic filters (REMEDIA) for PCDD/PCDF destruction (W.L. Gore & Associates, Inc., Elkton, USA)
2001-2003	Formation of brominated and brominated-chlorinated PXDD/PXDF in thermal processes. (IHI Co., Ltd. Yokohama, Japan)
1999-2002	Research and development of catalytic destruction of PCDD/PCDF and PCB on fly ashes (Hitachi Zoosen, Osaka & IHI Co. Ltd..Tokyo Japan,).
1997-2005	BAT implementation in approx. 20 municipal waste incinerators and hazardous waste incinerators reduction of PCDD/PCDF emission (IHI Co., Ltd. Yokohama and Tokyo, Japan).
1999 - 2003	Research and development on reduction and destruction of POPs in technical processes (IHI Co., Ltd. Yokohama, Japan).
1997-2003	Establishment/management of a dioxin research laboratory (IHI Co., Ltd.)
1996-1999	Formation mechanisms of PCDD/PCDF in thermal and industrial processes (IHI Co., Ltd. Yokohama/Japan, University Tübingen/Germany).
1995-1996	Evaluation of potential release of fluorinated and chlorinated-fluorinated PXDD/PXDF from Aluminium industry (facilities in Germany and Norway).

Civil society activities

Ambassador of the International HCH & Pesticides Association (IHPA) (www.ihpa.info).

Member of the International Panel on Chemical Pollution (IPCP) (http://www.ipcp.ch)

Board member of the NGO "SOL" (People for Solidarity, Ecology & Lifestyles) (www.nachhaltig.at/) member of the Norther Alliance .

Board member of the NGOs Aufbruch (Germany) for "sustainable lifestyle" (www.anders-besser-leben.de), awarded UNESCO project UN Decade for "Education for Sustainable Development".

Guidelines/Guidances and reports for UN agencies and POP Reviewing Committee

1. Stockholm Convention (2013) Guidance on Sampling, Screening and Analysis of Persistent Organic Pollutants in Products and Articles; Draft; (Lead Author)
2. Stockholm Convention (2012) Guidelines on Best Available Techniques and Best Environmental Practice for the Recycling and Disposal of Articles containing Polybrominated Diphenyl Ethers (PBDEs) under the Stockholm Convention on POPs (Lead author)
3. Stockholm Convention (2012) Guidance for strengthening regulatory framework/voluntary agreements for monitoring of products/articles that may contain new POPs (Lead author).
4. Stockholm Convention (2012) Guidance for the Inventory of commercial Pentabromodiphenyl ether (c-PentaBDE), commercial Octabromodiphenyl ether (c-OctaBDE) and Hexabromobiphenyls (HBB) under the Stockholm Convention on Persistent Organic Pollutants (co-author)
5. UNEP (2010) Technical review of the implications of recycling commercial penta and octabromodiphenyl ethers. Stockholm Convention document for 6th POP Reviewing Committee meeting (UNEP/POPS/POPRC.6/2) Geneva 11-15. October 2010.
6. UNEP (2010) Supporting Document for Technical review of the implications of recycling commercial penta and octabromodiphenyl ethers. Stockholm Convention document 6th POP Reviewing Committee meeting (UNEP/POPS/POPRC.6/INF/6) Geneva 11-15. Oct. 2010.
7. UNEP (2010) Debromination of brominated flame retardants. Stockholm Convention document for 6th POP Reviewing Committee meeting (UNEP/POPS/POPRC.6/INF/20) Geneva 11-15. October 2010
8. UNEP (2010) Additional consideration of new persistent organic pollutants: pentachlorobenzene. Stockholm Convention document for 6th POP Reviewing Committee meeting (UNEP/POPS/POPRC.6/INF/21) Geneva 11-15. October 2010.

Selected Publications (from ca. 140 reviewed papers):

In Book

1. R. Weber. Minimisation strategies for PCDD/PCDF emission in waste incineration. Chemical Risk Assessment Handbook, Asakura publisher, 2003 (In Japanese).

Review Articles and editorials

2. Weber R, Aliyeva G, Vijgen J. (2013) The need for an integrated approach to the global challenge of POPs management. Environ Sci Pollut Res Int. DOI 10.1007/s11356-012-1247-8 http://link.springer.com/article/10.1007%2Fs11356-012-1247-8?LI=true
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