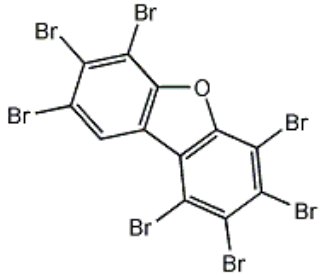
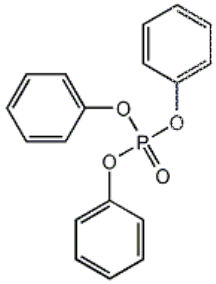
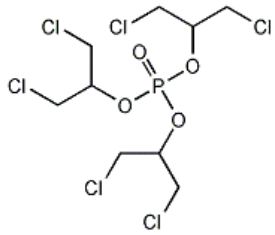
Effect and exposure analysis of contaminants in indoor dust by *in vitro* bioassays combined with chemical analysis



PBDFs



TPHP



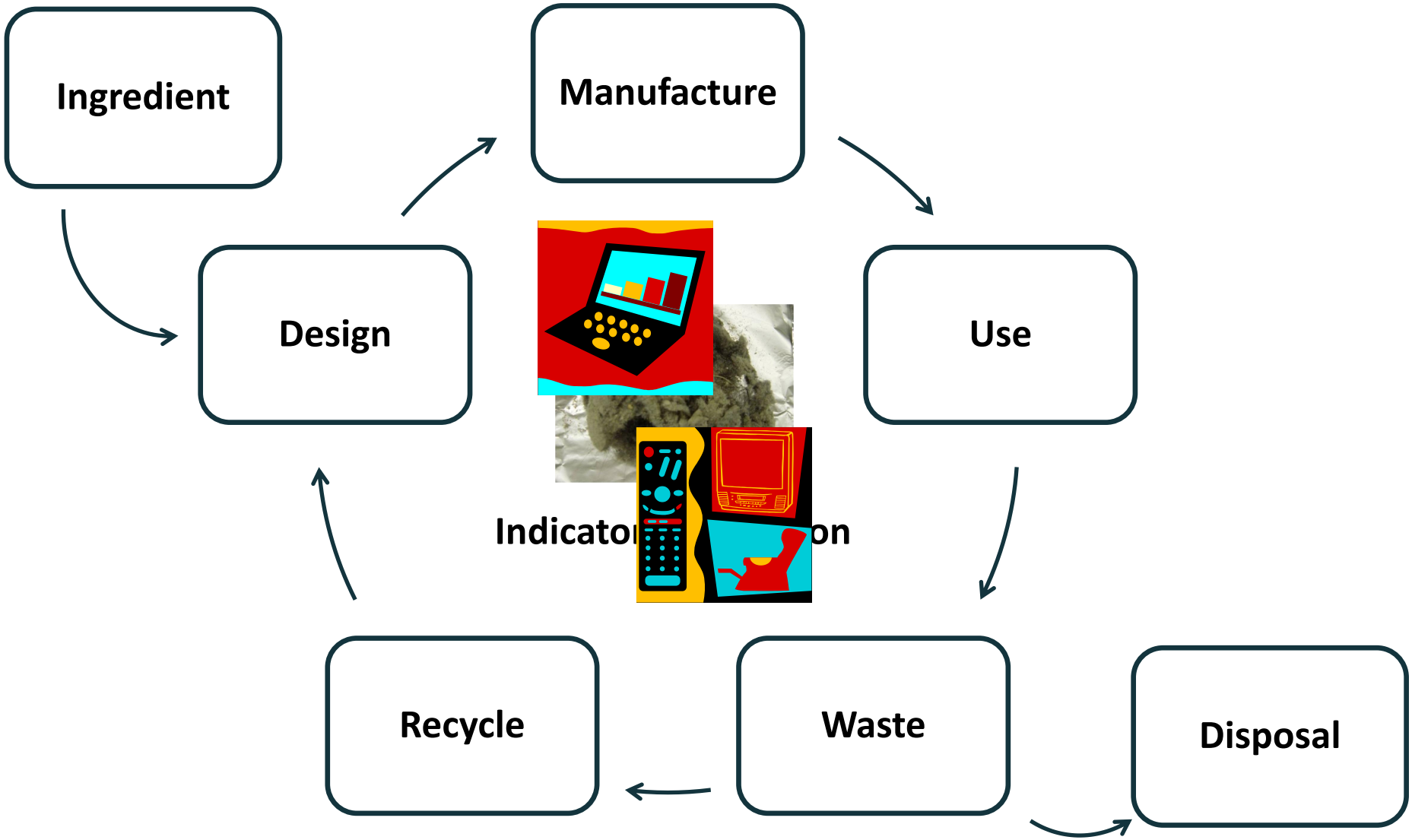
TDCIPP

Go Suzuki

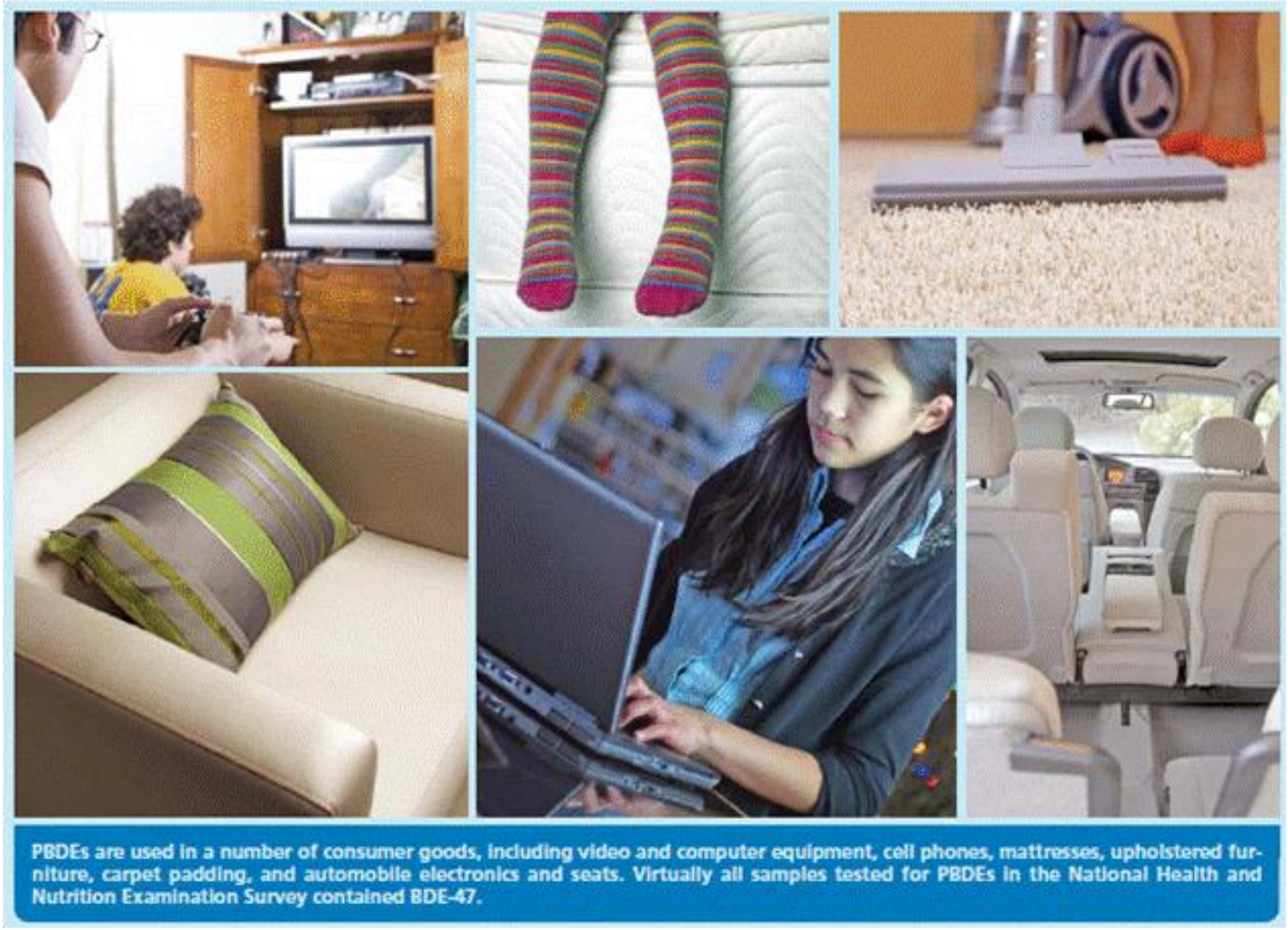
Material Lifecycle and Substance Management Section,
Center for Material Cycles and Waste Management Research,
National Institute for Environmental Studies,

Why indoor dust?

Management of resources/toxic substances during product lifecycle



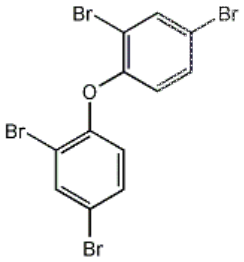
Concern about flame retardants (FRs) in indoor dust



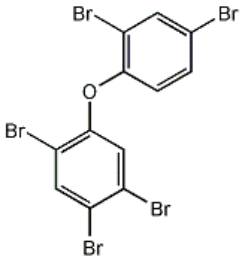
PBDEs are used in a number of consumer goods, including video and computer equipment, cell phones, mattresses, upholstered furniture, carpet padding, and automobile electronics and seats. Virtually all samples tested for PBDEs in the National Health and Nutrition Examination Survey contained BDE-47.

