The significance of classroom dust ingestion as a pathway of exposure of young children to Perfluoroalkyl compounds and Brominated flame retardants.

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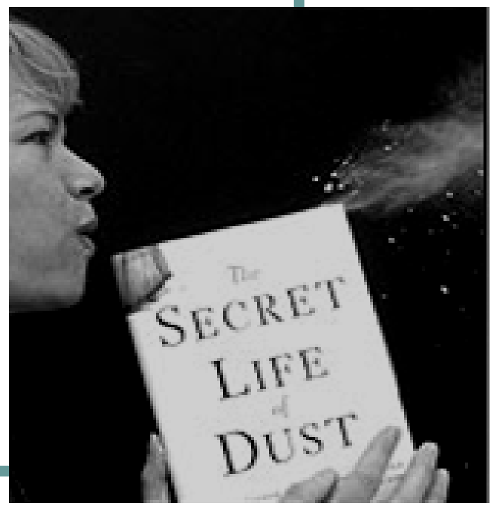

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Exposure to POPs

- Exposure to POPs via indoor pathways can rival exposure from dietary sources in the case of some compounds.
- Children more susceptible to the impacts of POPs; compounded by higher exposures due to e.g. higher dust ingestion and increased time spent in certain indoor environments.
- Monitoring of indoor environments primarily frequented by young children – better estimation of the exposure (and risk) children endure.
- Increased electronics and incorporation of information technology lessons at younger ages has potentially increased the sources of some brominated flame retardants in classrooms.

Indoor Contamination

- Treated goods are abundant in homes.
- Incorporation of POPs to building materials and building sealants and coatings.
- Higher emissions compounded by low ventilation rates.
- Removal can be minimal – vacuuming and room ventilation are the main losses of compounds in a room.
- Polyurethane foam filled furniture and carpet acts like a giant sponge absorbing and releasing contaminants.
- The overall objective of this study was to quantify the concentrations within indoor environments, in the context of characterising child exposure

Dust Ingestion

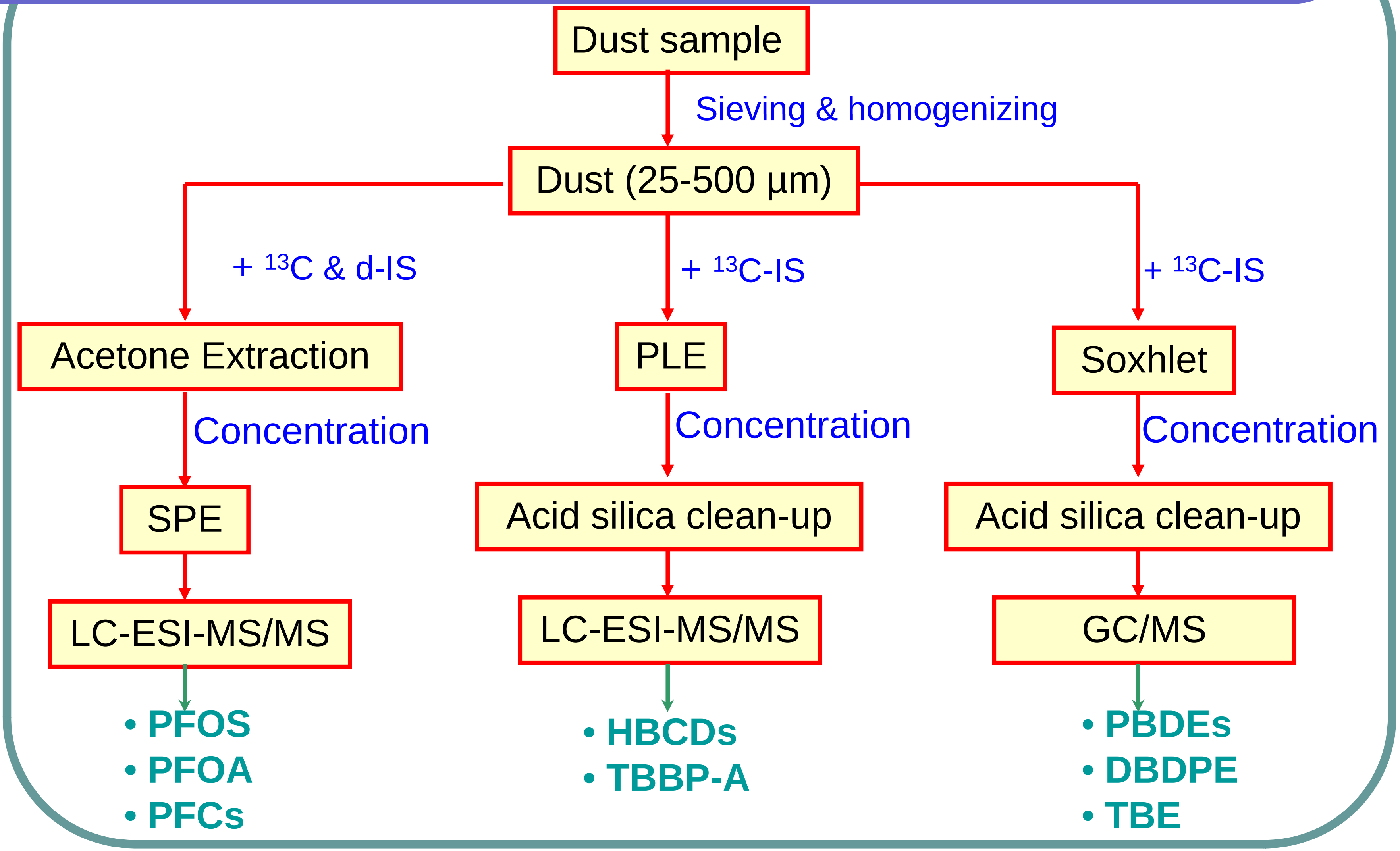
- Release of compounds from wear and tear of consumer household goods, release from cooking utensils when heated, and release from clothing.
- The main intake of dust is via ingestion, mainly via hand-to-mouth and object-to-mouth behaviour, with an increased rate for children.

House Dust Ingestion Rate (mg/d)		Oomen et al, 2008, RIVM Report
Adult	Child	
0.56 - 100	20 - 200	Various Studies collated
50	100	Average Ingestion

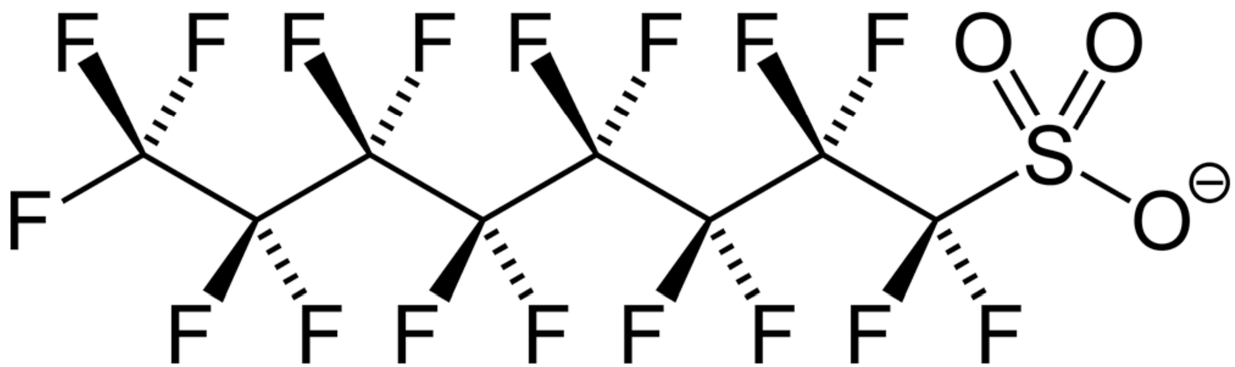
Sampling in Schools & Nurseries

- 43 school and nursery classrooms sampled (Birmingham and Shropshire, UK, 03/08 – 11/08)
- Age range: 0 yrs – 5 yrs old
- Whole room sampled
- Details of room contents noted:
  - Age of building, flooring, electronic products, textiles, vacuum frequency, ventilation.
- Inserted nylon collection sock at head of vacuum, collecting particles >25µm.

