

Brominated Flame Retardants in Consumer Products

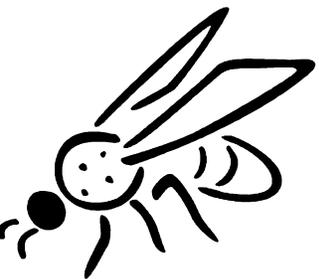
Environmental & Public Health Concerns

Ann Blake, Ph.D.

Northwest Hazardous Waste Conference

April 13, 2004

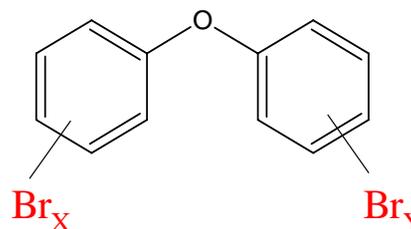




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- Researcher
 - molecular genetics of neural development
- Regulator:
 - California Environmental Protection Agency, Department of Toxic Substances Control
 - » RCRA inspector, local agency oversight
 - » Northern California Pollution Prevention Coordinator
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 - International POPs Elimination Network
 - Environmental Finance Center Region 9
 - Local governments, NGOs



Brominated Flame Retardants

- What are BFRs?
 - Broad class of chemicals, including PBDEs, TPPBA, HBCD
- Why do we use them?
 - Increased fire hazard with increased volume of flammable consumer products
- What's the concern?
 - Detected in human breast milk, ubiquitous in the environment
 - Found in blood of electronics recyclers
 - Routes of exposure remain largely unknown
- What's happening?
 - Voluntary Industry Phase-outs (electronics, Great Lakes Chemical)
 - Legislated Phase-outs (CA, WA, others)
 - Furniture Flammability regulations (CA TB117, CPSC national standard)

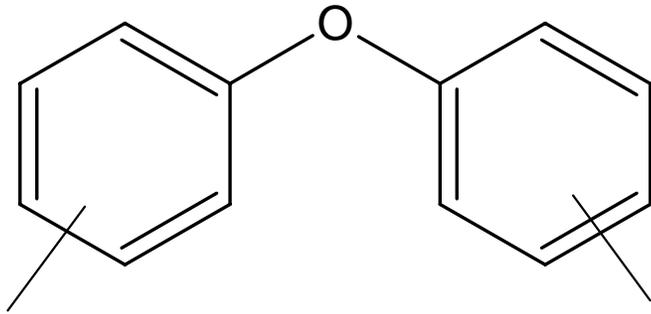


What Are the BFRs?

- Includes
 - Polybrominated diphenyl ethers, PBDEs
 - Bisphenols, Cyclododecane
- Commonly used as flame retardants
 - 95% of consumer electronics use deca-BDE
 - Computer casings, printed circuit boards, cabling, etc.
 - Upholstered furniture, drapes, carpeting
 - Penta-BDE in polyurethane foam
- 450 million pounds of BFRs manufactured annually worldwide
 - North America: highest usage; increasing in Asia, especially TBBPA



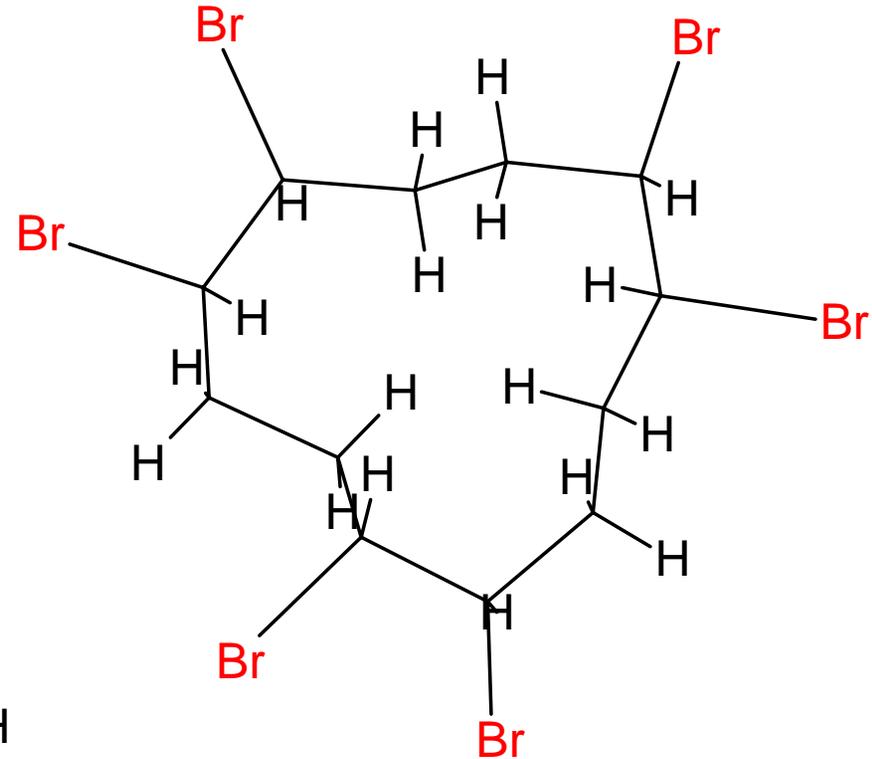
Chemical Structure of the BFRs



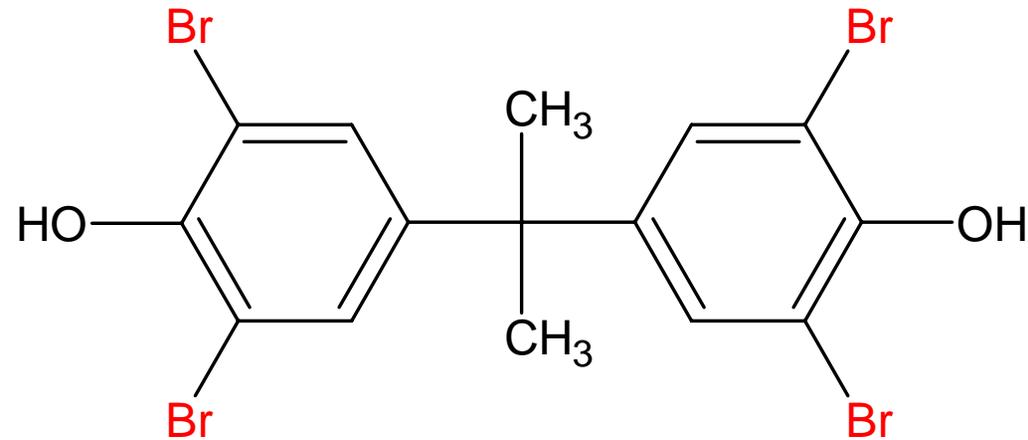
Br_X

Br_Y

Polybrominated diphenylethers (PBDE)



Hexabromocyclododecane (HBCD)



Tetrabromobisphenol A (TBBPA)

Where Are They Used?

