HALOGENATED FLAME RETARDANTS IN WASTE PLASTICS FROM IRELAND: CONCENTRATIONS, LEGISLATIVE COMPLIANCE, AND TEMPORAL TRENDS

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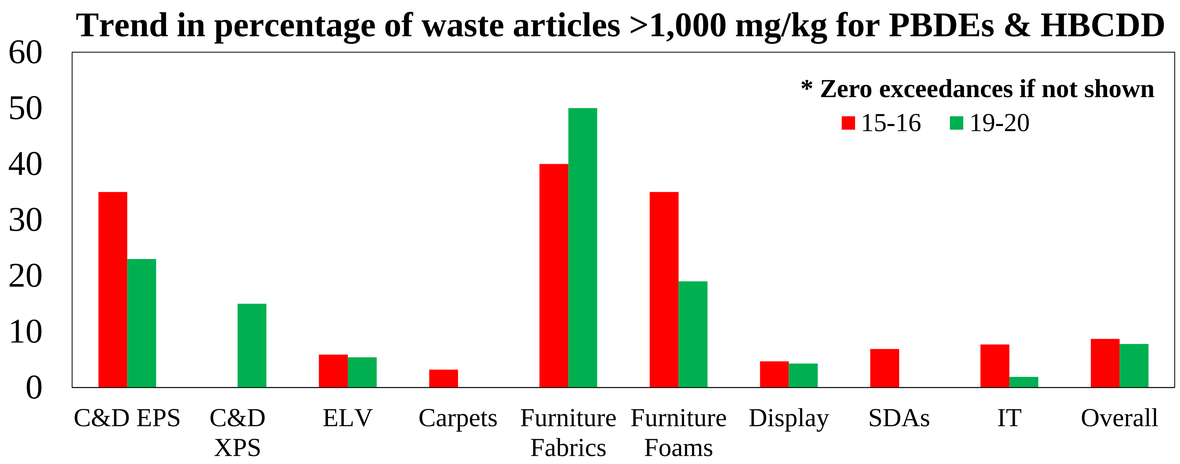
Introduction

Uncontrolled recycling of waste polymers containing halogenated flame retardants (HFRs) leads to the unintentional presence of such chemicals in articles in which their presence is not required, such as food contact materials, children's toys, and polystyrene packaging. In recognition of this, the EU has implemented Low POP Concentration Limit (LPCL) values for polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecane (HBCDD) which restrict recycling of waste polymers containing such chemicals at concentrations exceeding 1,000 mg/kg. Moreover, in the EU, waste which contains tetrabromobisphenol-A (TBBP-A) above 1,000 mg/kg is classified as "HP 14 – Ecotoxic", treated as hazardous waste and cannot be recycled. Within the recently completed WAFER project, we reported concentrations of PBDEs, HBCDD, and TBBP-A in ~550 samples of waste polymeric materials collected from various sites in the Republic of Ireland between 2015 and 2016 [1,2]. Importantly, we found that 8.7% of articles analysed in the WAFER project exceeded the LPCL value of 1,000 mg/kg for PBDEs and HBCDD. In the current study (the SAFER project), we collected ~470 samples to test the hypothesis that implementation of LPCLs for PBDEs and HBCDD would lead to: (a) lower concentrations of PBDEs and HBCDD in Irish waste polymers and a reduced proportion of samples exceeding the LPCL value; and (b) increased concentrations of halogenated FRs not covered by LPCLs such as decabromodiphenyl ethane (DBDPE). We also evaluate the impact of EU proposals to progressively lower the EU LPCL to 500, 200, and 100 mg/kg.

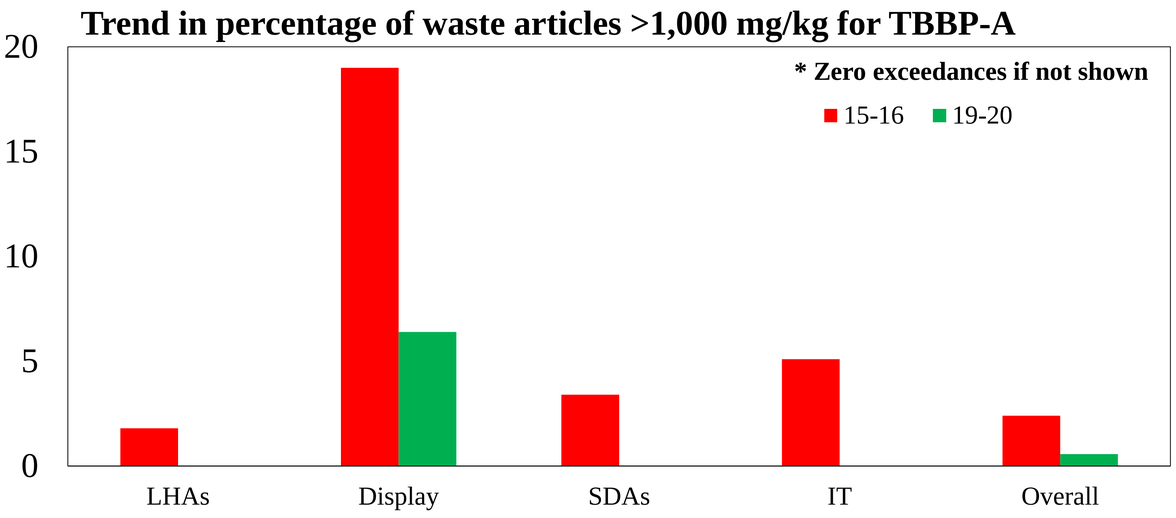
Table 1: Samples studied from WAFER (2015-16) and SAFER (2019-20)