Methodology



Perfluorinated Compounds



Perfluorinated Compounds

- PFOS
  - Aqueous fire fighting foam, surface active agents for metal plating, paints and coatings, processing of rubber.
  - Degradation product of PFOSEs and PFOSAs
- PFOA
  - For high performance coatings and production aid for fluoropolymers
  - Degradation product of fluorotelomers and fluoropolymers
- Perfluorooctane sulfonamides
  - Cleaning products and water- and oil-repellent surface coatings.
  - Metabolisation / biotransformation to PFOS
- Perfluorooctane sulfonamidoethanols
  - Surface coatings (commercial products), paints and waxes.
  - Degrades to PFOS and PFOA

Presence in the Environment

- Manufacturing began in 1970s
- PFOS began to be phased out in 2001
- PFCs have been monitored in various environments around the world.
- Longitudinal transportation via oceanic and atmospheric pathways.
- Indirect releases from homes which have air concentrations 10x that of the outdoor concentrations. (Shoeib et al, 2005)
- Bioaccumulation found in fish
- Exposure to people – concentrations in blood serum and breast milk.
- PFOS found in polar bears from the Artic – indicative of degradation of precursor PFCs.

Degradation of Precursors

- Atmospheric, oceanic degradation and metabolism of precursor compounds in the environment.
- Thermal degradation of compounds in food containers and kitchen apparatus.
- Initial loss of OH radicals from perfluorosulfonamido ethanols in atmospheric degradation
- Atmospheric reactions of FTOHs resulting in PFOA.
- Metabolism of PFOSAs leads to increased PFOS and PFOA concentrations in mothers milk of mice.
- The degradation of FTOH can produce intermediates that are more toxic than PFOS and PFOA.

Quality Assurance

- Standard reference materials are not currently available for perfluorinated compounds.

- A matrix spiked homogenised dust sample was used instead.
  - Consecutively analysed for reproducibility of the method.
  - Used periodically throughout samples to assess any changes in the reproducibility, resultant of changes in extraction and analysis.

- Use of internal standards – MPFOS, MPFOA, MPFHxS, d-N-MeFOSA, d7-N-MeFOSE.

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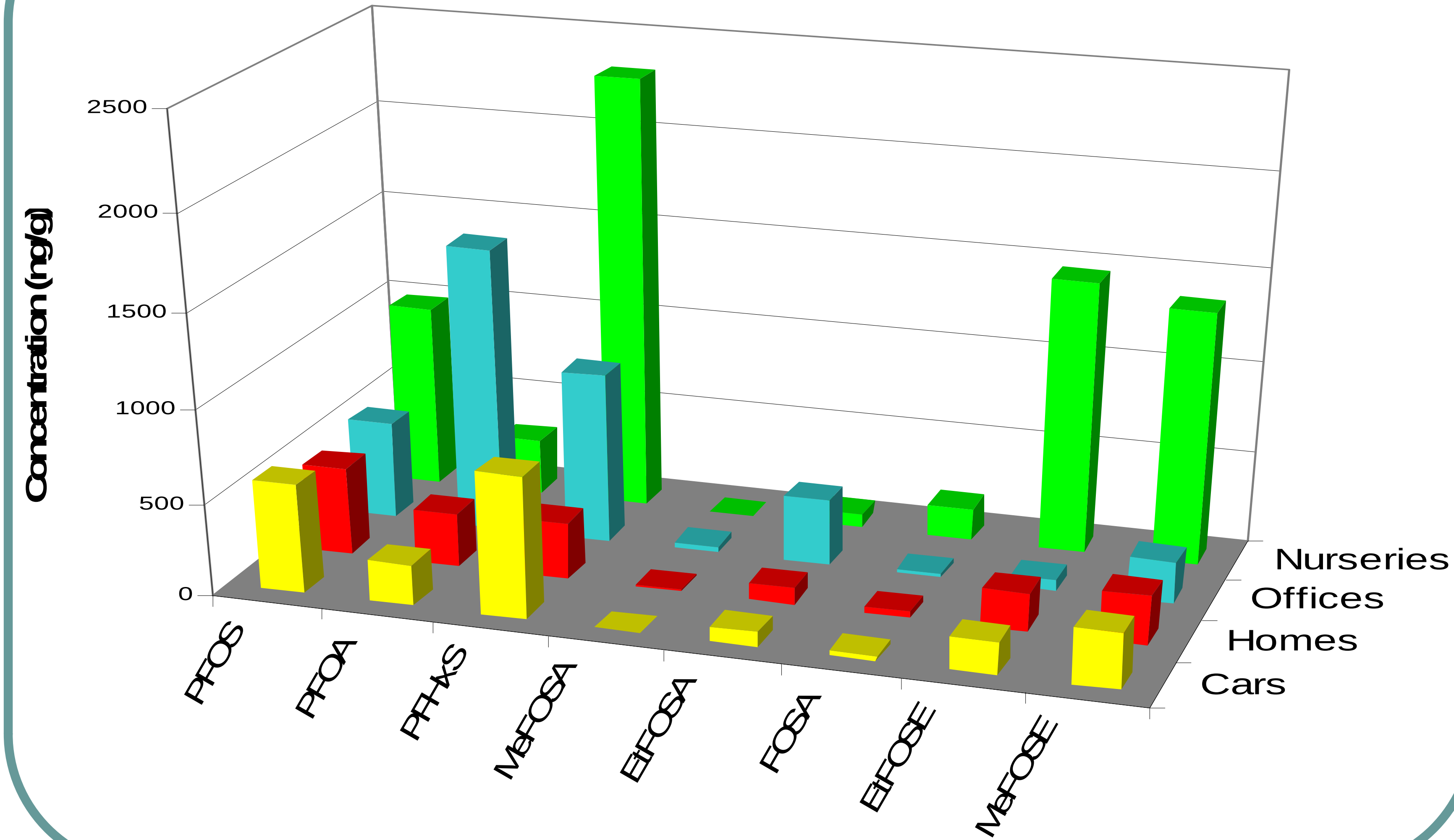
Results - Concentrations (ng/g)

Compound	5th %ile	Median	Average	95th %ile
PFOS	130	839	991	2418
PFOA	23	240	303	633
PFHxS	28	697	2318	7637
MeFOSA	<BDL	<BDL	<BDL	<BDL
EtFOSA	7	31	71	273
FOSA	6	34	173	609
EtFOSE	32	448	1462	4387
MeFOSE	109	883	1362	5498