Home

Couch, bed, chairs, television, stereo, hair dryer, iron, microwave oven, video, e-toys, carpets, curtains, lamp shades, water heater, wires, switches . . .

Travel

Cars, trucks, buses, airplanes, tents . . .

Office

Computer casings, circuit boards, wires and cables, carpets, copy and fax machines, printers, switches, sockets, plastic insulation, molding fillers, laminates, epoxy resins, lighting . . .

Global Market Demand for BFRs in 2001 (metric tons)

	America	Europe	Asia	Total
TBBPA	18,000	11,600	89,400	119,700
HBCD	2,800	9,500	3,900	16,700
DBDE	24,500	7,600	23,000	56,100
OBDE	1,500	610	1,500	3,790
PeBDE	7,100	150	150	7,500

Why do we use flame retardants?



- Fire prevention:
 - Fire kills over 4,000 people/year in US, including 100 firefighters; property damage ~\$11 billion annually
 - Retardants reduce risk of fire death/injury, property damage
 - TV sets without PBDEs are primary cause of domestic fires in Germany, increase in Sweden
- Historical perspective:
 - More products used to be wood and metal
 - Increase in flammability requirements in last 20-25 years with increase in flammable consumer products



Why BFRs?



- BFRs meet flammability requirements
 - Reduce likelihood of dripping and emission of flaming particles; reduces chance of flashover
 - Reduce off-gassing
- BFRs meet consumer product requirements
 - Mix easily with wide variety of plastics in electronics
 - Don't discolor high-density polyurethane foam or decrease its durability
- BFRs meet industry requirements
 - Most effective flame retardant at smallest concentrations
 - Voluntary furniture industry effort to reduce furniture flammability since 1970s: 70% reduction; most furniture fires are from smoldering cigarettes

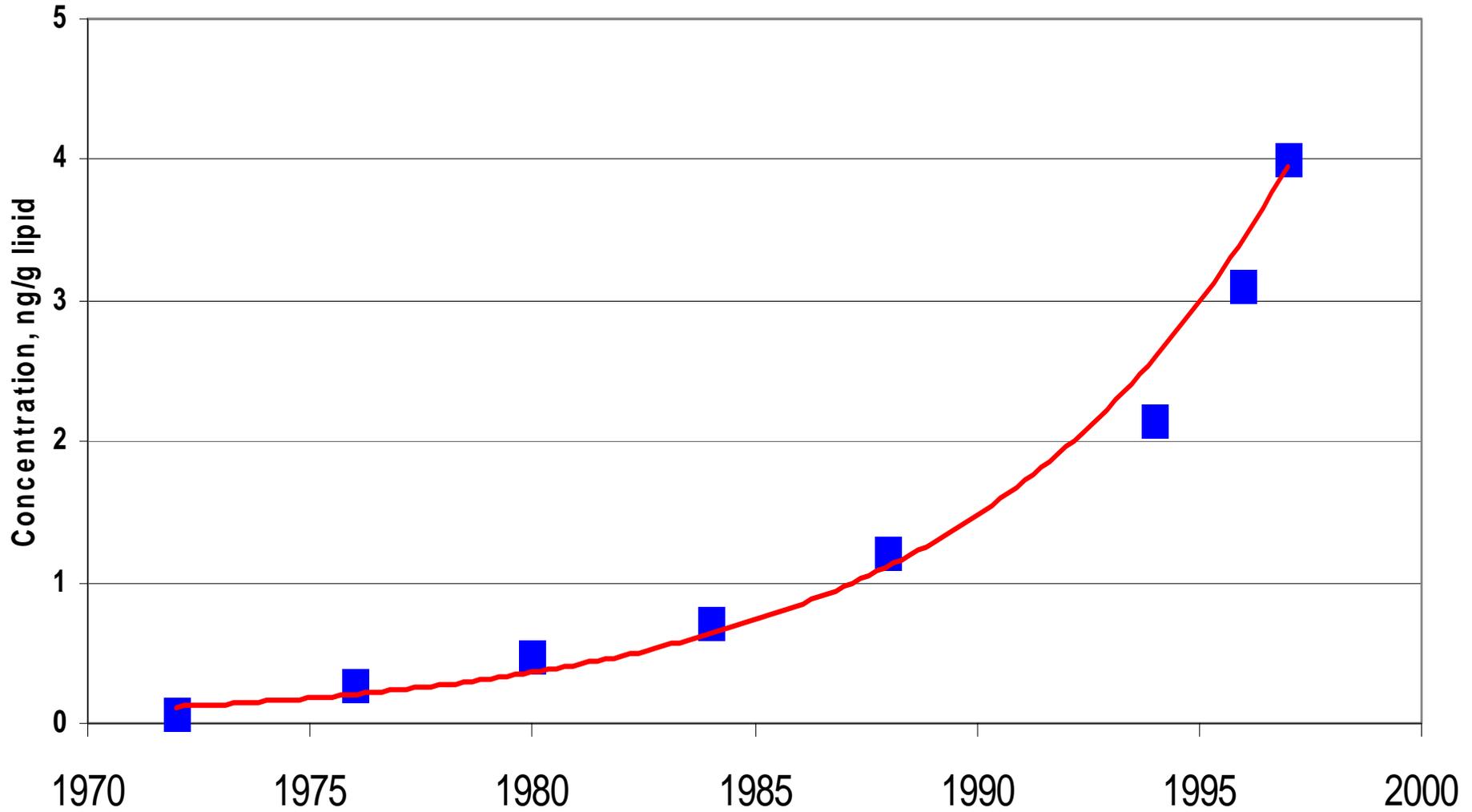
What's the Concern?

- PBDE concentrations are increasing in human tissue and biota
- PBDEs are of toxicological concern
 - Bioaccumulative
 - Endocrine disruptors
 - Affect fetal brain development
- Routes of exposure are largely unknown
 - Use or end-of-life exposure for consumer products?
 - Occupational exposure: recyclers, firefighters, others?
 - Air, soil, food?

