AN OVERVIEW OF MONITORING PROGRAMMES ON BROMINATED FLAME RETARDANTS IN AFRICA: LEVELS, TRENDS AND CHALLENGES

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Introduction

According to Marlair et al[9], a variety of flame retarding chemicals have been developed in the past few decades to lower the ignitability and flame spread performance of both plastics and natural materials used in construction and furniture industries. The widespread and increasing use of these chemicals has led to significant reduction in the number and severity of unwanted fires.

Of several flame retarding compounds, brominated flame retardants (BFRs) are ubiquitous and anthropogenic pollutants that have raised much concern in recent years in terms of the well being of humans and the environment as a result of their persistent, bio-accumulative and toxic (PBT) properties and continual detection at elevated levels in biotic and abiotic environment[19]. Studies have reported on their presence in most environmental compartments including; water[6], soil[5], sediment[21], food[2], human milk[3], adipose tissue, blood serum[18], human hair[12, 23], domestic dust[13,20] and birds[6] with most of them from Europe, America and Asia. This is not surprising; since BFRs are produced and used in these regions as a result of stringent fire and safety standards. At present, there are regulations on brominated flame retardants in developed countries in Europe and America which has led to the ban of polybromobiphenyls, Penta and OctaBDE commercial mixtures and subsequent inclusion on the list among the nine new POPs listed under the Stockholm Convention[25]. Other BFRs still in use such as HBCD, TBBPA and DecaBDE have been subjected to series of risk assessments and in some cases partial restrictions put in place. The situation, however, is different for most developing countries especially in Africa.

Information is very scarce on production (if any) and use of these chemicals in the African continent. The pertinent question to ask is; are BFRs present in Africa? If yes, what are the sources? An important source worth mentioning is the high level trans-boundary movement of waste electrical electronic equipment (WEEE) which may contain BFRs into the developing countries and the absence of basic or state of the-art facilities for recovery and disposal. This is exacerbated by recycling operations that are carried out with very little or no personal protection equipment or pollution control measures. As a result, high levels of human exposure to toxins and environmental pollutants are inevitable[11]. The general sources of brominated flame retardants, exposure pathways and toxicity have been discussed elsewhere[14]. At present, there are little or no regulations on the use of brominated flame retardants in Africa. In Europe, the annual generation of electronic equipment is estimated at 9 million metric tonnes out of which only 3 million tonnes is collected in the official systems of the EU member states, a large chunk of the balance is exported to developing countries as used EEE[10]. Table 1 shows the distribution of imported used EEE into five African countries[24].

This study, therefore, reviews the few data that has recently become available on monitoring of brominated flame retardants in the African environment.

Table 1: Quantitative data for EEE in Benin, Cote d'Ivoire, Ghana, Liberia, and Nigeria related to EEE imports, use and e-waste generated.

Country	Year	Imports of EEE		EEE in use		E-waste generated	
		tonnes/year	thereof used EEE	tonnes	kg/inhabitant	tonnes/year	thereof collected
Benin	2009	16,000	30%	55,000	6.32	9,700	N/A
Cote d'Ivoire	2009	25,000	48%	100,000	4.8	15,000	N/A
Ghana	2009	215,000	70%	984,000	41	179,000	172,000
Liberia	2009	3,500	10%	17,000	4.6	N/A	N/A
Nigeria	2010	1,200,000	35-70%	6,800,000	44	1,100,000	N/A

Source:(SBC, 2011)

Result and discussion

Ghana

Cow milk: In the only literature from Ghana, Asante et al.[17] determined the presence of 2 BFRs (HBCD and PBDEs) in cow milk samples from two different locations in Accra; a coastal city and another major depot of used EEE. They reported the presence of 14 PBDE congeners ranging from 0.47 to 11 ng g^{-1} lipid weight for urban cows and 0.047 – 2.8 ng g^{-1} lipid weight for rural cows. BDE-47 and BDE-99 were the dominant congeners in all the samples with contributions of 48 – 55% and 18% for urban and rural cows respectively. BDE-209 concentration of 2.0 – 10 ng g^{-1} lipid weight was reported in 5 out of 21 samples but not HBCDs.

