

Supplementary material for:

Critical review of the analysis of brominated flame retardants and their environmental levels in Africa

Martin Brits ^{a,b,c*}, Jayne De Vos ^a, Jana M. Weiss ^d, Egmont R. Rohwer ^c, Jacob de Boer ^b

^a National Metrology Institute of South Africa (NMISA), Pretoria, South Africa

^b VU University, Institute for Environmental Studies (IVM), De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands

^c Laboratory for Separation Science, Department of Chemistry, Faculty of Natural and Agricultural Sciences, University of Pretoria, Lynnwood Road, Pretoria 0002, South Africa

^d Department of Environmental Science and Analytical Chemistry, Arrhenius Laboratory, Stockholm University, SE-10691 Stockholm

Content

Table S1 Summary of publications on BFRs in Africa

Table S1 Summary of publications on BFRs in Africa.				
Sampling Year	Sample Origin (Country)	Analysed (Country)	Summary	Ref.
2004-2005	South Africa	Norway	PBDEs and HBCD in bird eggs (first report on the presence of BFRs in biota from South Africa) <ul style="list-style-type: none"> BFR contamination not only around industrialized areas, but entered the food chain along the western coastline BFRs should be recognized as a potential chemical risk to bio-diversity, ecology and human health 	(Polder <i>et al.</i> , 2008)
Not Provided	South Africa	South Africa	Occurrence of PBDEs in leachates from selected landfill sites <ul style="list-style-type: none"> High concentrations of PBDEs with BDE209 not detected Due to inadequate lining of landfill sites, leachates may migrate into the underlying soil and ground water 	(Odusanya <i>et al.</i> , 2009)
2000-2002	Tanzania	Norway	Composition of organohalogen compounds in blubber of dolphins from the coastal waters of Zanzibar <ul style="list-style-type: none"> Methoxylated PBDEs found at higher concentrations than anthropogenic organochlorine pesticides 	(Mwevura <i>et al.</i> , 2010)
1990-2007	Guinea-Bissau	Sweden	Levels and temporal trend of human exposure to legacy and emerging POPs <ul style="list-style-type: none"> Presence of emerging POPs with decrease in temporal trends for legacy POPs PBDEs found at low concentrations, with increasing temporal trend for BDE153 	(Linderholm <i>et al.</i> , 2010)
Not Provided	South Africa	South Africa	Influences of gas chromatographic parameters on the analysis of BDE209 in indoor dust (first report on BDE209 in South African indoor dust) <ul style="list-style-type: none"> Indoor dust in South Africa contain BDE209, lower than global concentrations 	(Kefeni <i>et al.</i> , 2011)
2004 & 2009	Ghana	Japan	Human exposure to PCBs and BFRs, including PBDEs and HBCDs (first report on BFRs in human breast milk from Africa) <ul style="list-style-type: none"> Human breast milk contains PCB, PBDE and HBCD with elevated levels reported for densely populated cities Increased temporal trend in concentrations for PCBs and PBDEs 	(Asante <i>et al.</i> , 2011)
2007 & 2008	Senegal	France	PCB, OCP and PBDE contamination status in sediments and molluscs (first report on POPs contamination in the Senegalese marine environment) <ul style="list-style-type: none"> Exploited molluscs exposed to the same POPs as reported for sediment Low concentrations pose no health risk to humans through shellfish consumption 	(Bodin <i>et al.</i> , 2011)