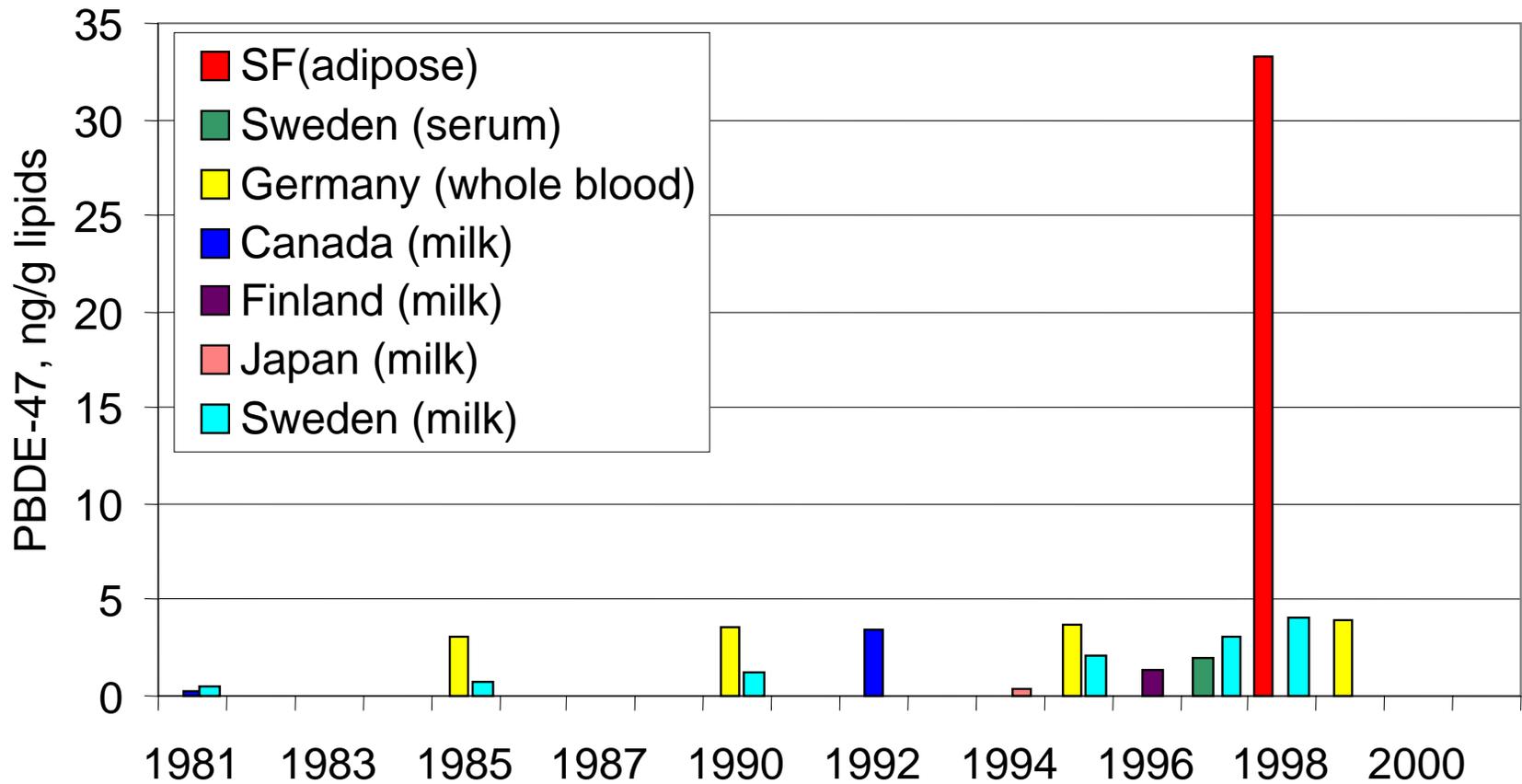


Total PBDEs, Swedish Milk Study

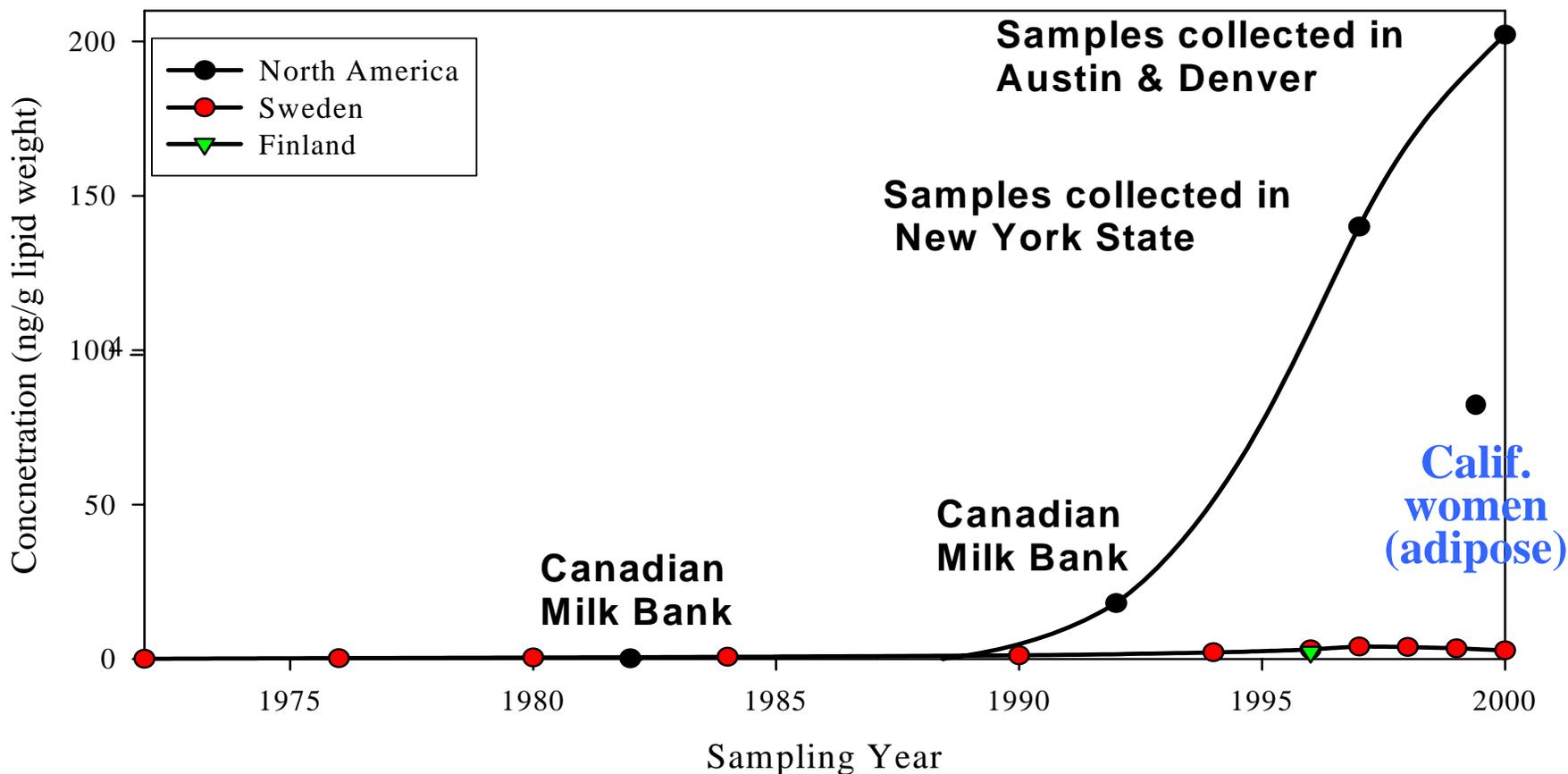
(Noren & Meironyte, 1998)