UK Comparisons



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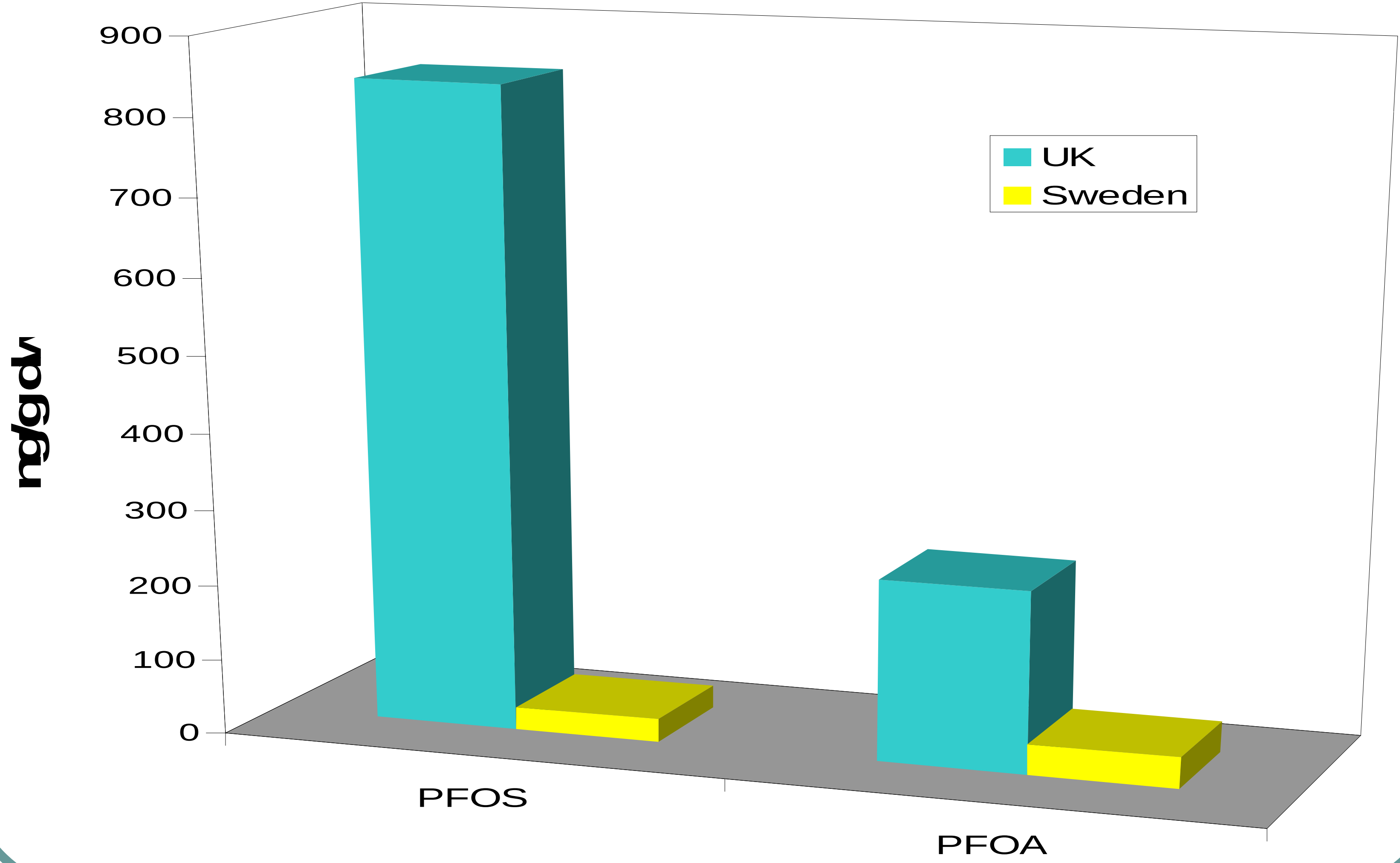
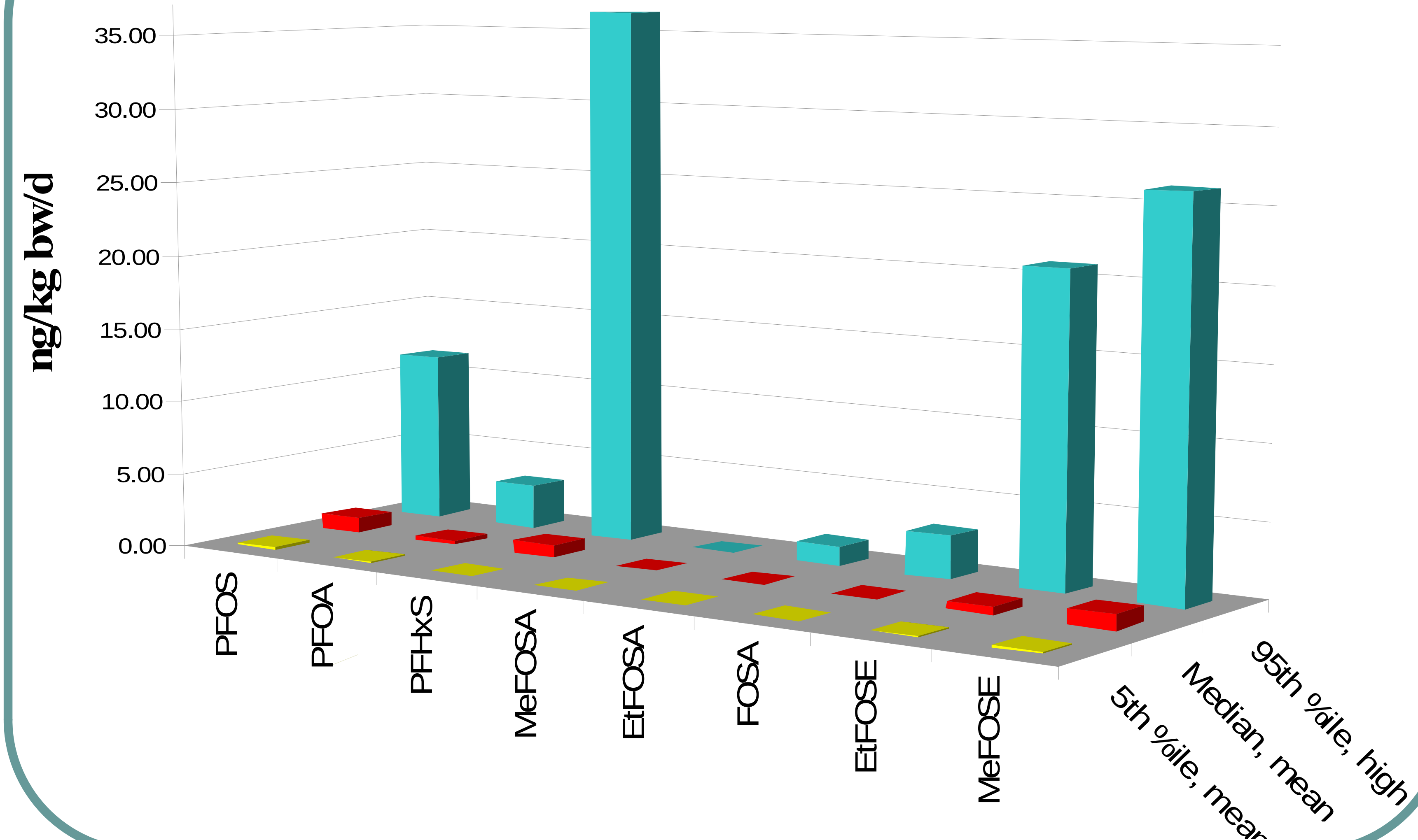
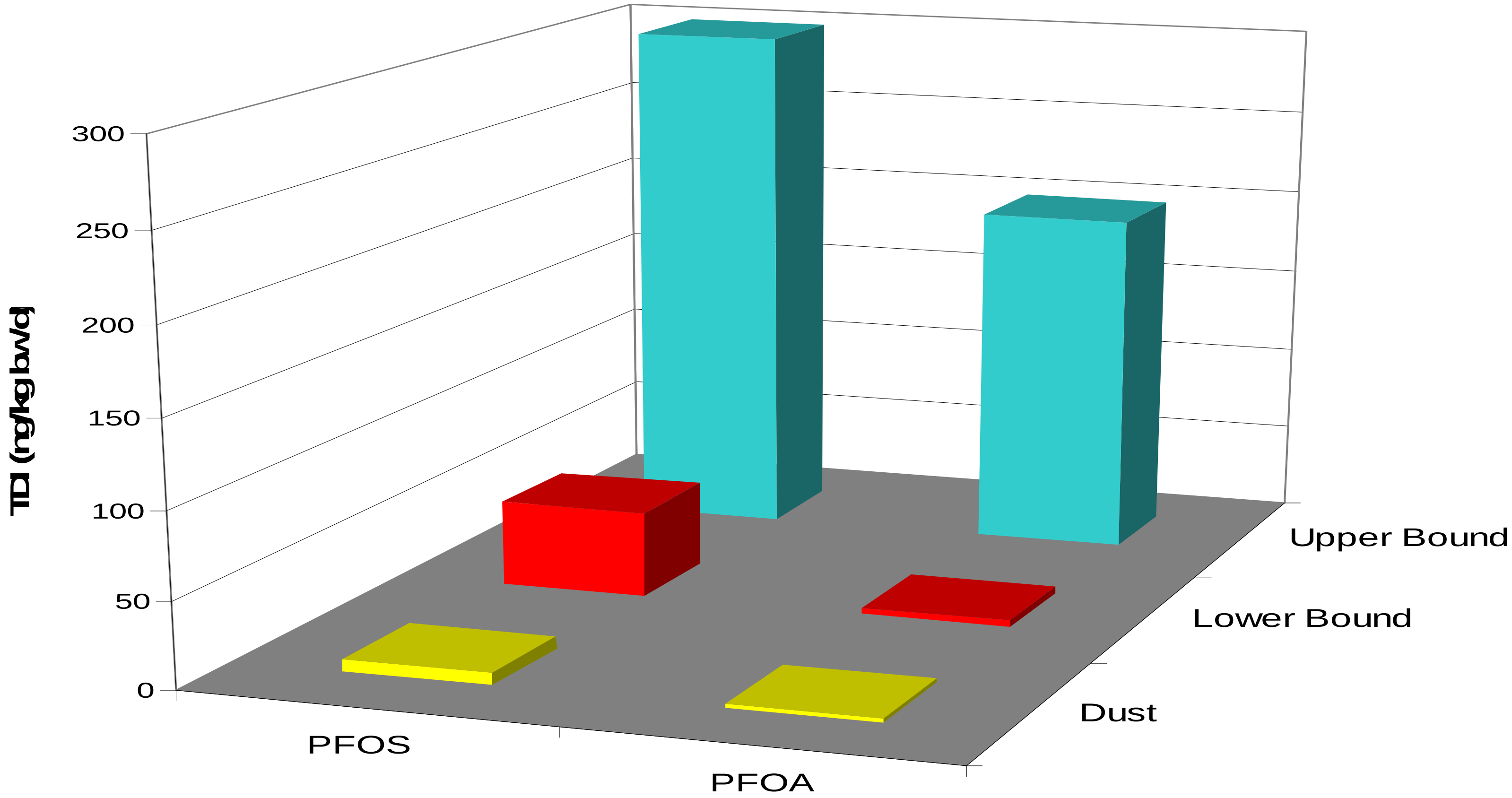
School & Nursery Comparisons



