An attempt to assess the present commercial production of brominated flame retardants

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Introduction

The use of brominated flame retardants (BFRs) have increased over time and today there is a production above 200 000 metric tons (1). The history of BFRs dates back 30-40 years but it has not been possible for us to determine the actual starting point for the production. Still, already in 1976, Norström and co-workers listed a number of BFRs, some of which were regarded as being of environmental concern (2). In 1997, IPCS listed more than 175 chemicals used as BFRs (3), a list that has been used by many of us to get a handle on which BFRs may be of significance in environmental and health perspective. Around 2000, BSEF reported production figures for TBBPA, three types of PBDEs and for HBCDD (1) but it is difficult to make any conclusive statements about the other BFRs being commercially produced. Some production data for BFRs and areas of application were reported for Japan (4) and in a global perspective (5).

Present BFR production

In the present attempt we are listing all BFRs that we have been able to trace as products from three major BFR manufacturers (Albermale Corporation, Dead Sea Bromine Group and Great Lakes Chemicals). The CAS number, molecular formula, CA name, chemical structure, producers and when production volumes are known these have been included in Table 1. The information on which the table has been built is from the websites: www.albemarle.com, www.dsbg.com and www.glcc.com/pa. Brominated compounds primarily used for polymer production and brominated polymers have not been included in the list. There are both reactive and additive BFRs in the list.

When looking at the list it is clear that brominated aromatics, cycloaliphatics and aliphatics are among the BFRs under production. The list seems to mainly contain single specific chemicals and few that is mixtures. It is brought forward as a basis for discussion and as a prioritising tool in our future research efforts. Information will be added on BFRs taken out of production over the years.

Acknowledgements
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References

1. BSEF, Major brominated flame retardants volume estimates, *http://www.bsef-site.com/docs/BFR_vols_2001.doc*

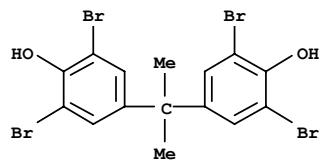
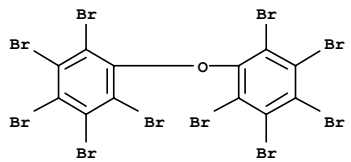
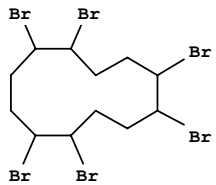
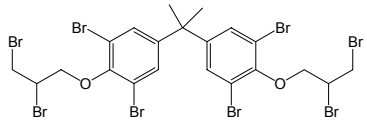
2. Norström, Å., Andersson, K., and Rappe, C., (1976), Major components of some brominated aromatics used as flame retardants, *Chemosphere*, **5**, 255-261

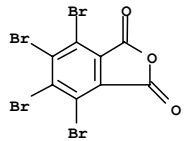
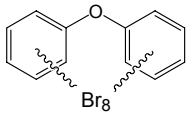
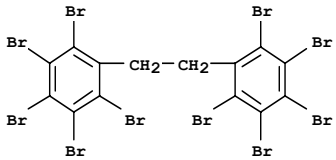
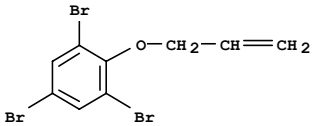
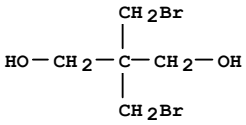
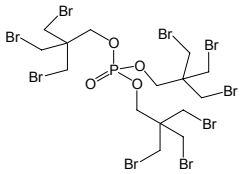
3. WHO, (1997), Environmental Health Criteria 192. Flame retardants: A general introduction, International Program on Chemical Safety, World Health Organization