2004	South Africa	Sweden	PBDEs and HBCD in breast milk and unique BDE congener profiles (first report on PBDEs and HBCD in South African breast milk) <ul style="list-style-type: none"> Breast milk contains BFRs at levels comparable to European countries Congener patterns differ from European countries with dominance of BDE183 	(Darnerud <i>et al.</i> , 2011)
2010	South Africa	South Africa	Analytical procedure for the analysis of PBDEs and BB153 in sediment (first report on PBDEs in South African sediment) <ul style="list-style-type: none"> Municipal and industrial effluents might contain penta- and octa-BDE formulations, BDE209 not analysed WWTP effluent proposed as possible source of contamination in the investigated river 	(Daso <i>et al.</i> , 2011)
Not Provided	South Africa	Belgium	Multivariate procedures to determine relationship between water and sediment quality, bio accumulative pollutant exposure and the related responses of fish <ul style="list-style-type: none"> Decreased fish health demonstrated by increased oxidative stress due to exposure to metals and organic pollutants 	(Wepener <i>et al.</i> , 2011)
2010-2011	South Africa	South Africa	Assess levels of selected PBDEs and BB153 in wastewater effluent and sewage sludge samples from a WWTP <ul style="list-style-type: none"> Inadequate removal of PBDEs from treated effluent WWTPs could be an important source of PBDEs to the aquatic environment 	(Daso <i>et al.</i> , 2012)
2010	South Africa	South Africa	Occurrence of PBDEs in river sediment <ul style="list-style-type: none"> Sediment contain PBDEs with BDE209 as the major congener PBDE levels were lower than reported from developed countries and may be affected by seasonal rainfall 	(Olukunle <i>et al.</i> , 2012)
Not Provided	South Africa	South Africa	PBB and PBDE concentrations and congener profiles in indoor dust (first report on levels and congener profiles in South African indoor dust) <ul style="list-style-type: none"> Low PBDE concentrations compare to developed countries No correlation between PBB and PBDE concentrations and amount of electronic equipment 	(Kefeni and Okonkwo, 2012)
2009-2010	Nigeria	China	Comparative assessment of heavy metal, PAH, PCB and PBDE contamination in soil and plants; evaluate the genotoxicity of e-waste leachates using human peripheral blood lymphocyte comet assay <ul style="list-style-type: none"> PBDEs were detected in the soil and plant samples from Nigeria with BDE209 as the major congener 	(Alabi <i>et al.</i> , 2012)
2008	Ile Cocos	Norway	POPs, in marine bird eggs from an Indian oceanic island (first report on BFRs in marine bird eggs from a remote island in the Indian Ocean) <ul style="list-style-type: none"> Provide concentrations for PCBs, DDTs, mirex, chlordanes, toxaphenes and BFRs Low levels of BFRs detected in marine bird eggs distant from notable sources 	(Bouwman <i>et al.</i> , 2012)
2010	Tunisia	Spain	OCP, PCB, and PBDE residues in breast milk of Tunisian mothers (first report on PBDEs in Tunisian human milk) <ul style="list-style-type: none"> DDTs, HCB and PCBs were dominant compounds identified in all breast milk samples Higher PBDEs concentrations than reported for European and Asiatic countries 	(Hassine <i>et al.</i> , 2012)