Exposure from Schools & Nurseries (ng/kg bw/d)



Median Nursery Dust Exposure vs Dietary Exposure



Dietary data from Food Standards Agency, UK, 2006

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Dust Exposures Relative to Tolerable Daily Intakes

Nursery PFOS TDI	PFOS TDI	Nursery PFOA TDI	PFOA TDI	Reference
1	300	0.3	3000	COT FSA, UK[i] [ii]
	150		1500	CONTAM, EFSA, EU[iii]
	100		100	BfR, De[iv]

[i]Food Standards Agency 2006. Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment. COT Statement on the Tolerable Daily Intake for Perfluorooctane Sulfonate.

[ii] Food Standards Agency 2006. Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment. COT Statement on the Tolerable Daily Intake for Perfluorooctanoic Acid.

[iii]European Food Safety Authority, 2008. Opinion of the Scientific Panel on Contaminants in the Food Chain on Perfluorooctane Sulfonate (PFOS), Perfluorooctanoic Acid (PFOA) and their Salts. The EFSA Journal (2008), 653, p1-131.

[iv] Federal Institute for Risk Assessment, 2006. High Levels of Perfluorinated Organic Surfactants in Fish are Likely to be Harmful to Human Health. BfR, Stellungahme Nr.035/2006 des BfR.

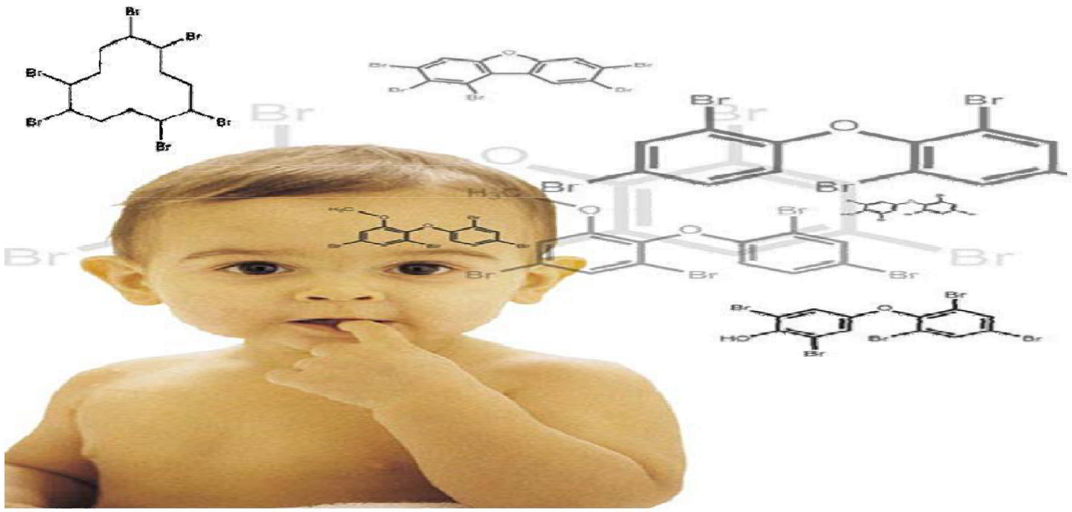
Final Conclusion

- Exposure of young children to PFOS via ingestion of dust from schools and nurseries in the worst case scenario is 1/10th of the UK set TDI, though in comparison reaches 1/3rd of the German recommended TDI.

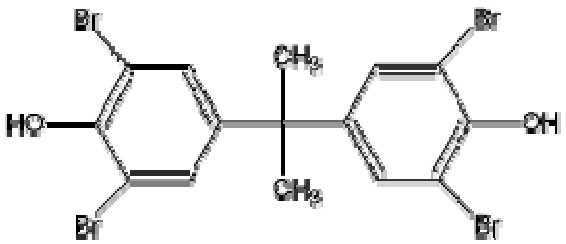
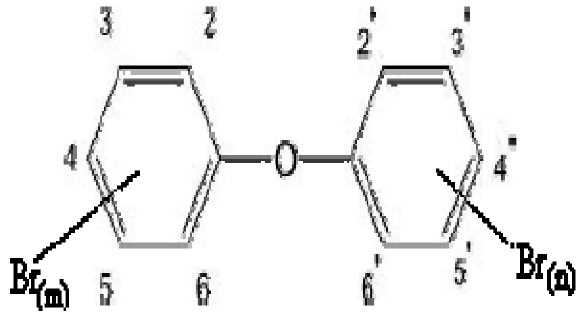
- Concentrations in our nursery/primary school dust samples are high compared to Swedish nursery school data, and exceed the concentrations found in other UK microenvironments.

- Significant correlation between
  - PFOS and PFOA at the 0.05 level
  - PFHxS and EtFOSA at 0.1 level
  - MeFOSE and EtFOSE at 0.1 level

Brominated Flame Retardants (BFRs)



Studied BFRs

Name	Chemical structure	Production volume	Main Applications
TetraBromoBis Phenol-A (TBBP-A)		170000 MT	Printed circuit boards and epoxy resin.
Tri-hepta BDEs (BDE 28,47, 66 99, 100, 153, 154 and 183)		7500 MT	➢ Furniture (PUFs). ➢ Wire and cable insulation (styrene copolymers). ➢ Electronics and computers (HIPs).
Octa BDEs (BDE 196, 197 and 203)		3790 MT	
Deca BDE (BDE-209		56100 MT	

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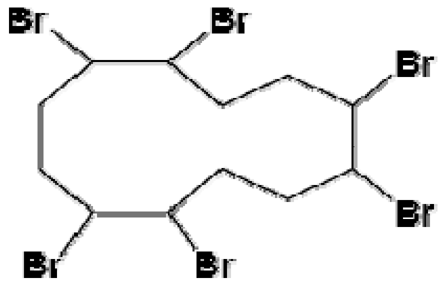
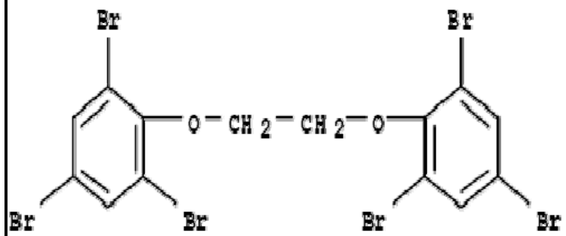
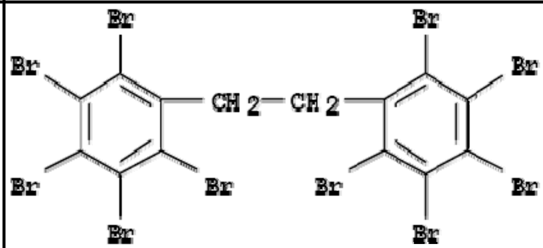
Studied BFRs (continued)