PBDE-47 in Human Tissues

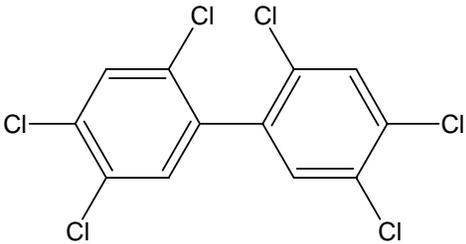


Comparison Between Concentrations of PBDEs in Breast Milk from North America and Europe

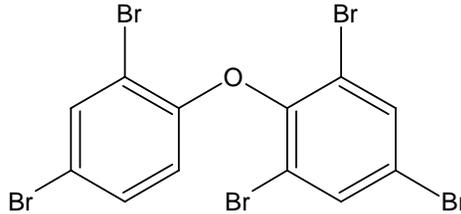


Canadian Milk Bank and New York State from Ryan and Patry 2000, Denver and Austin results from Papke et al 2001; Swedish data from Meironyte Guvernus and Noren 2001, Finnish data from Strandman et al. 2000

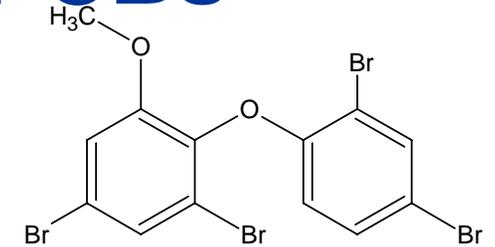
Structural Similarity of PBDEs, Their Metabolites and Environmental Derivatives to T4 and PCBs



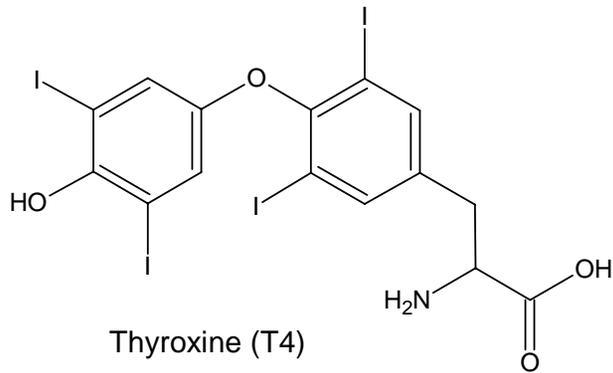
2,2',4,4',5,5'-hexachlorobiphenyl
(PCB-153)



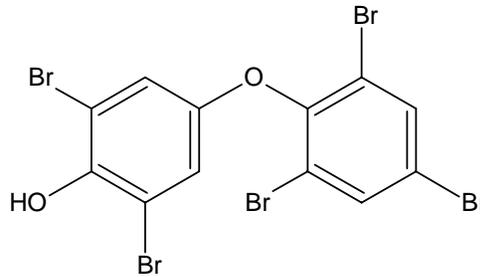
2,2',4,4',6-pentabromodiphenylether
(PBDE-100)



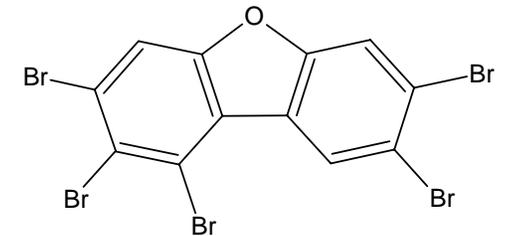
2-(2',4'-dibromophenoxy)-4,6-dibromoanisole
(methoxy-PBDE)



Thyroxine (T4)



4-(2',4',6'-tribromophenoxy)-2,6-dibromophenol
(hydroxy-PBDE)



2,3,4,7,8-pentabromodibenzofuran
(PBDF)

What We Know

- Ubiquitous in environment, biota
- Mammalian Toxicity
 - Endocrine disruption (PBDEs, TBBPA)
 - Dioxin formation (PBDEs, TBBPA)
 - Altered behavior and learning (PBDEs)
 - Inadequate testing for cancer, brain development, sensitization effects
- Ecological Toxicity
 - Photolytic and/or anaerobic debromination
 - Formation of dioxins, furans upon incineration



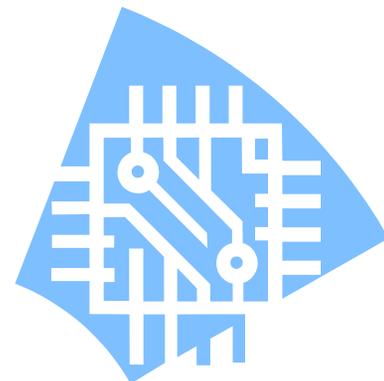
PBDEs Are Everywhere

- Indoor/ outdoor air, office dust
 - European Parliament buildings: Greenpeace
- Rivers, lakes, sediments
- Bio-solids, used for agricultural fertilizer
- Arctic, marine and terrestrial mammals
 - Long-range transport
 - Bio-concentration
- Food