Not Provided	South Africa	South Africa	Amperometric horseradish peroxidase biosensor for the determination of selected POPs in landfill leachates, compare results with GC-MS data <ul style="list-style-type: none"> Inhibition mechanism is competitive for PBDEs and non-competitive for biphenyls (PCBs and PBBs) Biosensor as a screening method for different halogenated aromatic hydrocarbons; comparable with GC-MS data 	(Nomngongo <i>et al.</i> , 2012)
Not Provided	South Africa	South Africa	Development of a GC-MS method for APEs and BFRs analysis, using SPE and derivatization with HFBA <ul style="list-style-type: none"> Method showed acceptable relative recoveries for the determination of APEs and BFRs in wastewater samples Levels for TBBPA and HBCD were reported and lower substituted PBBs were not detected 	(Chokwe <i>et al.</i> , 2012)
Not Provided	South Africa	South Africa	PBDEs in indoor dust; examine the correlation between congener and trace metal concentrations <ul style="list-style-type: none"> Settled indoor dusts are contaminated with organic and inorganic chemicals Significant correlation between PBDE and trace metal concentrations from home dust 	(Kefeni and Okonkwo, 2013)
2009-2011	Tanzania	Belgium	Concentrations and profiles of organohalogenated compounds in environmental samples from the Pangani river basin (PRB) <ul style="list-style-type: none"> Low levels for POPS were reported for the PRB PCB and PBDE concentrations were linked to urbanisation and atmospheric deposition 	(Hellar-Kihampa <i>et al.</i> , 2013)
2010-2011	South Africa	South Africa	PBDEs and BB153 in river water and source identification <ul style="list-style-type: none"> Low PBDE concentrations with BDE47 as dominant congener Potential PBDE contamination sources include WWTP, grey water intrusion, seepages from landfill sites, urban and agricultural runoff 	(Daso <i>et al.</i> , 2013a)
2010-2011	South Africa	South Africa	PBDE and BB153 concentrations in landfill leachates <ul style="list-style-type: none"> High PBDE concentrations with BDE209 as major congener Landfill leachates could be a possible source of PBDE contamination in ground and surface water 	(Daso <i>et al.</i> , 2013b)
2011	Tanzania	Italy	PBDE congeners in an altitudinal soil transect in Tanzania <ul style="list-style-type: none"> PBDE concentrations might be higher than similar semi-remote environment PBDE contamination pattern characterized by the prevalence of intermediate brominated congeners 	(Parolini <i>et al.</i> , 2013)
2010	Ghana	Japan	BFR and PCB contamination in fish from water bodies in Ghana (first report on PBDEs and HBCDs in fish from Ghana) <ul style="list-style-type: none"> Freshwater environments in Ghana are exposed to PBDEs and HBCDs PBDE and HBCD concentrations pose no health risk to humans through fish consumption 	(Asante <i>et al.</i> , 2013)
Not Provided	South Africa	Norway	Investigate the presence, levels, relationships, impacts, and risks of pesticides, PCBs, and BFRs in terrestrial and aquatic bird eggs in South Africa <ul style="list-style-type: none"> Highest ΣDDT levels in wild bird eggs BFR concentrations were lower compare to similar studies 	(Bouwman <i>et al.</i> , 2013)
2010	Congo	Belgium	POPs in sediment and biota (first report on POPs in sediment, invertebrates and fish from Congo) <ul style="list-style-type: none"> Low PBDE levels in sediment and biota compared to similar studies Increase in BDE47 and 99 concentrations in river basins with increased trophic levels 	(Verhaert <i>et al.</i> , 2013)
2011	South Africa	USA	PBDEs and alt-BFRs in inland and coastal sediment (first data reported for alt-BFRs in South African sediment) <ul style="list-style-type: none"> High PBDE and alt-BFR concentrations in sediment with BDE209 and TBB as most frequent detected BFRs PBDE levels were higher than previously reported for the San Francisco Bay 	(La Guardia <i>et al.</i> , 2013)
2008-2010	Uganda	Canada	Measured temporal variation of PBDEs and alt-BFRs in air samples and estimated the fluxes of the BFRs in precipitation samples (first study to report FRs in high volume air samples and precipitation in Equatorial Africa) <ul style="list-style-type: none"> PBDEs and Alt-BFRs levels in air generally increased from 2008 to 2010 PBDE levels in air samples have been associated with slow moving low altitude air masses with BTBPE as the most frequent detected alt-BFR 	(Arinaitwe <i>et al.</i> , 2014)
2010-2011	South Africa	South Africa	PBDE and PBB concentrations and congener profiles in indoor dust; examine the correlation with socioeconomic status <ul style="list-style-type: none"> Low concentrations of PBDEs No correlation between the PBDE concentration and the three socioeconomic categories considered 	(Kefeni <i>et al.</i> , 2014)
2011	South Africa	South Africa	Correlation between PBDE congener distribution and indoor dust particle size <ul style="list-style-type: none"> PBDE concentrations increase with particle size factions Imported electronic products identified as a major contamination source 	(Kefeni and Okonkwo, 2014)
2009	South Africa	Norway	Selected halogenated organic pollutants in crocodile eggs to assess the possible role in mortalities (first report on BFRs in crocodile eggs) <ul style="list-style-type: none"> Low BFR concentrations and unlikely that targeted pollutants have contributed to the mortalities 	(Bouwman <i>et al.</i> , 2014)
2011	Tanzania	Norway	Occurrence of POPs in fish from four different Lakes in Tanzania, assess the implications on human health <ul style="list-style-type: none"> BDE47 and BDE209 were only PBDEs detected, with BDE209 prevalent at highest levels in all lakes Industrial area close to the shoreline identified as a possible contamination source 	(Polder <i>et al.</i> , 2014)
Not Provided	Uganda	China	PBDEs in sediments and fish from Lake Victoria (first report on PBDEs in sediments and fish from Murchison Bay, Lake Victoria) <ul style="list-style-type: none"> Concentrations in sediment and fish were low to moderate compared to similar studies Fish consumption from the study area does not pose any risk to human health regarding PCDD/Fs and PBDEs 	(Ssebugere <i>et al.</i> , 2014)