Category	Sub-category	Number of Samples (2019-20)	Number of Samples (2015-16)
Construction and Demolition	EPS	12	40
	XPS	13	20
End of Life Vehicle (ELV) Foam and Fabrics		111	119
Soft Furnishings	Carpets	20	31
	Curtains	25	15
	Furniture Fabrics	16	22
	Furniture Foam Filling	16	20
	Mattress Foam Filling	27	17
	Mattress Fabric Covering	20	17
Waste Electrical and Electronic Equipment	Large Household Appliances	21	57
	Cooling Appliances	30	30
	Display	47	43
	Small Domestic Appliances	60	29
	IT and Telecommunications	52	78

Trend in percentage of waste articles >1,000 mg/kg for PBDEs & HBCDD



Trend in percentage of waste articles >1,000 mg/kg for TBBP-A



Results

Overall, concentrations of PBDEs, HBCDD, and TBBP-A have remained broadly similar since the WAFER study conducted in 2015-2016. In ELV fabrics and foams, both PBDE and HBCDD concentrations declined significantly ($p<0.05$) between 2015-16 and 2019-20. A similar significant decline is observed for TBBP-A in IT & telecommunication articles.

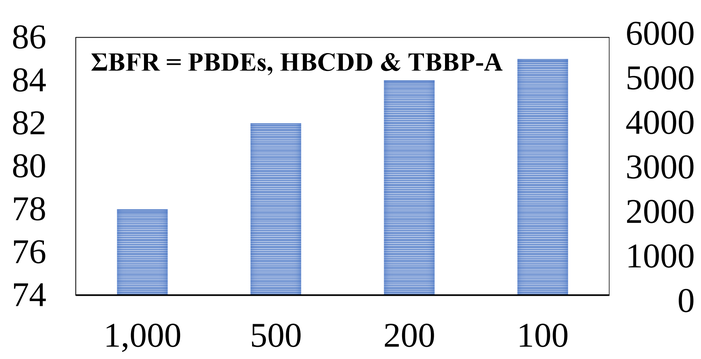
Table 2: Estimated Annual Mass of PBDEs, HBCDD, and TBBP-A Associated with Different Categories of Waste Generated in Ireland in 2019

Category	tonnes waste /yr	PBDEs (kg/yr)	HBCDD (kg/yr)	POP-BFR (kg/yr)	TBBP-A (kg/yr)	ΣBFRs (kg/yr)
C&D	5500	5.1	2900	2900	0.20	2900
ELV	3800	2300	110	2400	0.50	2400
Carpets	7600	22	91	110	0.08	110
Curtains	740	2.9	1.3	4.2	0.17	4.4
Furniture foam	2600	1200	51	1300	0.01	1300
Furniture fabrics	880	530	560	1100	0.004	1100
Mattress foam	6100	40	47	87	0.61	88
Mattress fabrics	2500	27	3.5	30	0.04	30
LHA	37000	0.09	0.02	7.7	0.15	7.9
Cooling	10000	1.5	0.65	2.2	4.1	6.3
Display	5000	660	5.2	660	1500	2200
SDA	8100	0.33	0.001	0.34	0.11	0.44
IT & Telecoms articles	1900	16	0.37	17	25	42
Total	92000	4800	3800	8600	1600	10000

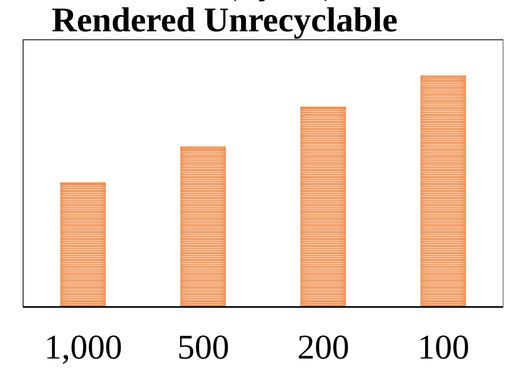
Alternative Halogenated FRs?

- Alternative HFRs detected infrequently both in samples collected in 2019-20 and in those archived from 2015-16.
- Specifically in 2019-20, *anti*-DP and DBDPE were the only alternative HFRs detected in at least one waste category at a detection frequency >20%, at maximum concentrations of 96 and 1,100 mg/kg respectively.
- However, TTBP-TAZ was detected in 3 display/IT products (internet router and 2 TVs) collected in 2019-20 at 14,000-32,000 mg/kg.
- Another TV contained 1,100 mg/kg DBDPE.
- DBDPE in Irish indoor dust highest in world, so likely DBDPE concentrations in waste will increase.

Impact of Lowering Limit Value (mg/kg) on %ΣBFR Removal Efficiency



Impact of Lowering Limit Value (mg/kg) on Annual Mass (t/year) of Waste Rendered Unrecyclable



Summary

- Between 2015-16 and 2019-20, only modest changes seen in the presence of BFRs in Irish waste plastics
- Implementation of current limits on PBDEs, HBCDD, and TBBP-A in waste will remove ~78% from the recycling stream
- Progressively lowering this limit to 100 mg/kg will remove a further 7%
- However, lowering the limit from 1,000 to 100 mg/kg will also increase the mass of waste that cannot be recycled in Ireland from 2,800 to 5,200 t/year
- Implementation of Circular Economy not straightforward…

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