Betts *Environ Health Perspect* 2008

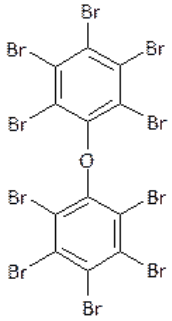
FRs detected in house dust around the world



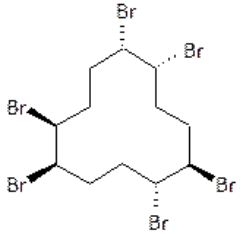
BDE-47



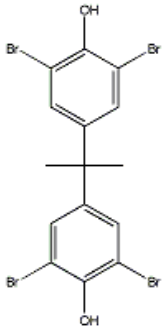
BDE-99



BDE-209



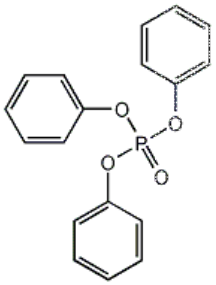
γ-HBCD



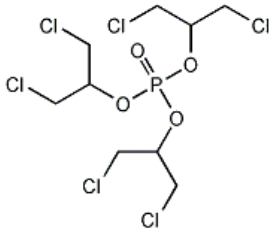
TBBPA

Brominated FRs

Indoor dust



TPhP

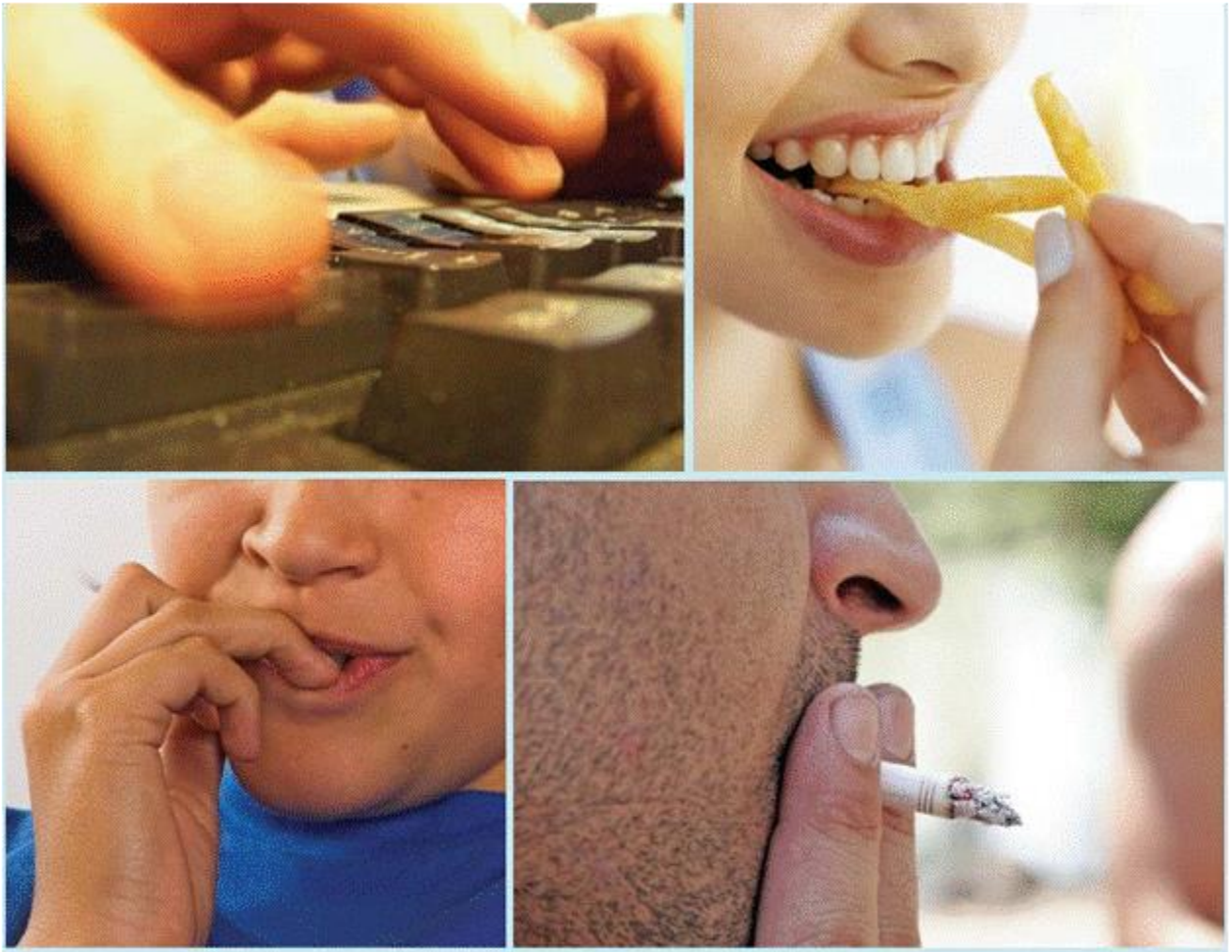


TDCIPP

Phosphorus FRs

Brommer et al. *J Environ Monitor* 2012; Marklund et al. *Chemosphere* 2003; Stapleton et al. *Environ Sci Technol* 2005;2009; Suzuki et al. 2008; 2010, Takigami et al. *Environ Int* 2009; Van den Eede et al. *Environ Int* 2011

Importance of indoor dust as human exposure pathway for FRs



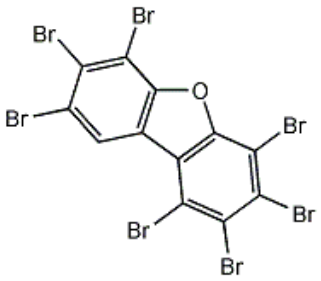
Hand-to-mouth exposure is thought to account for much of people's intake of PBDEs. Although this may help explain why some of the highest concentrations of PBDEs have been found in children's blood, hand-to-mouth exposure isn't just for toddlers—adults may unwittingly consume the chemicals as they smoke, eat, or bite their nails.

Betts *Environ Health Perspect* 2008

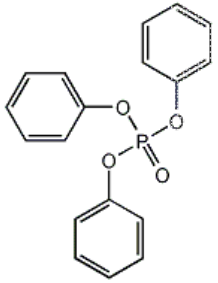
Need for effective chemical assessment to reveal contaminants

Indoor dust

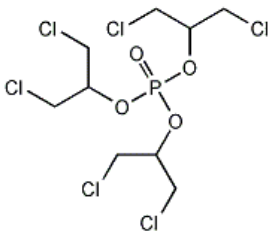
Effect and exposure analysis by using CALUX assays