Name	Chemical structure	Production volume	Main Applications
HexaBromoCycloDodecanes (α, β, γ-HBCD)		16700 MT	Thermal insulation (XPS & EPS), Fabrics, Furniture and casing of electronics (HIPs)
1,2-bis(2,4,6-TriBromophenoxy) Ethane (TBE)		5000 MT	ABS in computers, TVs and mobiles. Alternative for Octa-BDE.
DecaBromoDi-Phenyl Ethane (DBDPE, Deca-ethane)		4500 MT	HIPs and ABS. Alternative for Deca-BDE

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Aims

- Study the levels of brominated flame retardants (BFRs) in dust from 42 classrooms frequented by young children and toddlers (0-5 years) from nurseries and primary schools in Birmingham, UK.
- Compare the levels of BFRs in classroom dust to those reported previously by our group in house, office and car dust samples from Birmingham, UK.
- Estimate toddlers exposure to BFRs via ingestion of classroom dust and compare it to their exposure via ingestion of dust from other microenvironments (i.e. houses and cars) and dietary exposure.
- Compare toddlers exposure to BFRs via classroom dust to adults exposure via office dust.

Table 1: Summary of concentrations (ng/g) of target compounds in classroom dust.

	5th %ile	Median	Average	95th %ile
Σtri-octa BDEs	8	91	133	282
BDE-209	132	4997	8455	40186
ΣBDEs	140	5131	8605	40378
DBDPE	68	201	381	1195
TBE	8	21	46	204
α- HBCD	92	1441	2149	5927
β- HBCD	52	547	981	3395
γ- HBCD	192	1729	5814	23470
Σ HBCDs	365	4130	8944	36883
TBBP-A	20	109	203	458

Fig. 1: Median PBDEs concentrations (ng/g) in dust from different microenvironments

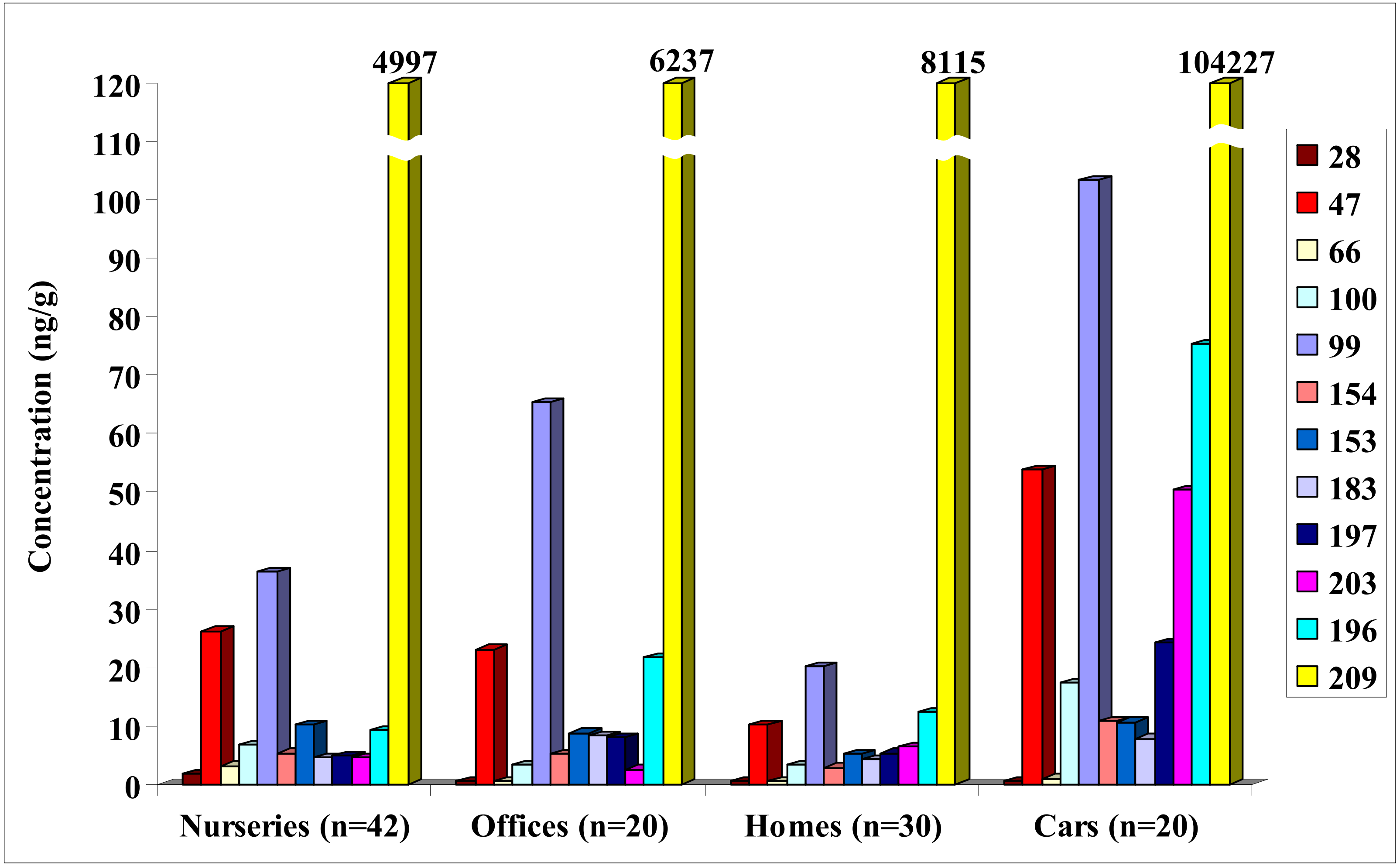

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Fig. 2: Median HBCDs concentrations (ng/g) in dust from different microenvironments