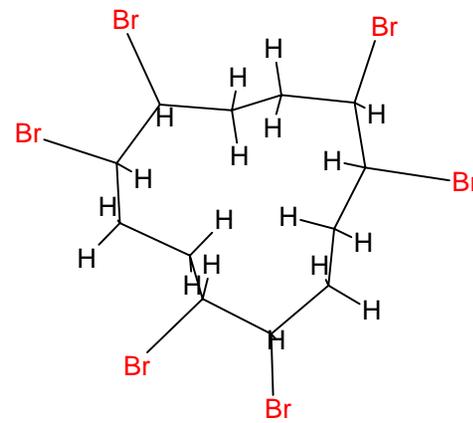
Mammalian Toxicity

- **PBDEs: consumer electronics, foam**
 - Lipophilic; metabolites are endocrine disruptors
 - Deca-BDE a hepatocarcinogen at high dosage
 - Developmental exposure increases adult susceptibility to PBDEs; altered behavior and learning
- **HBCD: polystyrene resins, textiles**
 - Persistent, bioaccumulative
 - Developmental toxicant
- **TPPBA: printed circuit boards**
 - Immunotoxic, hepatotoxic, neurotoxic
 - Endocrine disruptor



Toxicity of Alternatives

- HBCD
 - Substitute for penta-BDE in foam
 - Effects are parallel to PBDEs, PCBs
 - Changes in behavior
 - Neurodevelopmental effects
 - Found in workplace air (2001), breastmilk (2002)
 - Exposure data gaps are huge



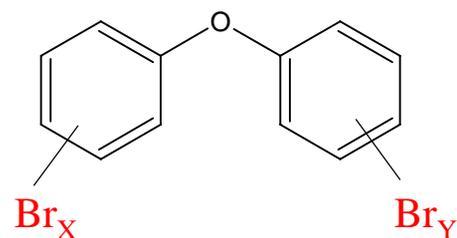
New Data on Deca-BDE

- Highest volume usage (although TBBPA increasing)
- Thought to be stable, but it's NOT
 - Uptake by humans, lab animals, wildlife
 - Debrominates in the environment and biota into lower, more acutely toxic congeners
- Found in
 - Indoor air at home and workplaces
 - Sediment, sewage sludge