PBDFs



TPhP



TDCIPP

Important pollutants

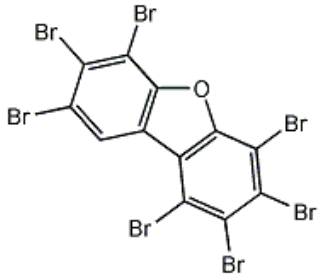
Topics

Effect and exposure analysis by using

DR-CALUX assay and steroidal CALUX assays

Effect and exposure analysis by using DR-CALUX assay

Dioxin-like compounds



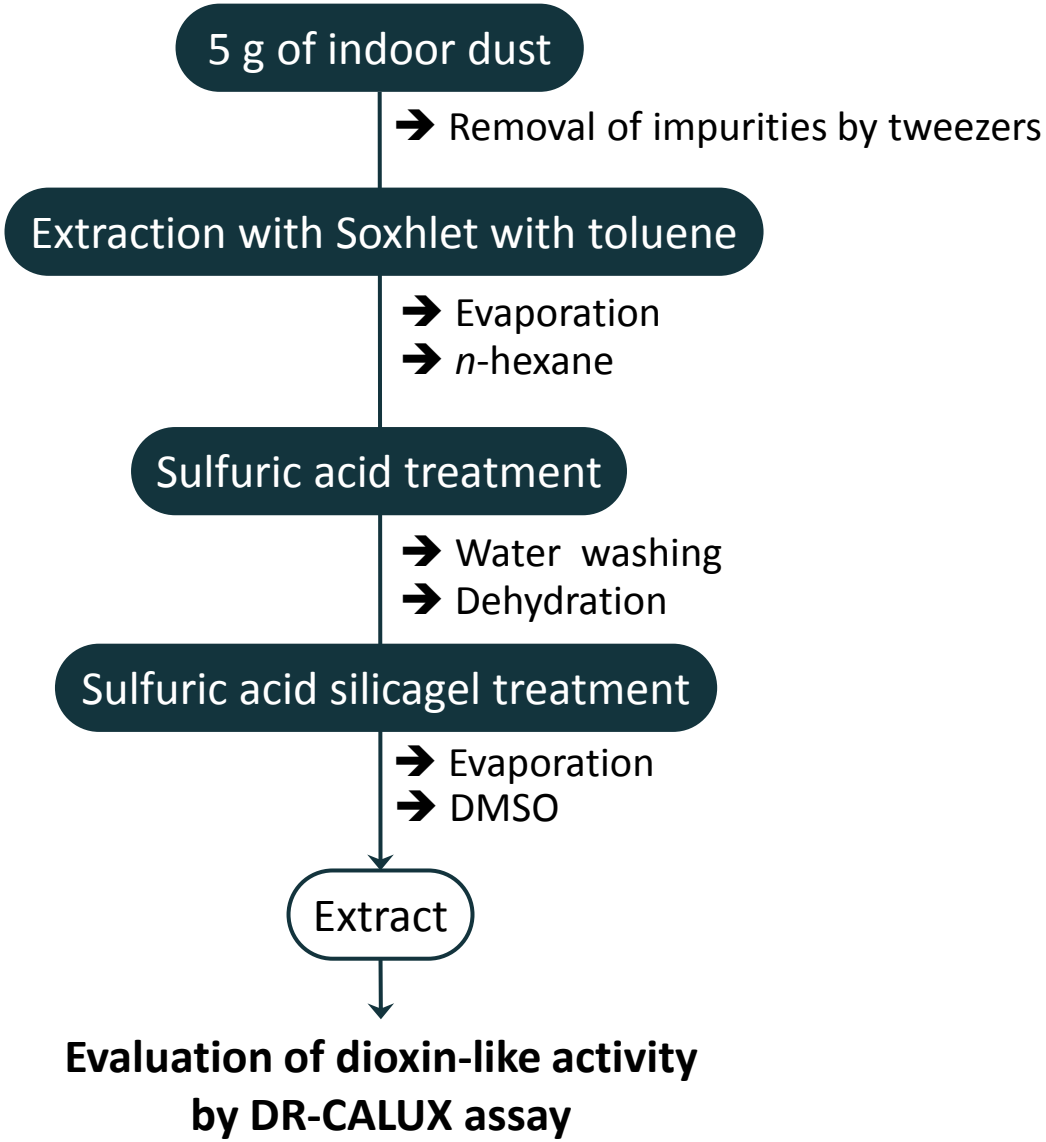
PBDFs

Impurity in commercial PBDE mixture

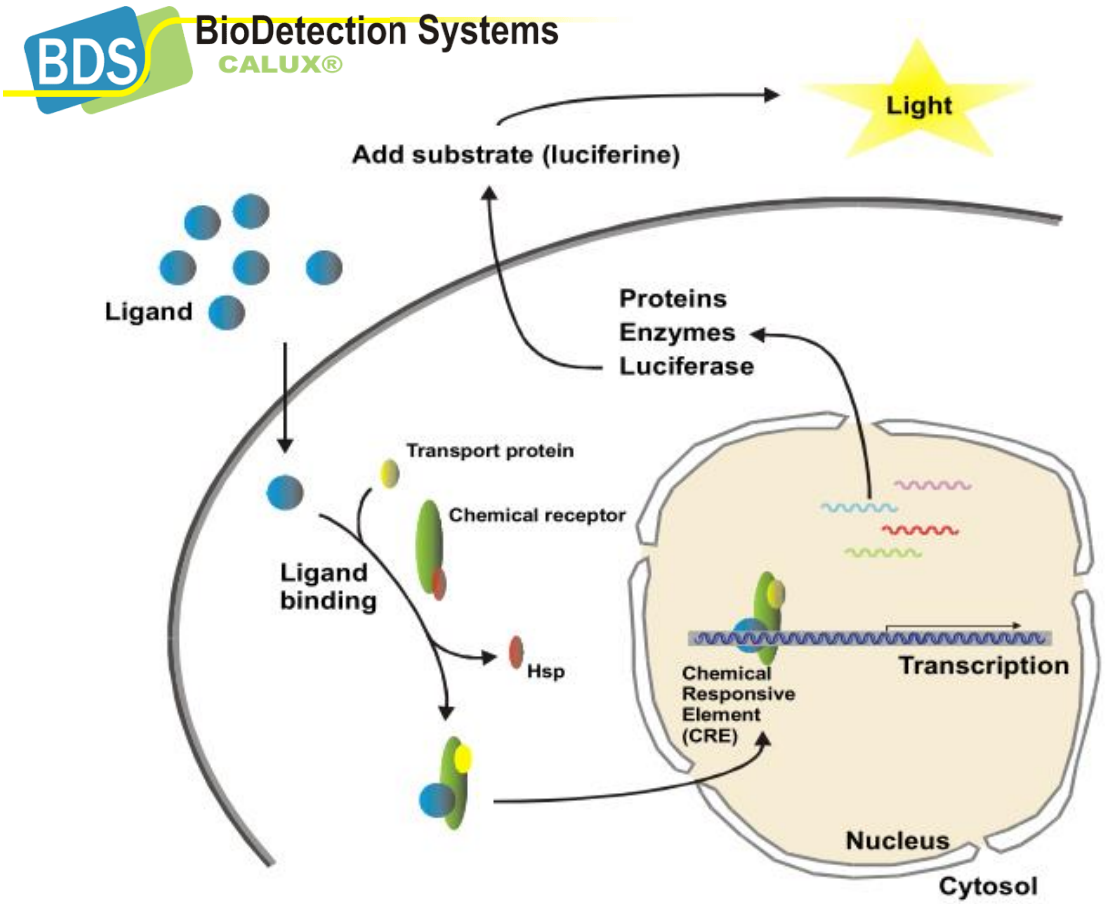
Decomposition product from PBDEs

Suzuki et al. *Environ Sci Technol* 2007; 2010

Tested indoor dust extract

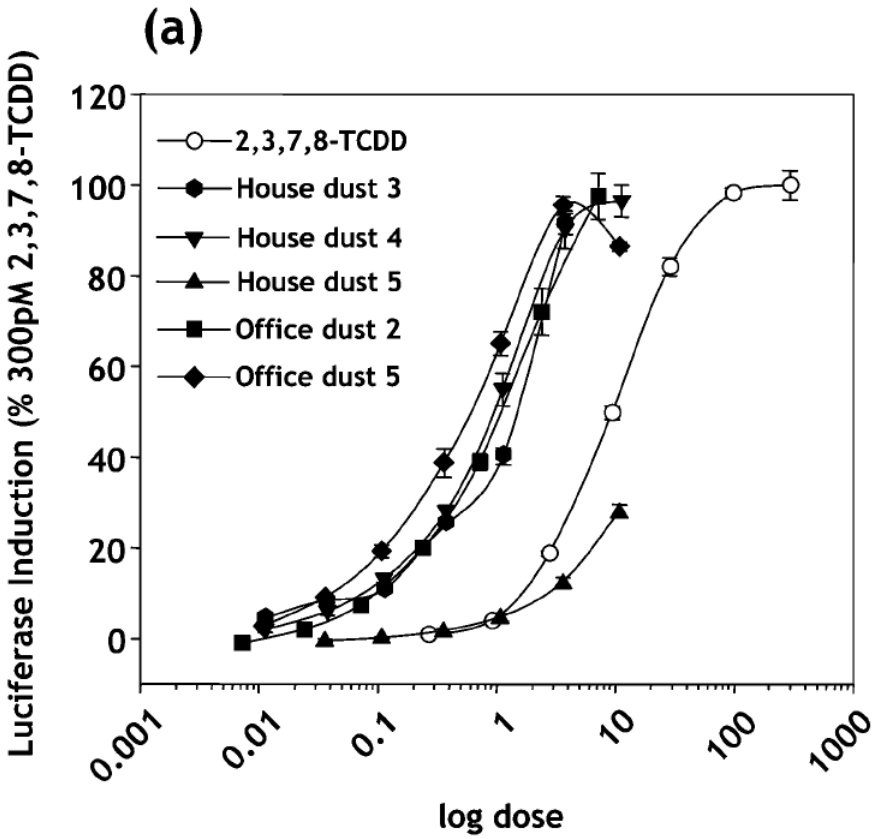


DR-CALUX assays for detection of dioxin-like compounds



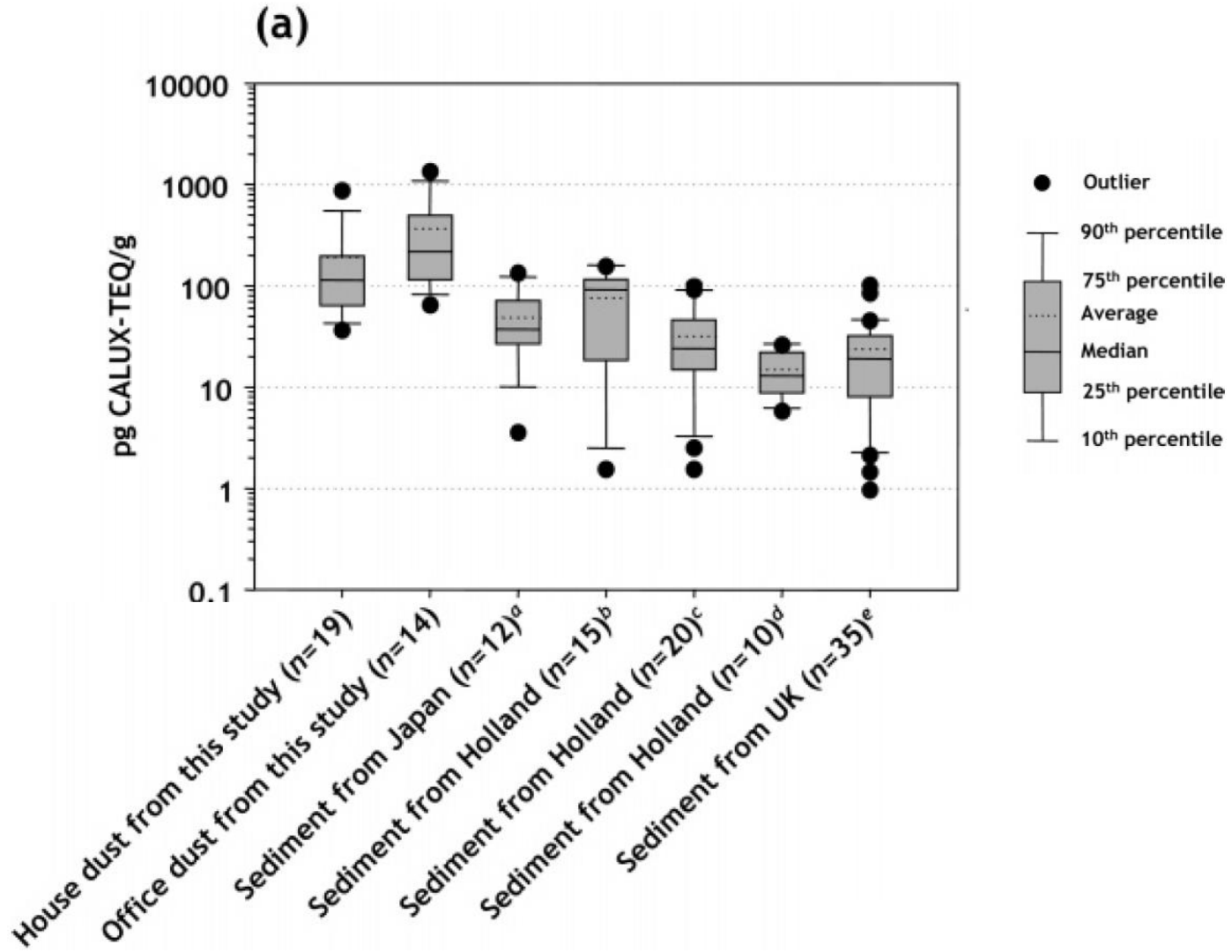
DR-CALUX reporter gene assays with rat H4IIE