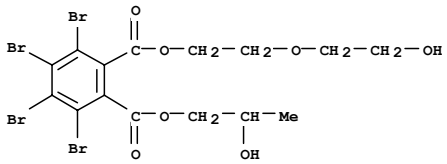
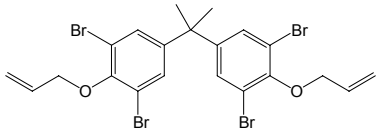
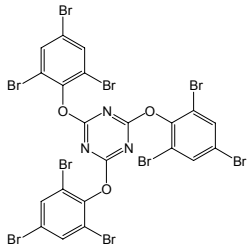
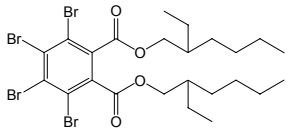
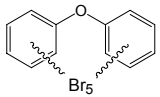
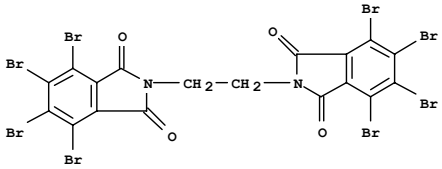
4. Watanabe, I. and Sakai, S.-I., (2003), Environmetal release and behavior of brominated flame retardants, *Environment International*, **29**, 665-682

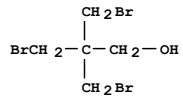
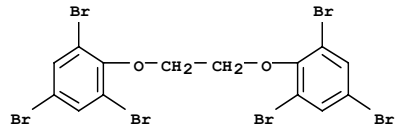
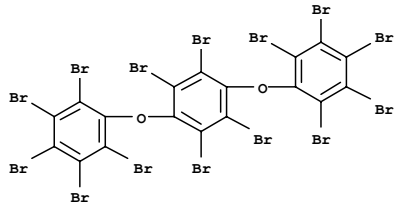
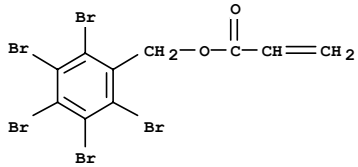
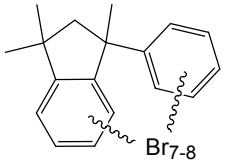
5. Alaee, M., Arias, P., Sjödin, A., and Bergman, Å., (2003), An overview of commercially used brominated flame retardants (BFRs) and their applications, changes in their use pattern in different countries/regions over time and possible modes of release, *Environment International*, **29**, 683-689

Table 1 Brominated flame retardants that are commercially available.
Commercial sources: **A**=Albemarle Corporation; **D**=Dead Sea Bromine Group; **G**=Great Lakes Chemical Corp.

CAS no	Molecular formula	CA name	Structure	IPCS	Com. source	Anual consumption (metric tons)	Other names
79-94-7	C15 H12 Br4 O2	Phenol, 4,4'-(1-methylethylidene)bis[2,6-dibromo-		x	ADG	119 7(27 3	TBBPA; Tetrabromobisphenol A;
1163-19-5	C12 Br10 O	Benzene, 1,1'-oxybis[2,3,4,5,6-pentabromo-		x	ADG	56 1 2 5	2,2',3,3',4,4',5,5',6,6'-Decabromodiphenyl ether; Decabromodiphenyl oxide; BDE209
3194-55-6	C12 H18 Br6	Cyclododecane, 1,2,5,6,9,10-hexabromo-		x	ADG	16 7 2 2	1,2,5,6,9,10-Hexabromocyclododecane;
21850-44-2	C21 H20 Br8 O2	Benzene, 1,1'-(1-methylethylidene)bis[3,5-dibromo-4-(2,3-dibromopropoxy)-		x	ADG	1 (	Tetrabromobisphenol A 2,3-dibromopropyl ether; Tetrabromobisphenol A bis(2,3-dibromopropyl ether)