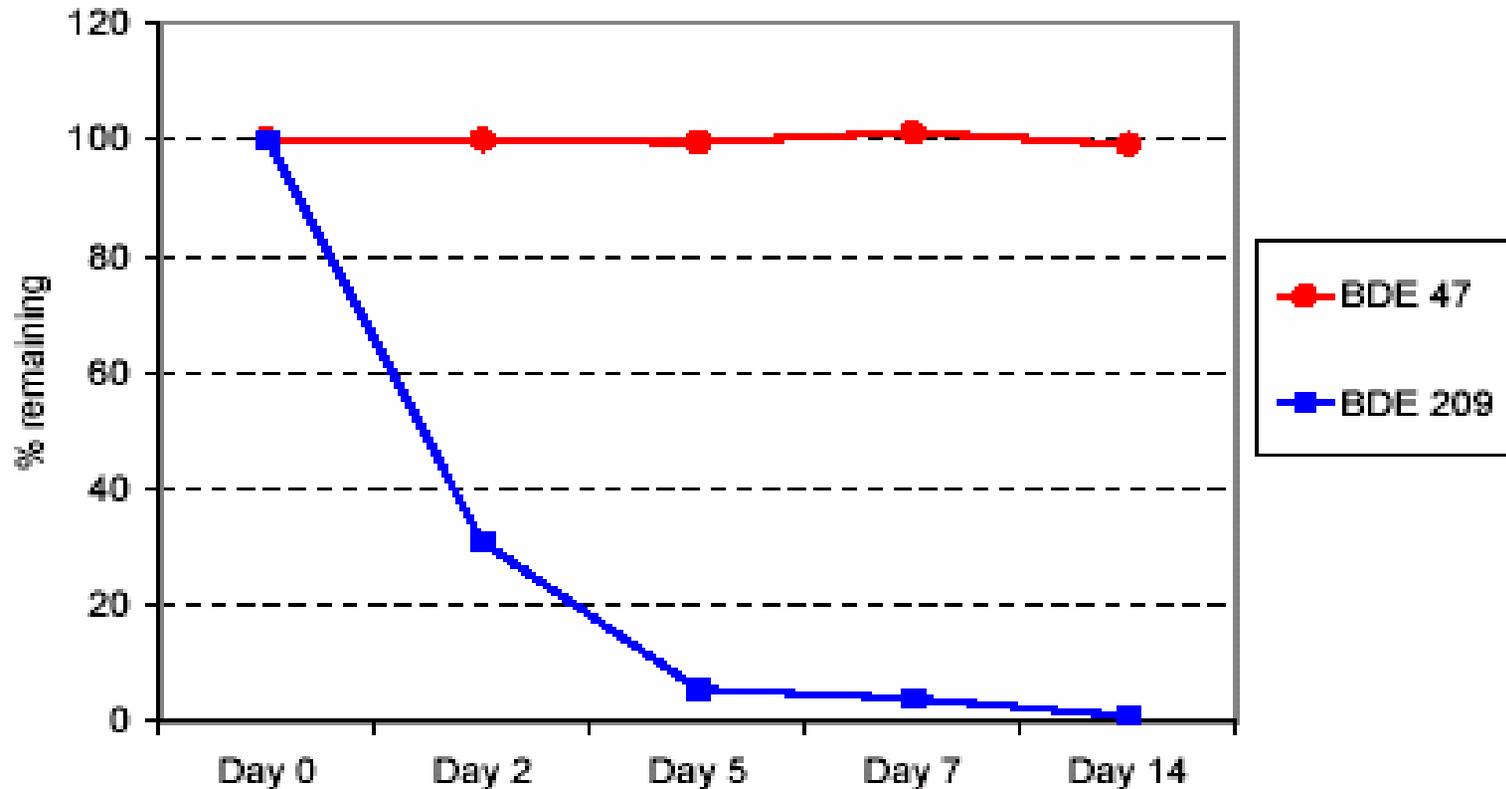


Deca Concerns, cont'd

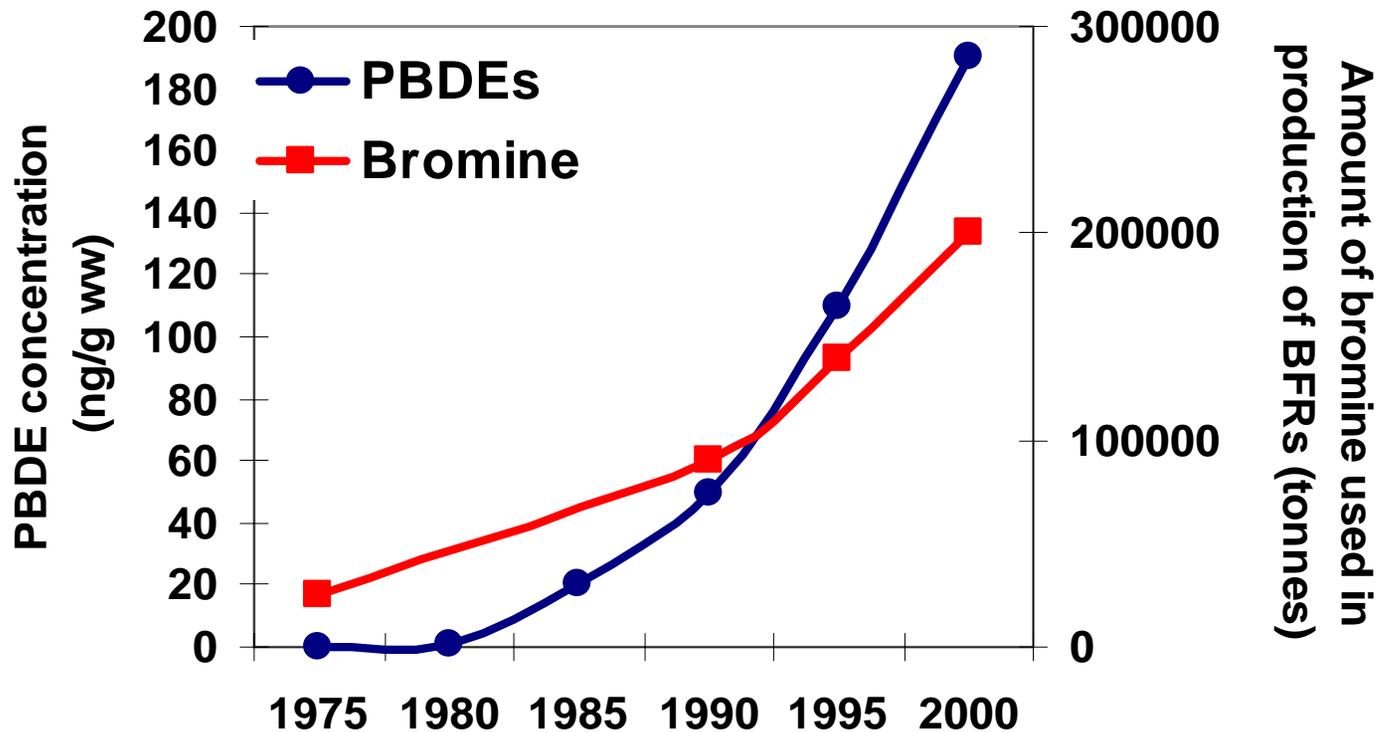
- Large reservoir: consumer electronics and peripherals
- Long-range transport
 - Arctic
- Occupational exposure among recyclers
- Problems similar to penta and octa, but not banned
- Switch to HBCD and TBBPA are also of concern



Debromination of deca-BDE in toluene + sun: 1/3 left after 2 days



Comparison of Total PBDEs in Lake Ontario lake trout and total use of Bromine in BFR production (Alaee et al., 2002)



What We Don't Know

- Routes of Exposure
 - Manufacture versus consumer use
 - End-of-life disposal of electronics, furniture?
 - Foods: fish, dairy, meats, other?
- Environmental Fate
 - Industrial, environmental, biota profiles differ
- Toxicology of Alternatives
 - Phosphorus-based flame retardants, others
- Effects in Humans?
 - Rat and mouse studies
 - Extrapolation from PCBs, dioxins
 - Need more data on cancer, brain development, sensitization