Dose-response of indoor dust extracts on DR-CALUX cells



pM 2,3,7,8-TCDD in well
mg dust in well

CALUX-TCDD equivalent for indoor dust extracts



CALUX-TEQ for indoor dust extracts from Vietnam

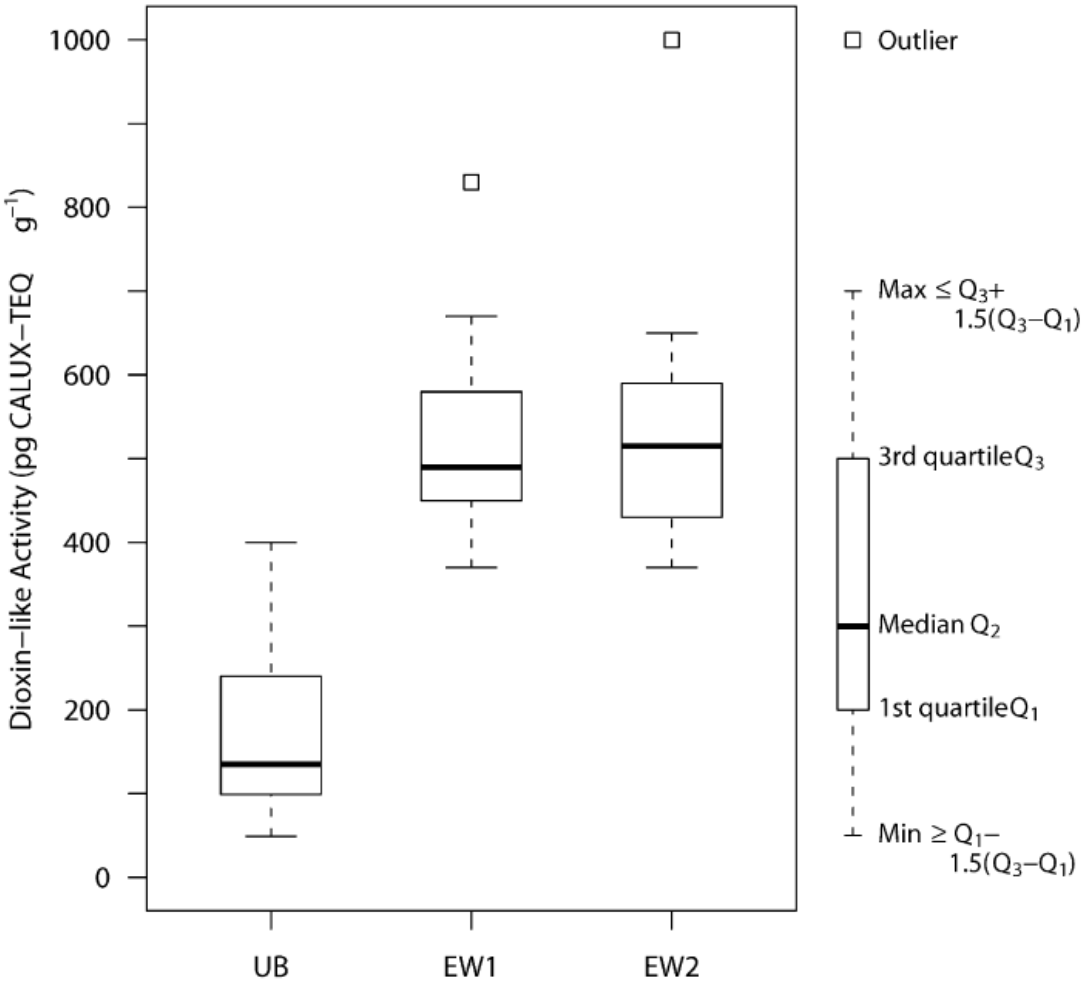
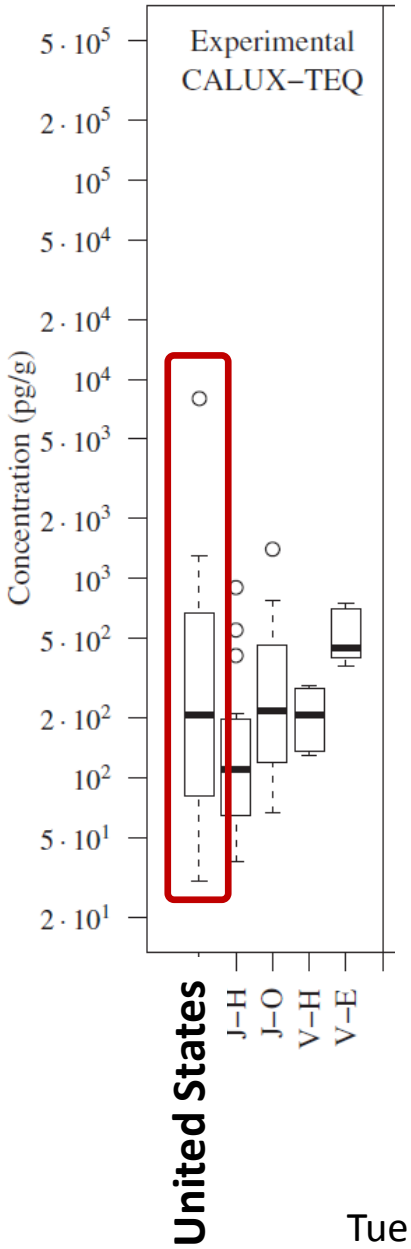


FIGURE 1. Dioxin-like activities determined using DR-CALUX in settled house dust from the urban (UB) and e-waste recycling (EW1 and EW2) sites.

Tue et al. *Environ Sci Technol* 2010

CALUX-TEQ for indoor dust extracts from United States



Tue et al. *Environ Sci Technol* 2013

Average daily doses of dioxin-like compounds via house dust

TABLE 2. Average Daily Doses (ADDs; in pg CALUX-TEQ/day) of Dioxin-Like Compounds via House Dust for Adults (at Least 18 Years) and Children (1–5 Years)[a]