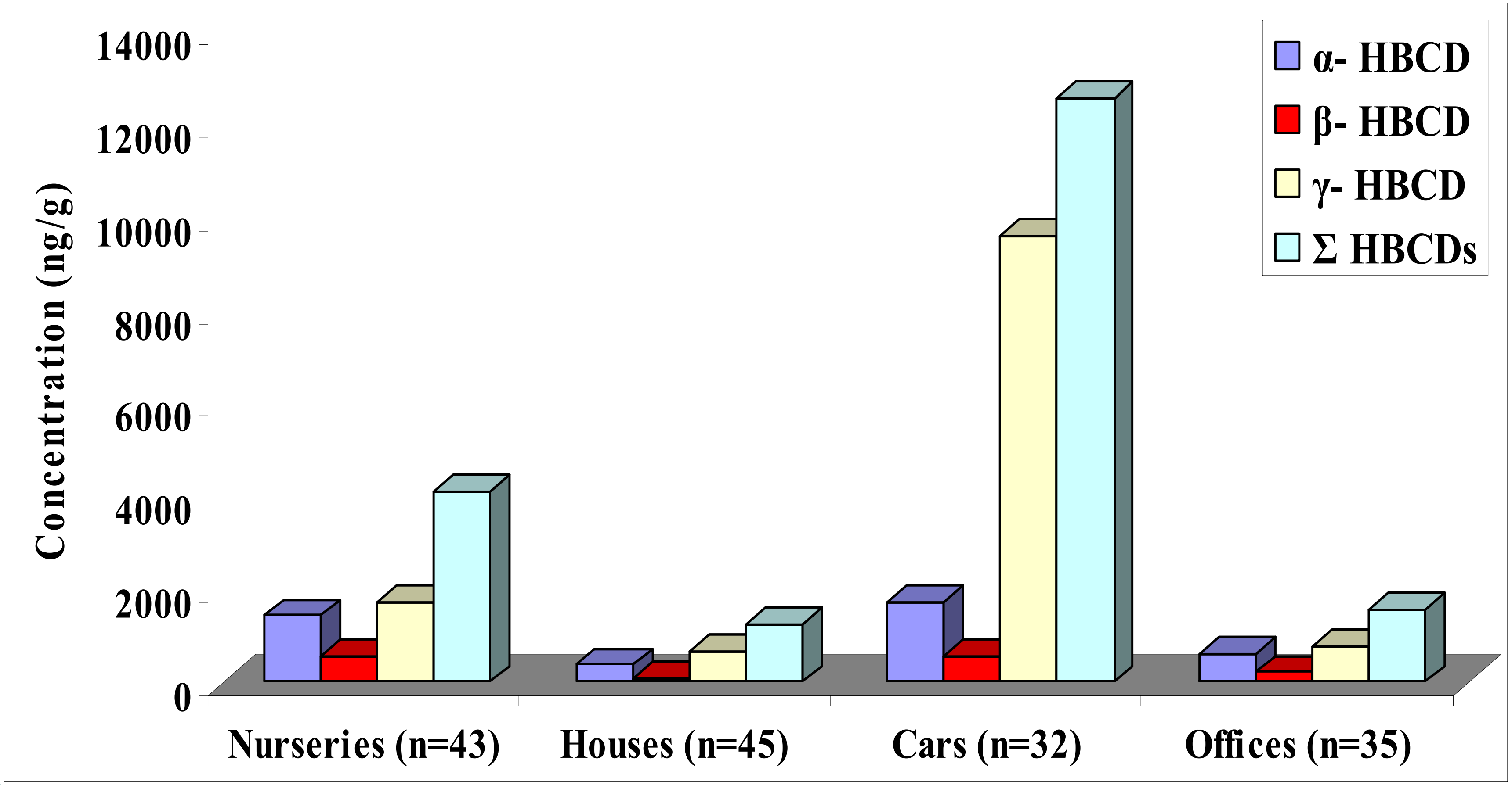

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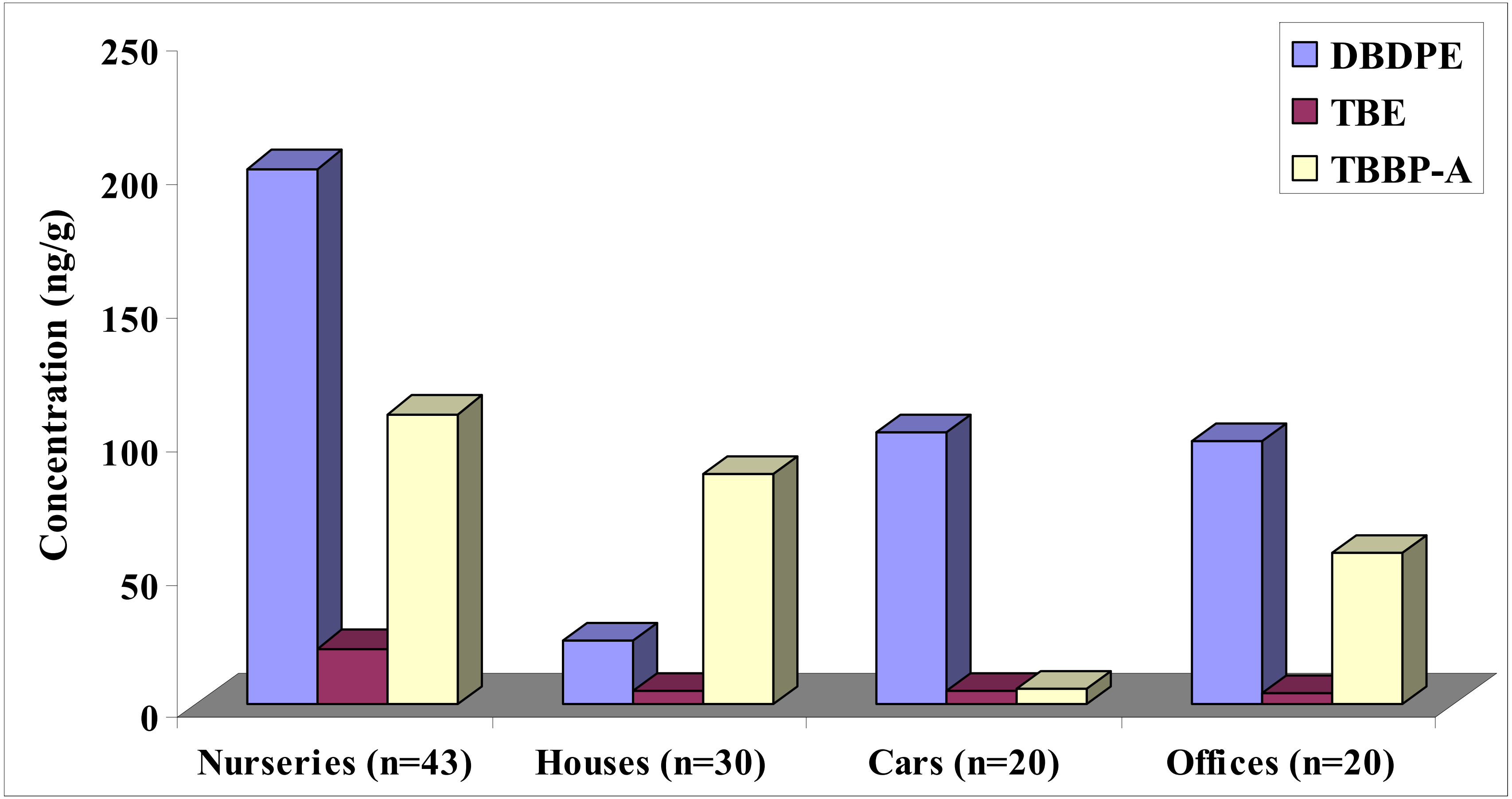
Fig. 3: Median TBBP-A, DPDPE and TBE concentrations (ng/g) in dust from different microenvironments



Estimation of toddlers exposure to BFRs via ingestion of classroom dust

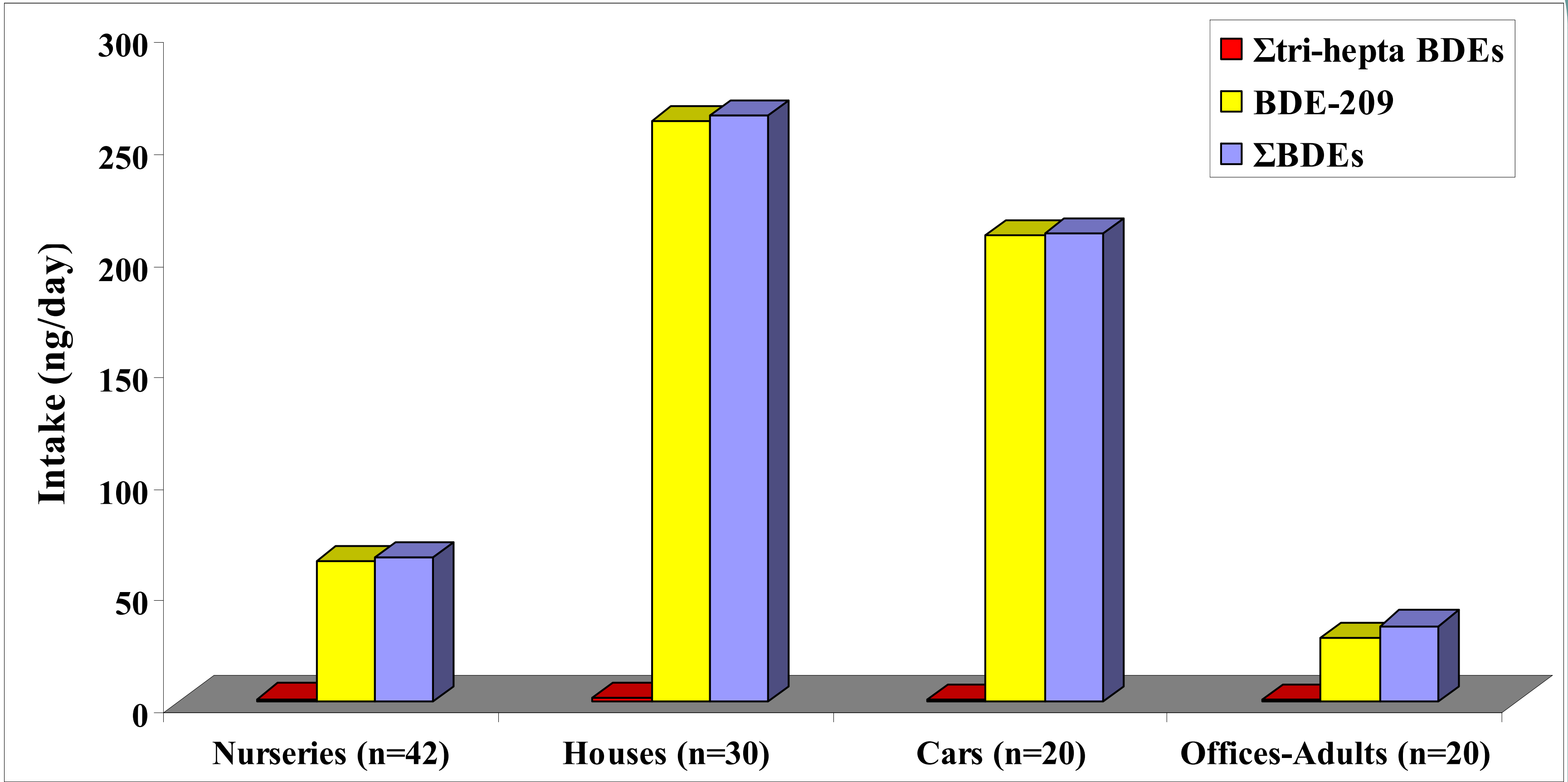
- Assuming 100% absorption of intake.
- Mean dust ingestion rate = 50 mg/ day; high dust ingestion rate 200 mg/ day[a].
- Average time fractions spent in classrooms =23.81%; at home= 63.48% and in cars = 4.18%[b].