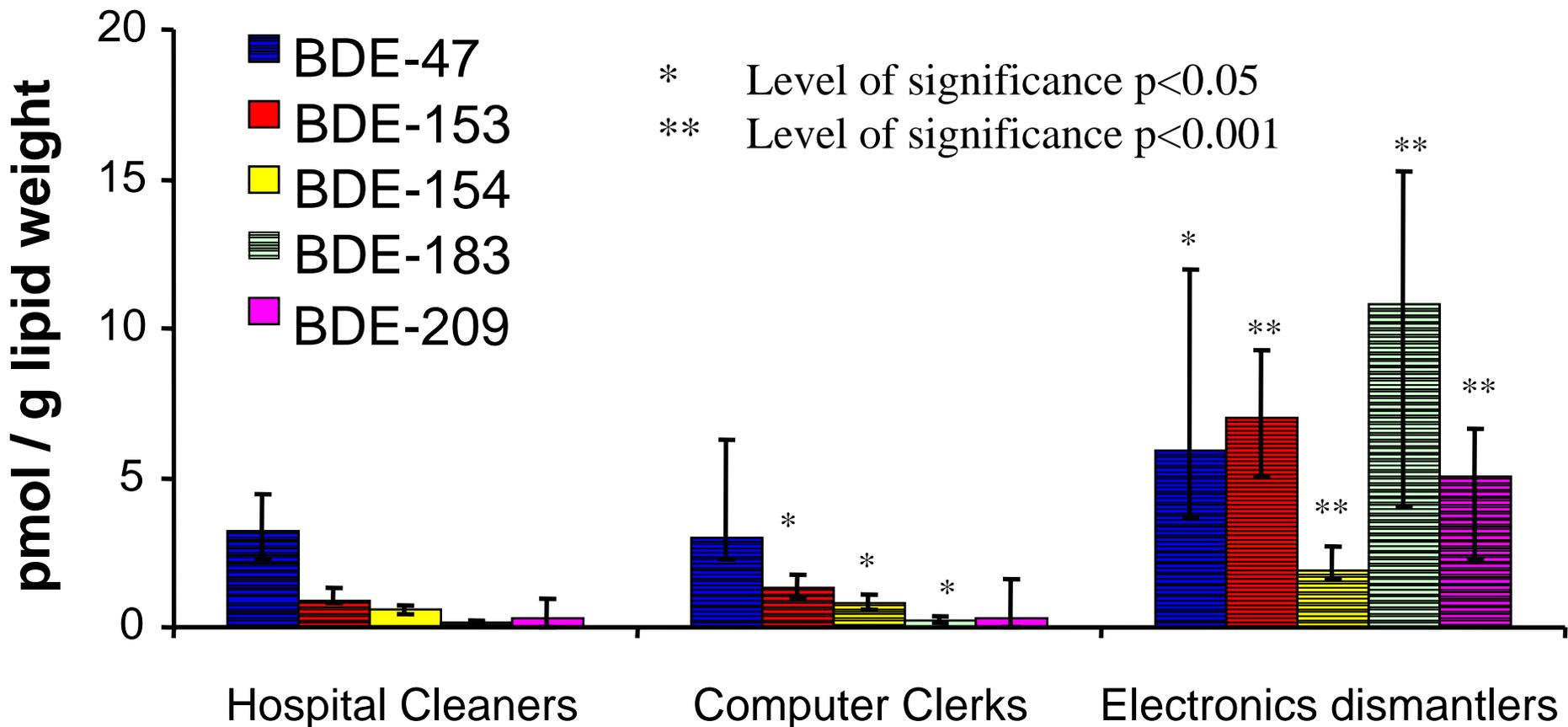


Likely Routes of Exposure

- Dust
- Sludge, food
- Air deposition
- Similar to dioxin exposures?
- Occupation, diet

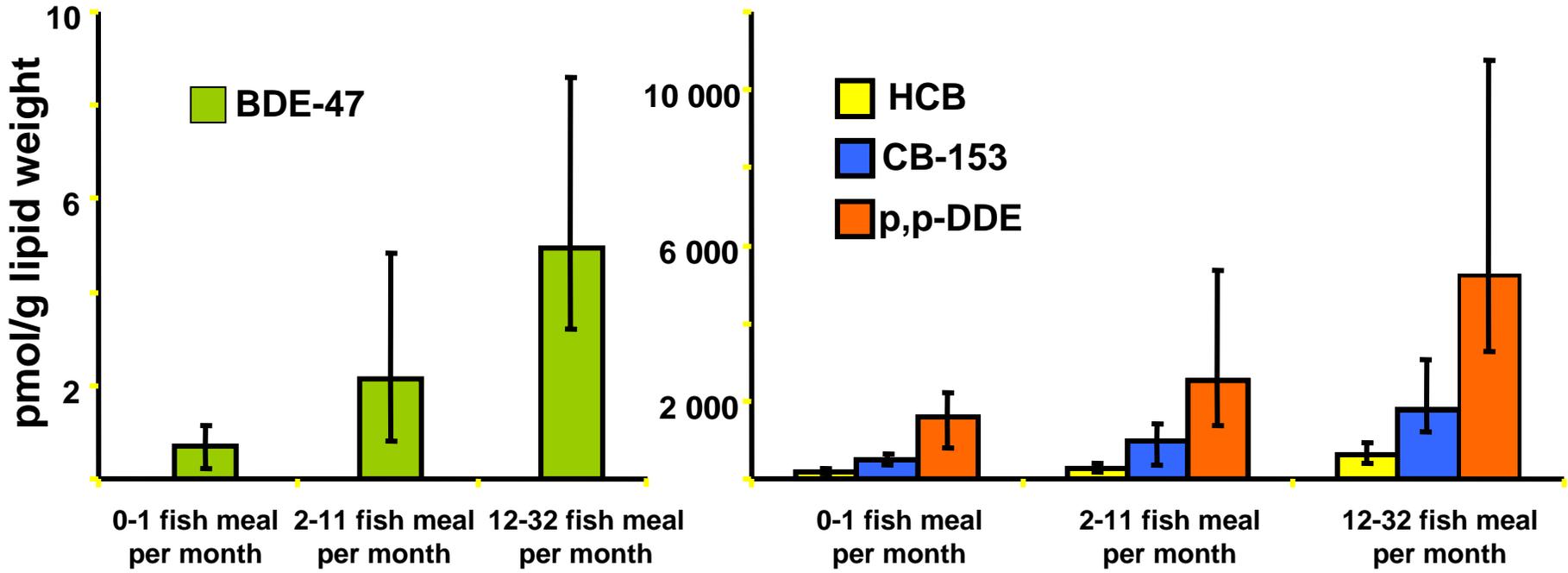


Serum PBDE Levels in Three Occupational Groups



Sjodin et.al. Environ. Health Perspect. 1999, 107, 643-47.

Dietary Exposure to Organohalogen Compounds



Sjodin et.al. Environ Health Perspectives, 2000, 108, 1035-41.



Stakeholder Response

- Communities/ NGOs:
 - Immediate regulatory ban
 - Community bio-monitoring
 - Implement Precautionary Principle
- Industry:
 - Electronics industry
 - voluntary phase out:
 - » printed circuit boards, outer casings
 - concern over alternatives
 - » Toxicity unknown, less effective flame retardant
 - Plastics industry
 - » used in many mixtures; will take time to find alternatives
 - Great Lakes Chemical
 - » Under pressure from US EPA Region 9 government-industry-activist roundtables



Regulatory Response

- Europe:
 - Waste Electronic and Electrical Equipment Directive and Reduction of Hazardous Substances (ROHS)
 - Ban of penta and octa; equivocal deca risk assessment
- California
 - 2003 Legislation to ban/ phase out penta- and octa-BDE starting January 2008
- Other States
 - Washington Executive Order
 - Other states taking action (MA, NY, MI, etc.)
- International
 - High on the list to be added to the Stockholm POPs Convention, now ratified and in force