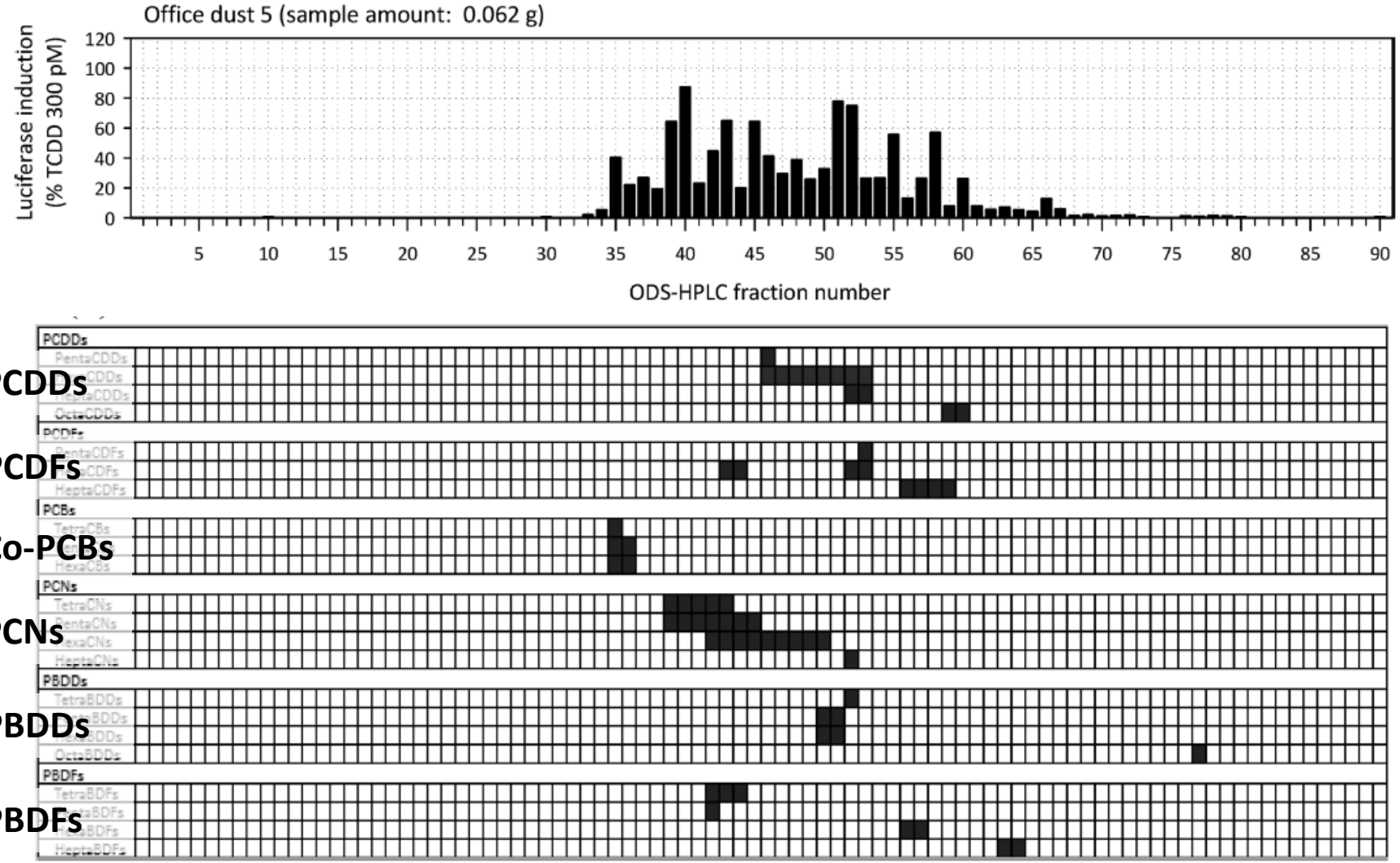
	adults (18+ yrs old)				
dust ingestion	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile
moderate scenario[b]	0.024	0.036	0.062	0.11	0.33
worst scenario[c]	0.84	1.3	2.2	3.9	12
	children (1–5 yrs old)				
dust ingestion	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile
moderate scenario[d]	2.1	3.3	5.5	10	29
worst scenario[e]	8.4	13	22	39	120

[a] Estimation explained in detail under "Assessment of Exposure to Dioxin-Like Compounds in House Dust" in Discussion and in Supporting Information. [b] Assuming dust ingestion of 0.00056 g/day as a moderate scenario for adults (*1*, *6*). [c] Assuming dust ingestion of 0.02 g/day as a worst-case scenario for adults (*5*, *34*). [d] Assuming dust ingestion of 0.05 g/day as a moderate-case scenario for children (*5*, *34*, *36*). [e] Assuming dust ingestion of 0.2 g/day as a worst-case scenario for children (*1*, *5–7*, *35*, *37*).

WHO TDI for dioxins: 1 to 4 pg WHO-TEQ/kg

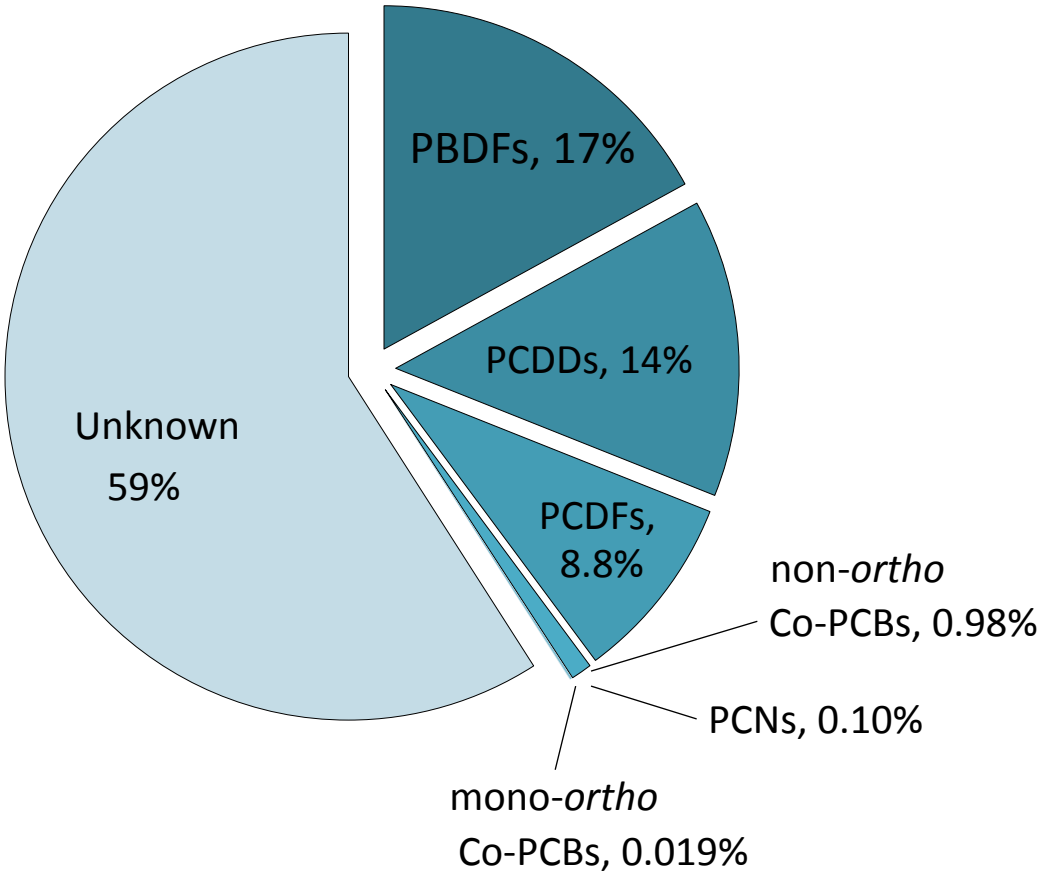
DR-CALUX-directed chemical analysis for indoor dust

Well-known dioxin-like compounds were detected in fractions indicating activities



PBDFs are an important contributor

Median-based contribution ratio for dioxin-like compounds in indoor dust (*n*=33)



TOXICOLOGICAL SCIENCES 133(2), 197–208 2013
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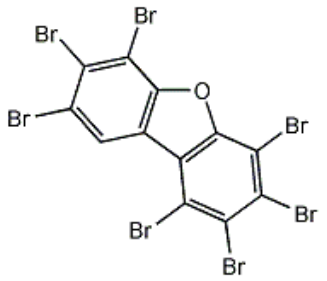
Advance Access publication March 14, 2013

REVIEW

Polybrominated Dibenzo-*p*-Dioxins, Dibenzofurans, and Biphenyls: Inclusion in the Toxicity Equivalency Factor Concept for Dioxin-Like Compounds

Martin van den Berg,[1,*] Michael S. Denison,[†] Linda S. Birnbaum,[‡] Michael J. DeVito,[‡] Heidelore Fiedler,[§] Jerzy Falandysz,[¶] Martin Rose,[‖] Dieter Schrenk,[‖‖] Stephen Safe,[‖‖‖] Chiharu Tohyama,[#] Angelika Tritscher,[**] Mats Tysklind,[††] and Richard E. Peterson[‡‡]

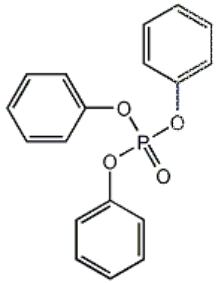
Another source of direct human exposure to PBDDs and PBDFs is house and office dust, which may originate from wear and tear processes of common household products, e.g., polyurethane foam, TV sets, computers, and other electronic and electrical equipment, containing flame retardants such as PBDEs. 2,3,7,8-Substituted PBDDs and PBDFs are detected at significant quantities, e.g., in house dust and sewage sludge (Brorstrom-Lunden *et al.*, 2010; Suzuki *et al.*, 2010). If similar TEF values are applied for the 2,3,7,8-substituted PBDDs and PBDFs as for the chlorinated congeners, the brominated congeners can contribute up to 17% of the total amount of TEQs in Japanese house dust (Suzuki *et al.*, 2010). Due to the wide-