[a] Jones-Otazo etal. *Environ. Sci. Technol*. **2005**; 39: 5121.
[b] From our Questionnaires.

Table 2: Exposure (nd/day) of toddlers to BFRs via ingestion of classroom dust

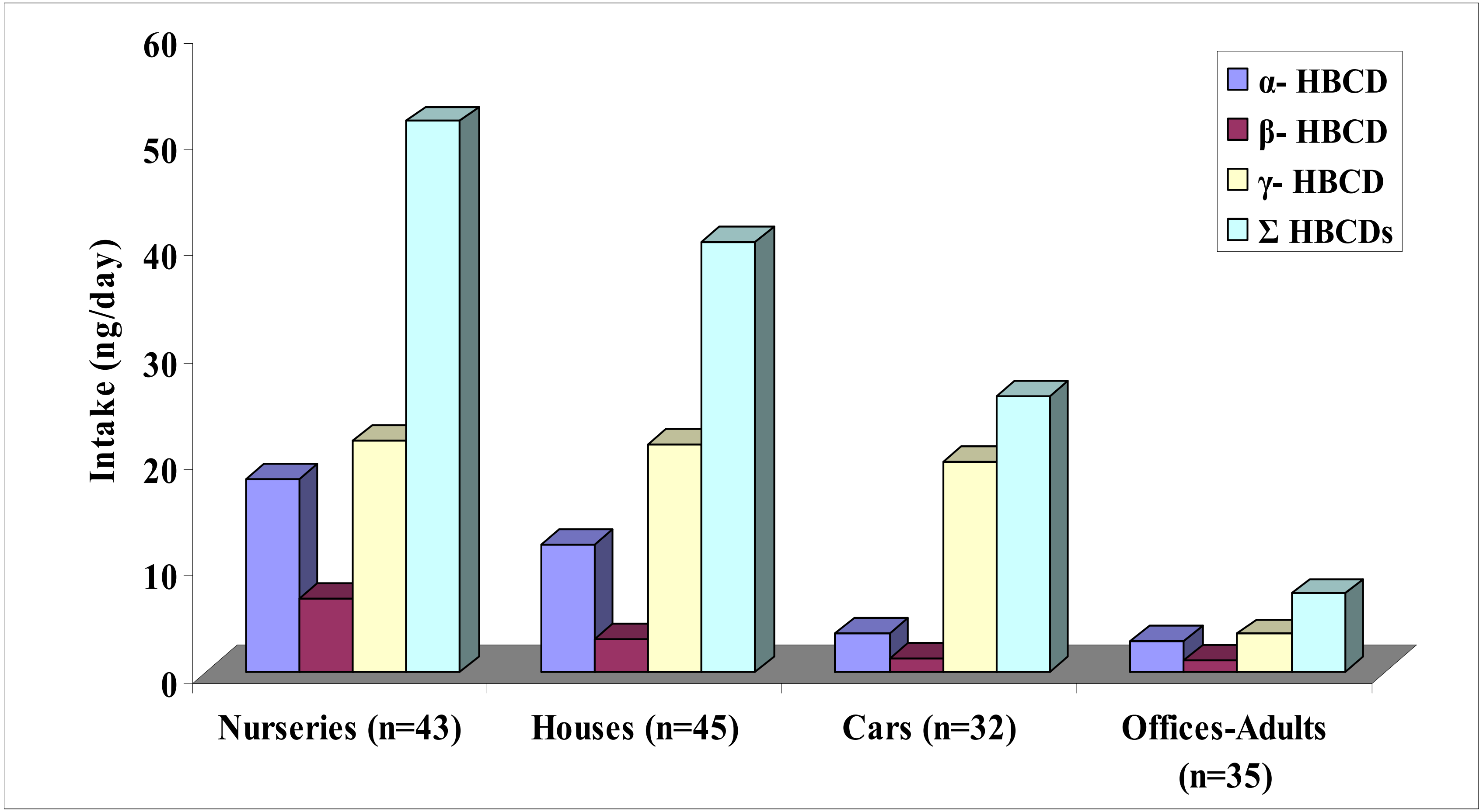
	Mean dust intake			High dust intake		
	5th %ile	Median	95th %ile	5th %ile	Median	95th %ile
Σtri-hepta BDEs	0.1	1.1	3.5	0.4	4.6	14.1
BDE-209	1.7	62.5	502.3	6.6	249.9	2009.3
ΣBDEs	1.8	64.1	504.7	7	256.6	2018.9
α- HBCD	1.2	18	74.1	4.6	72	296.4
β- HBCD	0.6	6.8	42.4	2.6	27.4	169.7
γ- HBCD	2.4	21.6	293.4	9.6	86.4	1173.5
Σ HBCDs	4.6	51.6	461	18.2	206.5	1844.2
TBBP-A	0.3	1.4	5.7	1	5.4	22.9
DBDPE	0.9	2.5	14.9	3.4	10.1	59.8
TBE	0.1	0.3	2.6	0.4	1.1	10.2

Fig. 4: Median daily exposure (ng/day) of toddlers to PBDEs via dust ingestion from different microenvironments*



* Calculated using median PBDEs levels in dust and average dust intake scenario.

Fig. 5: Median daily exposure (ng/day) of toddlers to HBCDs via dust ingestion from different microenvironments*



* Calculated using median PBDEs levels in dust and average dust intake scenario.