632-79-1	C8 Br4 O3	1,3-Isobenzofurandione, 4,5,6,7-tetrabromo-		x	AG		Tetrabromophthalic acid anhydride; Tetrabromophthalic anhydride
32536-52-0	C12 H2 Br8 O	Benzene, 1,1'-oxybis-, oktabromo deriv.		x	DG	3	Octabromodiphenyl ether; Octabromodiphenyl oxide; Okta-BDE
84852-53-9	C14 H4 Br10	Benzene, 1,1'-[1,2-ethanediylbis]bis[2,3,4,5,6-pentabromo-			AG	4	1,2-Bis(2,3,4,5,6-pentabromophenyl)ethane; 1,2-Bis(pentabromo-phenyl)ethane; Decabromo-diphenylethane;
3278-89-5	C9 H7 Br3 O	Benzene, 1,3,5-tribromo-2-(2-propenyloxy)-		x	G		2,4,6-Tribromophenyl allyl ether;
3296-90-0	C5 H10 Br2 O2	1,3-Propanediol, 2,2-bis(bromomethyl)-		x	D		Pentaerythritol dibromide; Pentaerythritol dibromohydrin
19186-97-1	C15 H24 Br9 O4 P	1-Propanol, 3-bromo-2,2-bis(bromomethyl)-, phosphate			D		Tris[3-bromo-2,2-bis(bromomethyl)propyl] phosphate

20566-35-2	C15 H16 Br4 O7	1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, 2-(2-hydroxyethoxy)ethyl 2-hydroxypropyl ester		x	G		2-(2-Hydroxyethoxy)ethyl 2-hydroxypropyl 3,4,5,6-tetrabromophthalate
25327-89-3	C21 H20 Br4 O2	Benzene, 1,1'-(1-methylethylidene)bis[3,5-dibromo-4-(2-propenyloxy)-		x	G		Tetrabromobisphenol A bis(allyl ether); Tetrabromobisphenol A diallyl ether
25713-60-4	C21 H6 Br9 N3 O3	1,3,5-Triazine, 2,4,6-tris(2,4,6-tribromophenoxy)-			D		2,4,6-Tris(2,4,6-tribromophenoxy)-1,3,5-triazine
26040-51-7	C24 H34 Br4 O4	1,2-Benzenedicarboxylic acid, 3,4,5,6-tetrabromo-, bis(2-ethylhexyl) ester			G		Di(2-ethylhexyl) tetrabromophthalate
32534-81-9	C12 H5 Br5 O	Benzene, 1,1'-oxybis-, pentabromo deriv.		x	G	7 5	Pentabromodiphenyl ether; Pentabromodiphenyl oxide; PentaBDE
32588-76-4	C18 H4 Br8 N2 O4	1H-Isoindole-1,3(2H)-dione, 2,2'-(1,2-ethanediyl)bis[4,5,6,7-tetrabromo-		x	A	1 1	1,2-Bis(tetrabromo-phthalimido)ethane; N,N'-Ethylenebis (tetrabromophthalimide)

36483-57-5	C5 H9 Br3 O	1-Propanol, 3-bromo-2,2-bis(bromomethyl)-		x	D		Tribromoneopentyl alcohol
37853-59-1	C14 H8 Br6 O2	Benzene, 1,1'-[1,2-ethanediylbis(oxy)]bis[2,4,6-tribromo-		x	G		1,2-Bis(2,4,6-tribromophenoxy)ethane;
58965-66-5	C18 Br14 O2	Benzene, 1,2,4,5-tetrabromo-3,6-bis(pentabromophenoxy)-		x	A		1,4-Bis(pentabromo-phenoxy)tetrabromobenzene; Pentabromo-1,4-diphenoxybenzene;
59447-55-1	C10 H5 Br5 O2	2-Propenoic acid, (pentabromophenyl)methyl ester		x	D		2,3,4,5,6-Pentabromobenzyl acrylate; Pentabromobenzyl acrylate
155613-93-7	C18 H12 Br8	1H-Indane, 2,3-dihydro-1,1,3-trimethyl-3-phenyl-, octabromo deriv.			D		Brominated Trimethylphenyl Indane Octabromo-1-phenyl-1,3,3-trimethylindane

[1] BSEF Major Brominated Flame Retardants Volume Estimates (1) [2] Watanabe *et al.* (4)