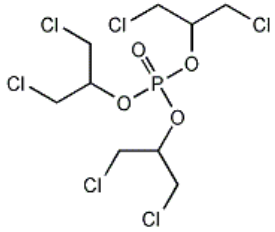
PBDFs

Effect and exposure analysis by using steroidal CALUX assay

Endocrine-disrupting compounds



TPHP



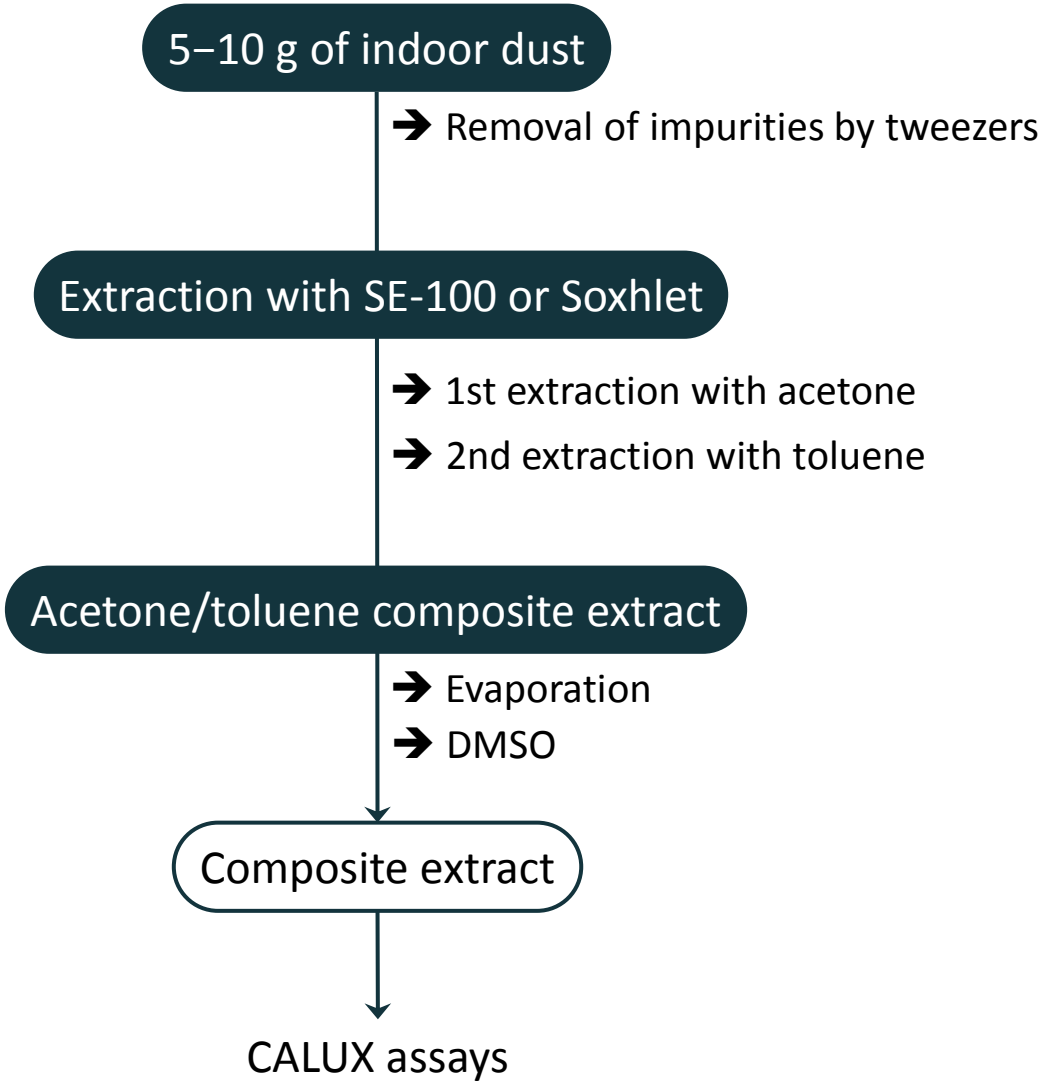
TDCIPP

?

Others

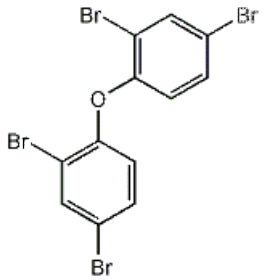
Suzuki et al. *Environ Sci Technol* 2013

Tested indoor dust extract of Japan, US, PHL, VN and IND

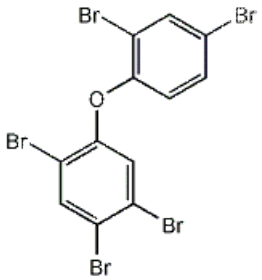


Tested brominated FRs

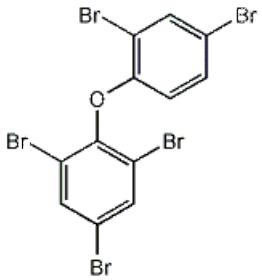
PBDEs designated as POPs



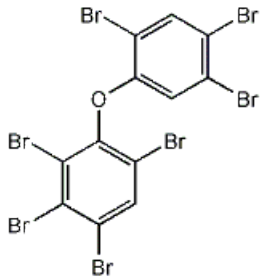
BDE-47



BDE-99

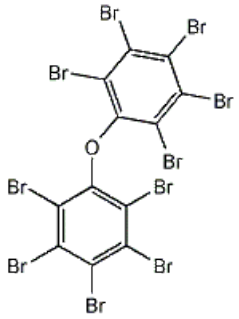


BDE-100

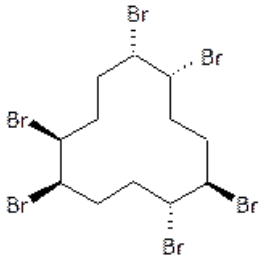


BDE-183

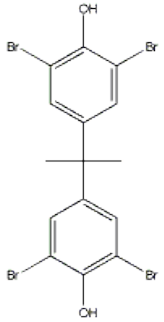
Major brominated FRs in the world



BDE-209



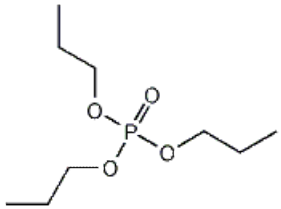
γ-HBCD



TBBPA

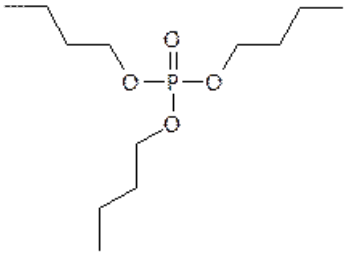
Tested phosphorus FRs

Phosphorus FRs detetcted in house dust at high concentration



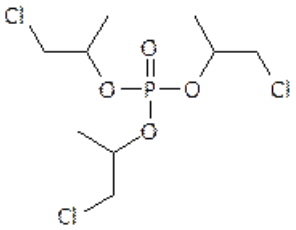
TPrP

(Tripropyl phosphate)



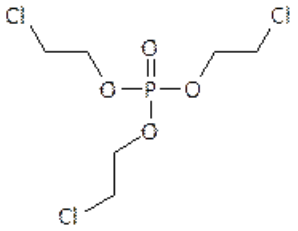
TBP

(Tributhyl phosphate)



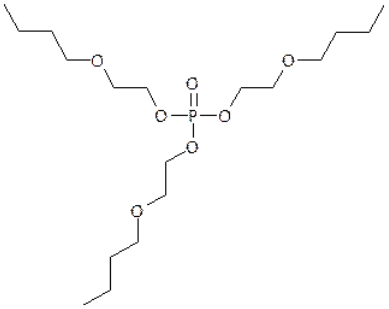
TCIPP

(Tris(2-chloroisopropyl)phosphate)



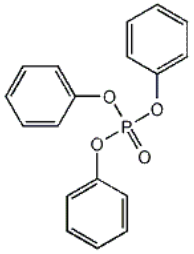
TCEP

(Tris(2-chloroethyl)phosphate)



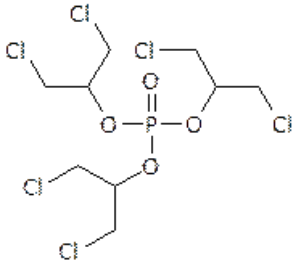
TBEP

(Tris(2-butoxyethyl) phosphate)



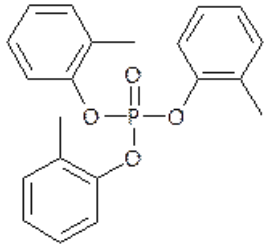
TPhP

(Triphenyl phosphate)



TDCIPP

(Tris(1,3-dichloroisopropyl)phosphate)



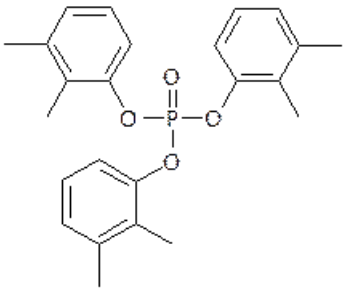
TCP

(Tricresyl phosphate)

Brommer et al. *J Environ Monitor* 2012; García et al. *J Chromatogr A* 2007; Kanazawa et al. *Indoor Air* 2010; Marklund et al. *Chemosphere* 2003; Stapleton et al. *Environ Sci Technol* 2009; Takigami et al. *Environ Int* 2009; Van den Eede et al. *Environ Int* 2011

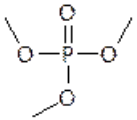
Phophorus FRs

Others



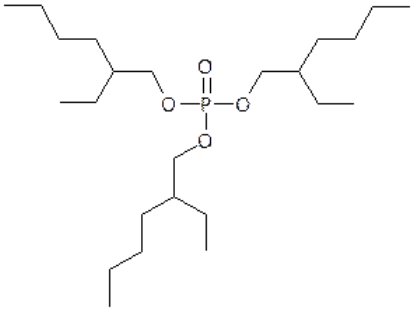
2,6-TXP

(Tris(2,6-dimethylphenyl) phosphate)



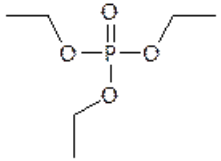
TMP

(Trimethyl phosphate)