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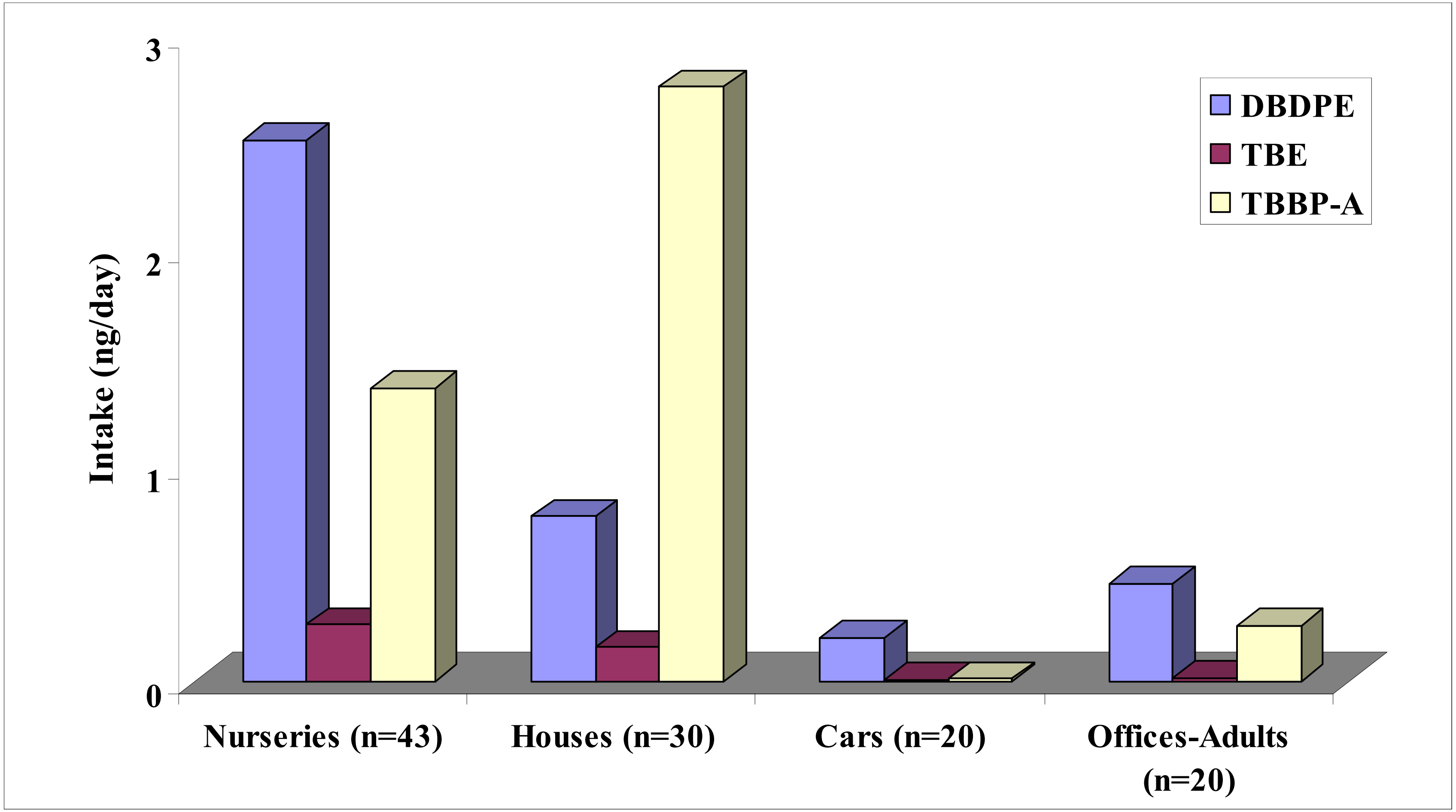
Fig. 5: Median daily exposure (ng/day) of toddlers to DBDPE, TBE, TBBPA via dust ingestion from different microenvironments*



* Calculated using median PBDEs levels in dust and average dust intake scenario.

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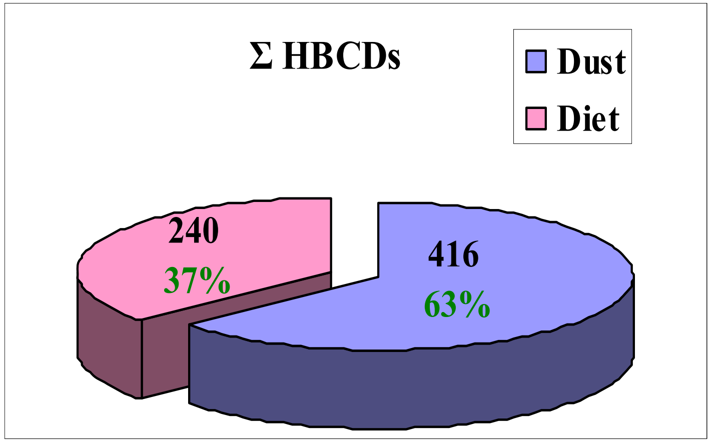
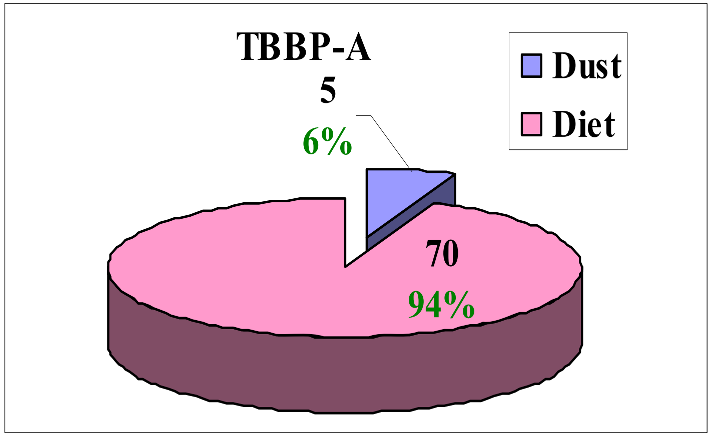
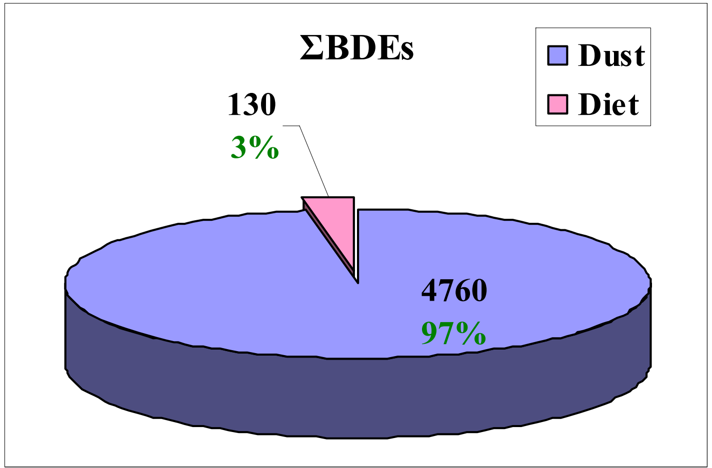
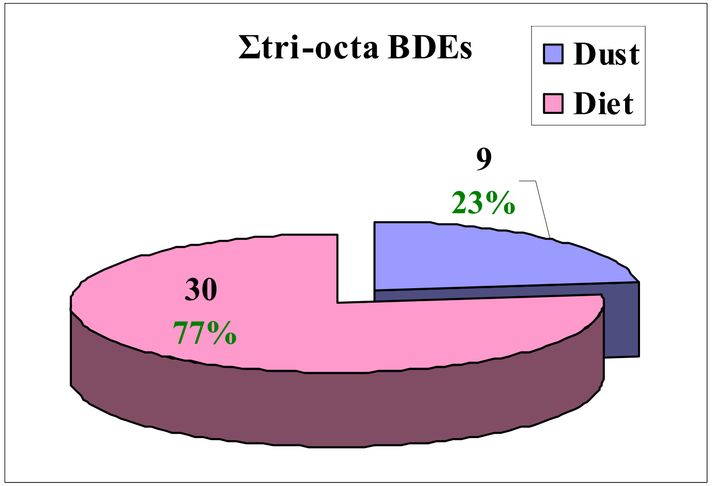
Relative significance of dust and diet (upper bound)* to the exposure (ng/day) of toddlers (average dust ingestion scenario) to the studied BFRs









* UK dietary intakes, 10/2006, http://www.food.gov.uk/multimedia/pdfs/ fsis1006.pdf

Conclusions

- Contamination of classroom dust by BFRs is in the order BDEs (mainly BDE-209) > HBCDs>>DBDPE>TBBP-A>TBE. This is in agreement with the production volume and usage of these BFRs except for TBBP-A.

- The low levels of TBBP-A in the studied samples and subsequent low exposure despite being the most widely used BFR likely reflects its less facile release from treated products due to its main use as a reactive flame retardant compared to other additive BFRs such as BDES and HBCDs.

- HBCDs levels in classroom dust are significantly higher than ($p<0.05$) than those found in house and office dust.

Conclusions (continued)

➢Toddlers exposure to all the studied BFRs via ingestion of classroom dust is significantly higher than that of adults via office dust.

➢Dust ingestion is the main exposure pathway of toddlers to HBCDs and BDE-209 while Diet plays a more important role in their exposure to TBBP-A and Σtri-octa BDEs.

➢ On average, a UK toddler is exposed to 9.8 μg/day of ΣBFRs in this study via both dust and diet.

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