

Indoor Sources of and Human Exposure to Brominated Flame Retardants (BFRs), Organophosphate Esters (OPEs), and Phthalate Esters (PAEs)

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Introduction

Indoor concentrations of, and exposures to brominated flame retardants (BFRs), organophosphate esters (OPEs) and phthalate plasticizers (PAEs) are influenced by poorly understood sources and, in some cases, poorly understood exposure pathways. Furthermore, the physical-chemical properties of compounds within each class vary greatly, influencing their indoor partitioning and residence time, and hence indoor levels and exposure. Here we report on a study of 51 participants residing in the Greater Toronto Area and Ottawa, Canada. Our goal was to characterize indoor concentrations and to estimate exposure of premenopausal women participants to BFRs, OPEs, and PAEs.

Materials and methods

Participants' ages varied between 26 and 46 years. For each participant, floor dust (n=76), and indoor air (n=90 sampled using PUF and PDMS passive air samplers) collected from bedrooms (BR=51) and most-used rooms (MUR=26) were analyzed for novel-BFRs (n=11), PBDEs (n=15), OPEs (n=24), and PAEs (n=6). Wipes (n=209) of principal household electronics were also analyzed to assess their potential for contributing to indoor concentrations of FRs and PAEs, while two sets of hand wipes for each participant, collected ~3 weeks apart (palms and backs wiped separately; n=102 for each), were analyzed to estimate potential exposure from hand-to-mouth contact. A questionnaire was developed and administered to gather personal demographic, lifestyle data, and environmental/household characteristics, which will facilitate a better understanding sources of and exposure to FRs and PAEs.

Results and discussion

A summary of concentrations in each sample type are shown in Table 1. PAEs had the highest overall concentrations followed by OPEs (~one order of magnitude less than PAEs) and NBFRs and PBDEs (three orders of magnitude less than PAEs). The dominant compounds in each compound class occurred with > 75% detection frequencies in all matrices indicating widespread usage of these compounds in electronic products and consistent exposure of participants via inhalation, dust ingestion and hand-to-mouth contact.

In air samples, TBB, BDE-47, TCPP and DnBP were the most abundant NBFRs, PBDEs, OPEs and PAEs, respectively. This list was TBPH and TBB, BDE-209, TBEP, and DiNP and DEHP for dust and hand surfaces, and TBB and DBDPE, BDE-209, TBEP, and DiNP and DEHP for electronic products. Multiple FRs were found in wipes of individual electronic products suggesting that many compounds are being used to meet flammability standards. Chemical profiles on a participant's hands resembled profiles found in that person's electronic products.

Table 1: Concentrations of NBFRs, PBDEs, OPEs, and PAEs in Household Air (by PUF, ng/m³), Dust (µg/g), Electronic Product Surfaces (ng/cm²), and Hand Wipes (ng/cm²) from Participants in Ontario, Canada.

| | | NBFRs | PBDEs | OPEs | PAEs |
|---|---------|----------|----------|----------|------------|
| Air (n=90; ng/m ³) | Range | 0.02-3.1 | 0.02-1.4 | 6.1-140 | 230-3,400 |
| | Median | 0.09 | 0.10 | 23 | 580 |
| | Average | 0.18 | 0.18 | 30 | 820 |
| Dust (n=76; µg/g) | Range | 0.19-28 | 0.14-39 | 4.0-240 | 170-2,600 |
| | Median | 1.7 | 2.7 | 26 | 620 |
| | Average | 3.2 | 4.7 | 35 | 690 |
| Electronic Surfaces (n=209; ng/cm ²) | Range | 0.01-320 | 0.01-370 | 0.09-610 | 0.56-7,400 |
| | Median | 0.17 | 0.08 | 6.2 | 55 |
| | Average | 3.7 | 6.6 | 31 | 230 |
| Hand Surfaces (n=102; ng/cm ²) | Range | 0.02-9.9 | 0.02-5.1 | 6.5-210 | 63-3,900 |
| | Median | 0.19 | 0.16 | 24 | 250 |
| | Average | 0.54 | 0.42 | 37 | 340 |

The median concentrations were used to estimate external exposure of participants to FRs and PAEs via inhalation, dust ingestion and hand-to-mouth contact. Exposure to PAEs and OPEs via hand-to-mouth contact exceeded that via dust ingestion by ~ 5 and 10 times, respectively, while the contribution of dust ingestion to NBFR and PBDE exposure was comparable with that via hand-to-mouth contact. Inhalation intake contributed the least to human exposure of all chemical groups.

Table 2. Exposure of Participants to NBFRs, PBDEs, OPEs and PAEs (ng/day)

| | NBFRs | PBDEs | OPEs | PAEs |
|-----------------------|-------|-------|--------|---------|
| Inhalation Intake | 1.4 | 1.6 | 370 | 9,300 |
| Dust Ingestion | 75 | 120 | 1,100 | 27,300 |
| Hand-to-Mouth Contact | 91 | 77 | 11,500 | 120,000 |

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