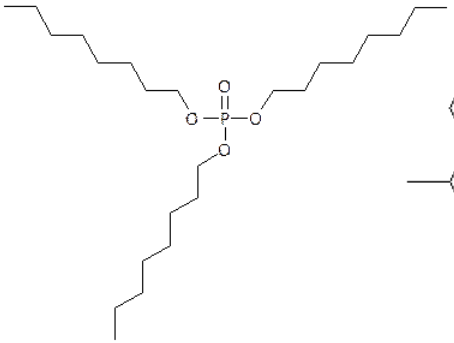
TEHP

(Tris(2-ethylhexyl) phosphate)



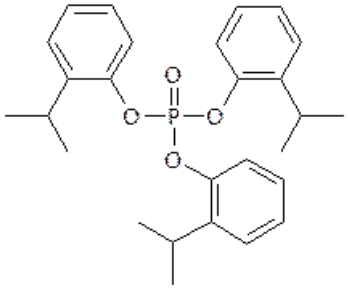
TEP

(Triethyl phosphate)



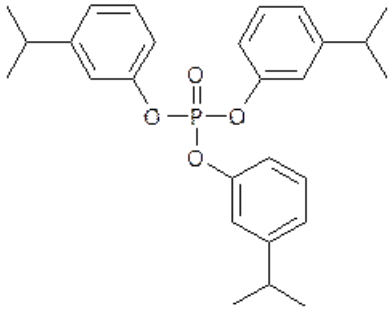
TOP

(Trioctyl phosphate)



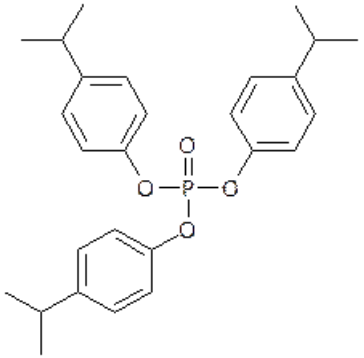
2-TIPP

(Tris(2-isopropylpenyl)phosphate)



3-TIPP

(Tris(3-isopropylpenyl)phosphate)

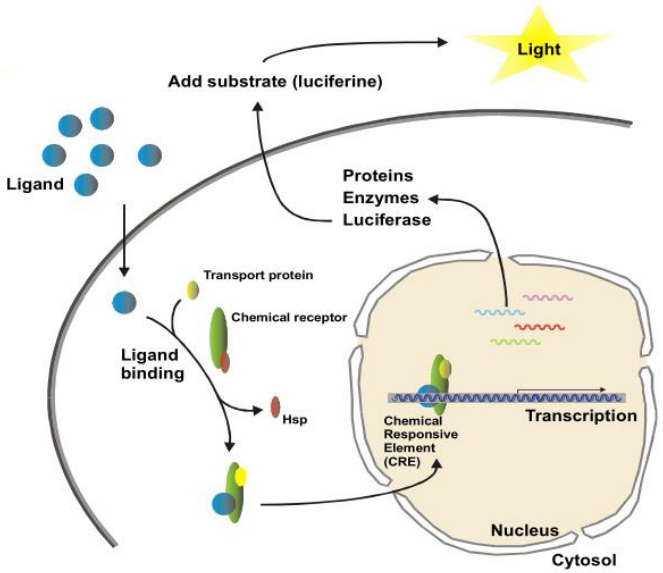


4-TIPP

(Tris(4-isopropylpenyl)phosphate)

CALUX assays for detection of endocrine-disrupting potencies

BioDetection Systems
CALUX®

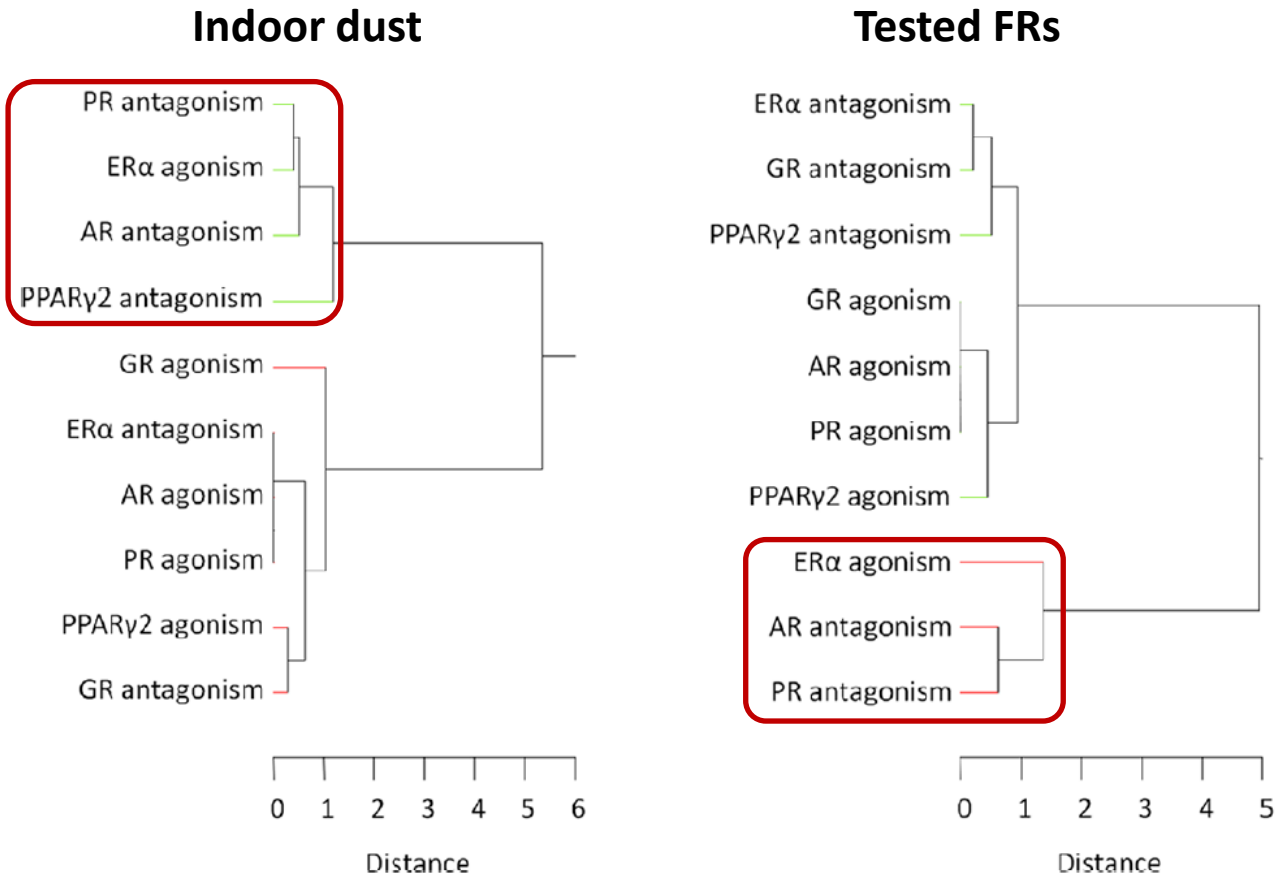


Androgen receptor (AR)
Estrogen receptor α (ERα)
Progesterone receptor (PR)

Glucocorticoid receptor (GR)
Peroxisome proliferator–activated receptor γ2 (PPARγ2)

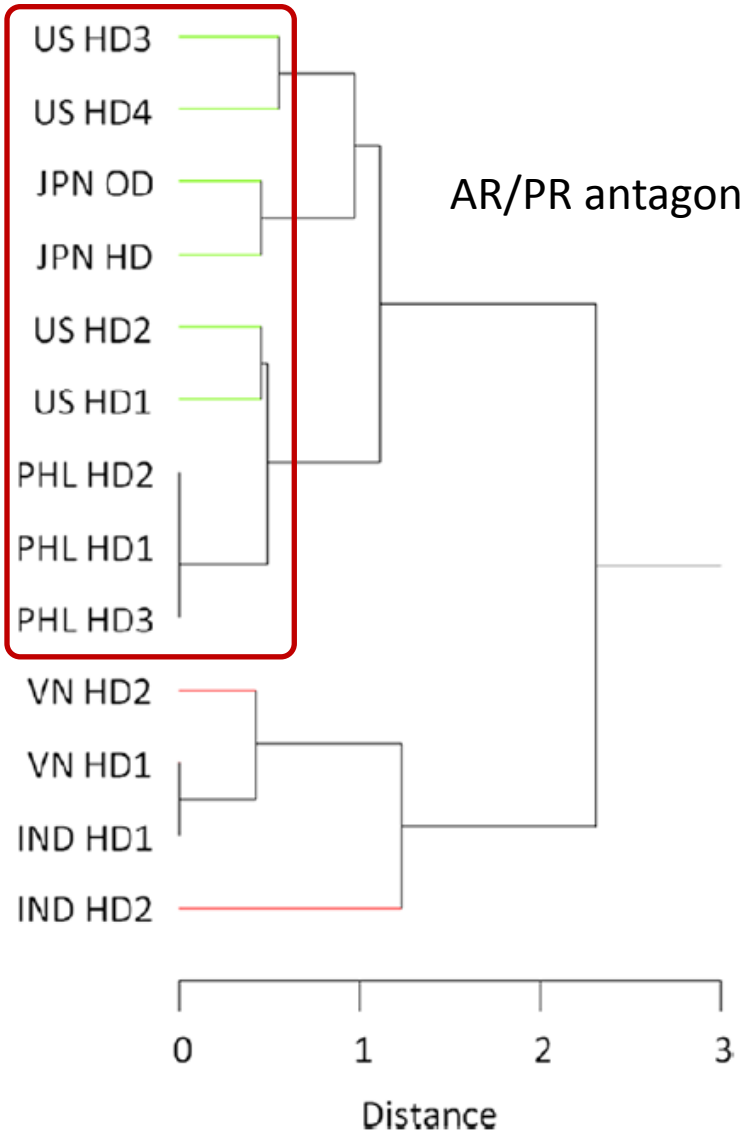
➔ Receptor-mediated agonistic and antagonistic potency