South Africa

Soil and Sediment: Recent studies have reported the presence of brominated flame retardants in two of South African rivers. Daso et al[1] reported relatively low concentration range of 0.35 – 4.43 ng g^{-1} d.w for $\sum_7$ PBDEs (BDE-28, -47,-100, -99, -154, -153 and -183) and BB-153 (0.51 – 0.89 ng g^{-1}d.w) in the upstream and downstream of the Black River in Cape Town. In a separate study by Olukunle et al[21] conducted on the Jukskei catchment in the city of Johannesburg which is regarded as a highly urbanised and industrialised catchment[26]. The levels of $\sum_{11}$ PBDE reported ranged from 0.92 – 6.76 ng g^{-1} d.w and BDE-209 as the dominant congener with a contribution of between 20 – 78%.

Bird eggs: Polder et al[4] showed the presence of some common PBDEs (BDE-47, -99, -100 and -154) in bird eggs from bird species living along the Vaal River, in the North-west and in species from the Western Cape Province in South Africa. They found the highest levels of ∑PBDEs (120 ng g^{-1} lipid weight) in the eggs of one sacred ibis at levels comparable to the eggs of Atlantic puffin (*Freatercula arctica*) at Hornoya, Northern Norway in 2003 and at two times higher when compared to levels (37 ng g^{-1} lipid weight) in eggs of Arctic tern (*Sterna paradisaea*) which is a migratory bird found in Southern Africa. HBCD was detected in only four bird species and highest concentration (71 ng g^{-1} lipid weights) was measured in one egg of African sacred ibis

Landfill leachates: Report by Odusanya et al[8] confirmed the presence of PBDEs in leachates from five landfill sites in South Africa. The report indicated BDE-28, -47, -71 and -75 as the dominant congeners with mean concentration range of $\sum_{13}$ PBDEs (2670, 6638, 7230, 4009 and 9793 pg L^{-1}) for Garankuwa, Hatherley, Kwaggasrand, Soshanguve and Temba landfill sites respectively

Breast milk: Darnerud et al[22] studied the non occupational exposure to brominated flame retardants (BDE-28, -47, -66, -99, -100, -138, -153, -154 and HBCD) and other persistent organic pollutants in human breast milk samples from mothers residing in Thohoyandou area, a rural district in the Limpopo province, Northern part of South Africa. They found PBDEs and HBCD at levels not too far from those shown in several European studies. The dominant PBDE congeners were BDE-47, -99, -153, and -183 while the remaining measured congeners had levels near or below limit of quantification. BDE-138 was found below detection in all samples except for one sample which showed 4.5 ng g^{-1} lipid weight, compared to the median levels of BDE-183 of 0.32 ng g^{-1}.

Office dust: Kefeni et al[15] detected high levels of five PBB (BB-2. -4, -30, -153 and -209) and 6 PBDE (BDE-47, -66, -85, -99, -153, and -209) congeners in office dust obtained in Pretoria out of 32 (16 PBB and 16 PBDE) considered. The $\sum_6$ PBDEs detected ranged between 21.4 and 578.6 ng g^{-1} for BDE-209. BDE-47 and BDE-99 were found to be dominant congeners with contributions to ∑PBDE of 62.5 and 81.3% respectively. However, lower concentrations, compared to PBBs were reported for $\sum_5$ PBBs (<dl- 196 ng g^{-1}) and the most frequently detected congeners were BB-4 (43.8%) and BB-2 (31.3%). Similarly, the same author in a separate study reported decaBDE concentrations in a hotel, office and computer classrooms in one of the tertiary institutions in Pretoria, South Africa. Findings showed a mean concentration of 103, 118 and 26 ng g^{-1} for office, hotel and computer classroom dust respectively[16].