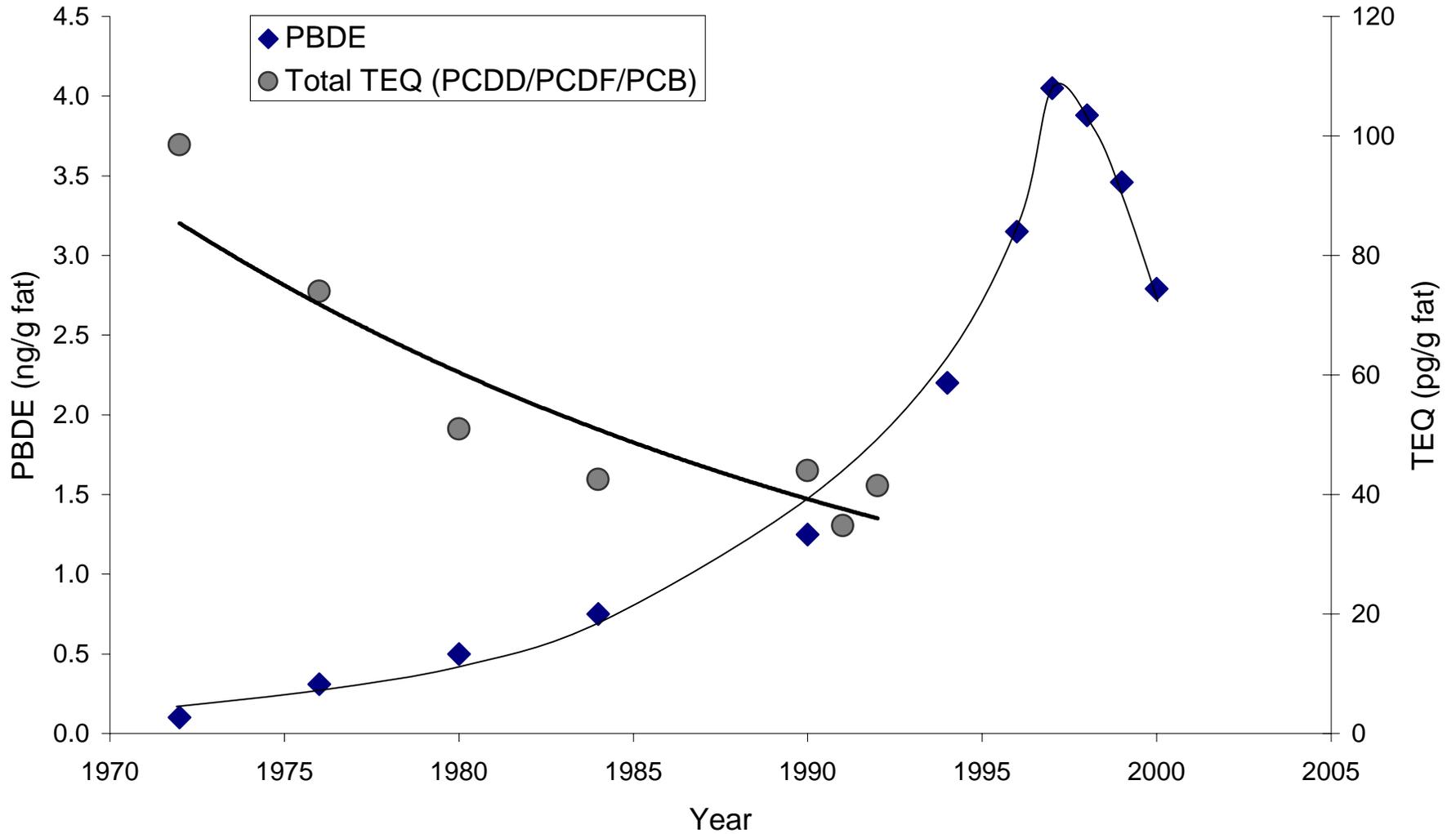


US Regulatory Activity

- **US EPA**
 - Reporting
 - Toxic Release Inventory (TRI), High Production Volume (HPV) Chemical Program
 - Testing
 - Toxic Substances Control Act (PMN)
 - Voluntary Children's Chemical Evaluation Program
- **Furniture Flammability Standards**
 - California TB 117
 - CPSC National Upholstery Standard (small flame)
 - Voluntary industry initiative in 1970s to avoid regulation gave us the BFR problem
 - Initial response of BIFMA, AFMA: working with supply chains (e.g. foamers) to find viable non-toxic alternatives

Organohalogen Compounds in Breast Milk in Sweden

(Norén K and Meironyté D, 1998; Guvenius DM and Norén K, 2001)



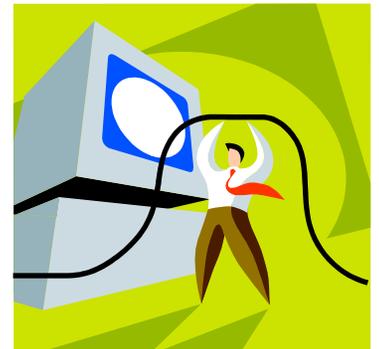
Where Are We?

- Bans work, but there's work to be done
 - Swedish breast milk data show PBDE drop off since phase-out
- Stockpiles of BFRs
 - Electronics, furniture, landfills, carpet, etc.
- How do we prevent a similar situation in the future?
 - Root cause analysis (smoking and furniture fires)
 - Product redesign
 - Full assessment of alternatives (Precautionary Principle)
 - Reconsider our chemicals management policies



Emerging Issues

- Potential exposures
 - Export of harm when recycling done off-shore
 - Use of prisoners for US electronics recycling
 - Fire fighters' occupational exposure
 - As yet unknown impact in foam, recycled foam industries (carpets, auto, etc.)
- Impact on Recycling
 - What do we do with BFR plastic from electronic waste?



Larger Impacts

- Case study for inadequacies of current chemicals management approach
 - Grossly inadequate data before chemicals put on market
 - » 85,000 chemicals in use, with 1,000 added every year
 - No data on interactions with other chemicals
 - No systematic assessment of potential persistence, bio-accumulative properties, long-range transport, breakdown, etc.
- Need:
 - Better ongoing monitoring of humans, environment
 - Better data PRIOR to putting chemicals on the market
 - Alternatives, alternatives, alternatives



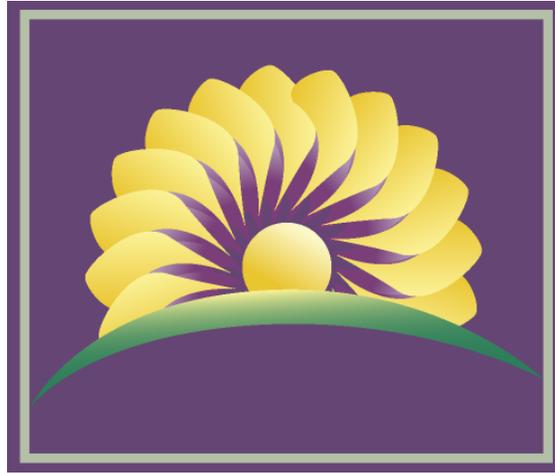
Alternatives



Concerns for HHW Facilities

- Where do BFR plastics go?
 - Check your waste handler
 - » MBA Polymers, HMR vs. overseas
- Modify handling practices to avoid liability?
 - Protect your workers
- How will your collection facility be affected by PBDE bans?





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