Hierarchical clustering for detected end points of indoor dust and FRs



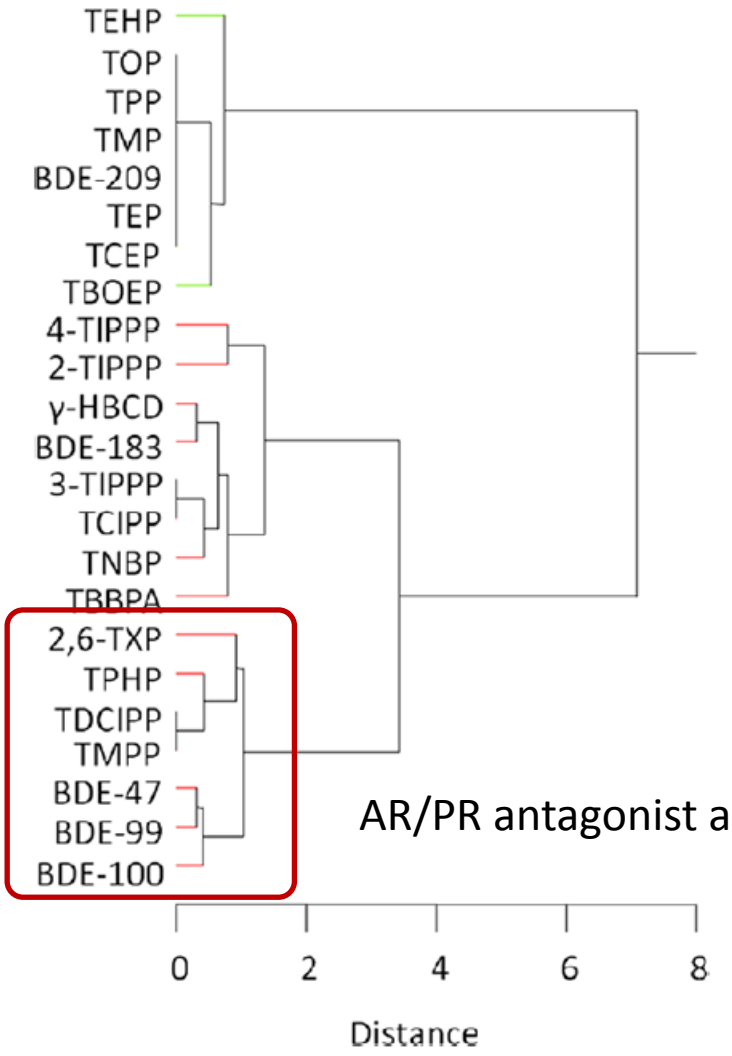
High-frequency effects: AR/PR antagonist and ERα agonist

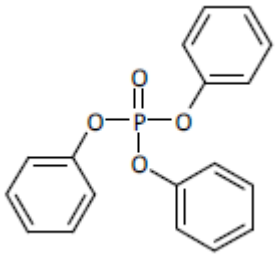
Hierarchical clustering for indoor dust



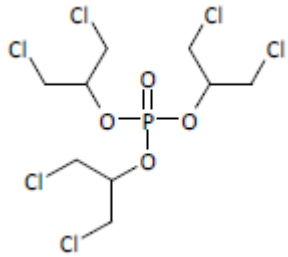
AR/PR antagonist and ERα agonist

Hierarchical clustering for tested FRs





TPHP

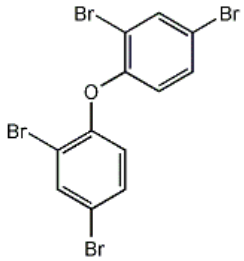


TDCIPP

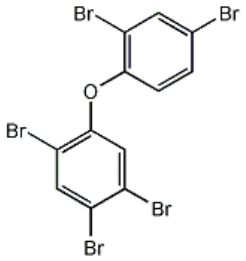
AR/PR antagonist and ERα agonist

FRs concentration in indoor dust from Japan (ng/g)

PBDEs designated as POPs (*n*=8)

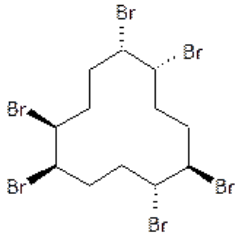


BDE-47
Median: 4.8
Range: 0.90 - 22

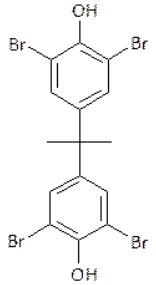


BDE-99
Median: 6.0
Range: 0.60 - 15

Major brominated FRs (*n*=8)

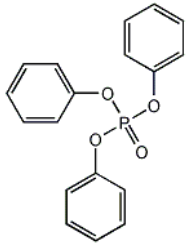


HBCDs
Median: 740
Range: 72 - 1300

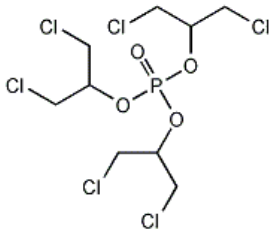


TBBPA
Median: 77
Range: 7.0 - 290

Phosphorus FRs (*n*=8)



TPHP
Median: 1200
Range: 110 - 2600

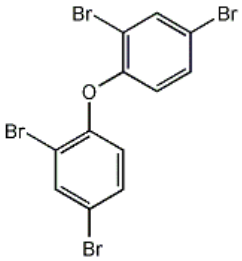


TDCIPP
Median：1700
Range：69 - 18000

Takigami et al *Environ Int* 2009

FRs concentration in indoor dust from US (ng/g)

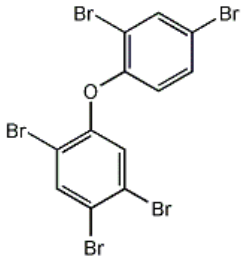
PBDEs designated as POPs (*n*=17)



BDE-47

Median: 640

Range: 100 - 2100

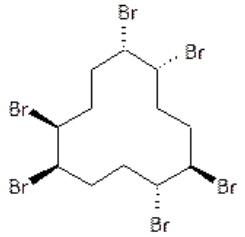


BDE-99

Median: 680

Range: 160 - 13800

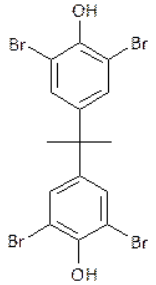
Major brominated FRs (*n*=50)



HBCDs

Median: 240

Range: < 2 - 2800

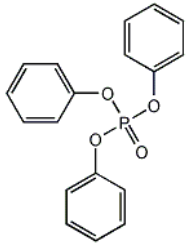


TBBPA

Median: -

Range: -

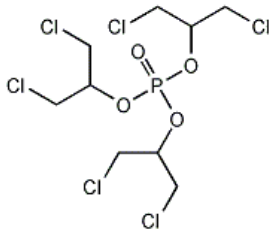
Phosphorus FRs (*n*=50)



TPHP

Median: 5500

Range: < 150 - 1800000



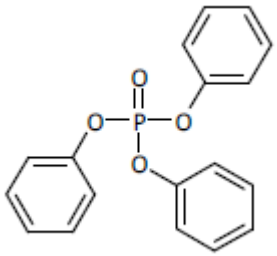
TDCIPP

Median：1900

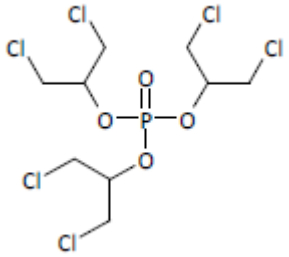
Range： < 90 - 56000

Stapleton et al *Environ Sci Technol* 2005; 2009

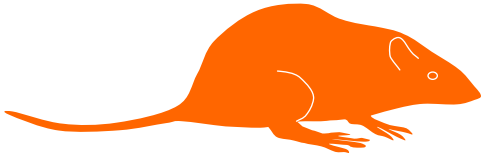
On-going studies



TPHP

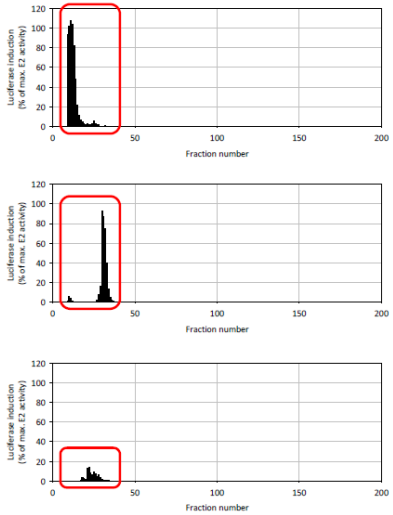


TDCIPP



In vivo experiment
(Anti-androgenic effects)

Indoor dust extract



Identification
&
Quantification

Effect-directed chemical analysis

Thank you for kind attention!

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