Challenges: In this short review of the very few studies conducted so far on BFRs in Africa, one of the major gaps identified include, but not limited, to the following: insufficient capacity to analyse these complex pollutants, constraints brought about by the high cost of standards and reference materials and non-affordability of the necessary equipment. It is also rather surprising that no study has been conducted on people professionally exposed to WEEE, despite the fact that large quantities of WEEE that may have been flame retarded with BFRs are imported into the continent.

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References:
1. Daso A, Fatoki O, Odendaal J. (2011) *Water SA.* 37(3):331-337
2. Schecter A, Haffner D, Colacino J, Patel K, Papke O, Opel M. (2010) *Environ Health Perspect.* 118(3):357-362
3. Sudaryanto A, Kajiwara N, Takahashi S, Muawanah H, Tanabe S. (2008) *Environ. Pollut*. 151(1):130-138
4. Polder A, Venter B, Skaare J, Bouwan H. (2008) *Chemosphere* 73(2):148-154
5. Sanchez-Brunete C, Miguel E, Tadeo J. (2009) *J. Chromatogr. A* 1216(29):5497-5503
6. Chen D, Watts B, La Guardia M, Harvey E, Mojica E. (2010) *Environ. pollut.* (158):1883-1889
7. Oros D, Hoover D, Rodigari F, Crane D, Sericano J. (2004) *Environ. Sci. Technol.* 39(1):33-41
8. Odusanya D, Okonkwo O, Botha B. (2008) *Waste Manage*. 29(1):96-102
9. Marlair G, Simonson M, Gann R. (2004) [Online] http://www.nist.gov/manuscript-publication-search.cfm?pub_id=861309 [Accessed: 24 April 2012]
10. Aniyie I. (2009) *Law Environment And Development Journal* 5/1:92-106
11. Nnorom I, Osibanjo O. (2008) *Resour Conserv Recy*. (52):1362-1372
12. Tadeo J, Sanche-Brunete C, Miguel E. (2009) *Talanta* 78(1):138-143
13. Regueiro J, Llompart M, Garc´Ia-Jares C, Cela R. (2006) *J. Chromatogr. A* (1137):1–7
14. Kefeni K, Okonkwo J, Olukunle O, Botha B. (2011) *Environ. Rev.* 19:238-253
15. Kefeni K, Okonkwo O. (2012) *Chemosphere* 87:1070-1075
16. Kefenik K, Okonkwo O, Botha B. (2011) *Chromatographia* 73:965-973
17. Asante K, Sudaryanto A, Devanathan G, Bello M, Takahashi S, Isobe T, Tanabe S. (2010) *Interdisciplinary Studies on Environmental Chemistry* 191–198
18. Jakobsson K, Thuresson K, Rylander L, Sjodin A, Hagmar L, Bergman A. (2002) *Chemosphere* 46(5):709-716
19. Birnbaum L, Staskal D. (2004) *Environ Health Perspect.* 112(1):9-17
20. Abb M, Stahl B, Lorenz W. (2011) *Chemosphere* 85(11):1657-1663

21. Olukunle O, Okonkwo O, Kefeni K, Lupankwa M. (2011) *Wat Sci Tech.* 65(4):743-749
22. Darnerud P, Aune M, Larsson L, Lignell S, Mutshatshi T, Okonkwo J, Botha B, Agyei N. (2011) *Sci Total Environ.* 409:4048-4053
23. Kang Y, Wang H, Cheung K, Wong M. (2011) *Atmos. Environ.* 45(14):2386-2393
24. SBC. (2011) [Online]: www.basel.int/Portals/4/download.aspx?d. [Accessed: 24 April 2012]
25. UNEP. (2010) [Online]:chm.pops.int/convention/media/publications/tabid/506/language/en-US/Default.aspx[Accessed: 24 April 2012]
26. DWASA. (2003) Department of Water Affairs, South Africa.