2013	South Africa	South Africa	PBDE concentration in landfill leachate and sediment and river sediment; investigate the relationship between trace metals, anions and water quality parameters <ul style="list-style-type: none"> • High PBDE concentrations with BDE209 as major congener • Highest PBDE concentrations for leachates from landfill sites equipped with geomembranes 	(Olukunle <i>et al.</i> , 2014)
2011	Nigeria	Germany	Assess the presence of the PBDE (listed as POPs) and other BFRs in plastic of cathode ray tubes (CRT) from TV and computer monitors <ul style="list-style-type: none"> • CRT casings from TVs and computers imported to Nigeria contain high levels of BFRs • PBDEs present in TV CRT casings from the 1980s; BDE209 predominantly in all the CRT casings, EEE and e-waste from the last 30 years 	(Sindikou <i>et al.</i> , 2014)
2011-2012	South Africa	Norway	Present the prevalence and levels of organic pollutants in the African Penguin eggs; compare results to previous studies <ul style="list-style-type: none"> • ΣDDT concentrations remained mostly unchanged, while ΣPCBs levels decreased • PBDEs detected at low concentrations 	(Bouwman <i>et al.</i> , 2015)
2012	South Africa	South Africa	Provide data on PCBs and PBDEs in indoor dust <ul style="list-style-type: none"> • PCB levels were lower than PBDE levels • PBDE concentrations were lower than reported for developing countries 	(Abafe and Martincigh, 2014)
2012 & 2013	South Africa	South Africa	Examine the presence of PBDEs and PCBs in the indoor dust from e-waste recycling sites and electronic equipment repair workshop <ul style="list-style-type: none"> • PBDEs were detected at high concentrations • Outdated recycling technology may cause exposure to high levels for tetra- to hexa-BDEs and BDE 209 	(Abafe and Martincigh, 2015)
2012-2013	South Africa	South Africa	PBDE congeners in eggshells from two bird species <ul style="list-style-type: none"> • PBDE levels indicate an accumulation of the lower PBDE congeners • Estimated hazard quotients indicate Wattled Crane was subjected to high risk due to PBDE exposure 	(Daso <i>et al.</i> , 2015)
Not Provided	South Africa	South Africa	GC-MS method for the analysis of APEs, PBDEs, PBB101 and HBCD in fish, using ultrasonic extraction, SPE clean-up and derivatization <ul style="list-style-type: none"> • APEs and BFRs could simultaneously be analysed using the derivatization method • Moderate contamination of APEs and BFRs in fish, with inconsistent BFR levels 	(Chokwe <i>et al.</i> , 2015a)
2013	South Africa	South Africa	APE, PBDE, PBB101 and HBCD concentrations in water, fish, and sediment <ul style="list-style-type: none"> • Higher ΣHBCD concentrations reported for all matrices • WWTPs proposed as a possible source of contamination 	(Chokwe <i>et al.</i> , 2015b)
Not Provided	South Africa	South Africa	GC-MS method for simultaneous analysis of APEs and BFRs in sewage sludge from WWTPs, using ultrasonic extraction and HFBA derivatization <ul style="list-style-type: none"> • Industrial activities could be a potential source for contamination for one of the sampling sites 	(Chokwe <i>et al.</i> , 2015c)
2012	Nigeria	South Africa	PBDE concentrations in indoor dust in Nigeria <ul style="list-style-type: none"> • Positive correlation between PBDE concentrations and amount of electronic equipment • Higher dust exposure estimate compared to South Africa 	(Olukunle <i>et al.</i> , 2015a)
2014	Nigeria	South Africa	PBDE levels in car dust in Nigeria (first report on BDEs in car dust and ingestion rate estimations for Nigeria) <ul style="list-style-type: none"> • Car dust does contain PBDEs with BDE209 as dominant congener • Low daily ingestion rates show no health risk associated with PBDE exposure 	(Olukunle <i>et al.</i> , 2015b)
2013	Egypt	England	PBDE and alt-BFRs concentrations in indoor dust from the Greater Cairo region <ul style="list-style-type: none"> • PBDE congeners and alt-BFRs were detected, with BDE209 and HBCD as major congeners • PBDE and alt-BFRs concentrations in Egyptian dust are among the lowest levels reported 	(Hassan and Shoeib, 2015)
2013	South Africa	South Africa	Alt-BFR and HBCD concentrations for landfill leachates and sediments (first report on alt-BFRs and HBCD in South African landfills) <ul style="list-style-type: none"> • The Alt-BFR detection frequency was higher in leachates than in sediment • Higher ΣHBCD concentrations compare to river sediment from The Netherlands and Ireland 	(Olukunle and Okonkwo, 2015)
2010-2011	South Africa	South Africa	Provide baseline information on selected PBDE congeners and BB153 in sediment from two major rivers <ul style="list-style-type: none"> • The BFR contamination patterns vary for both rivers • Grey water from informal settlements and atmospheric deposition from landfills are possible contamination sources 	(Daso <i>et al.</i> , 2016)
2015	Kenya	China	Investigate the occurrence of OCPs, PCBs and PBDEs in soils from southern Kenya <ul style="list-style-type: none"> • The soils were less contaminated by PBDEs compared to OCP and PCBs • The dominant PBDE congeners were penta-, tri- or tetra-BDEs, varying among different sampling sites 	(Sun <i>et al.</i> , 2016)
2012	Tanzania	Norway	Reported POPs in native free-range chicken eggs and relate levels to human health (first report on BTBPE levels in African chicken eggs) <ul style="list-style-type: none"> • PBDE levels vary in collective egg samples with BDE209 as dominant congener • HCB found in moderate to high levels with BPBPE at lower concentrations 	(Polder <i>et al.</i> , 2016)
2012	Tanzania	Norway	BFRs in breast milk from the Northern parts of Tanzania (first study reporting on BFRs in human breast milk from Tanzania) <ul style="list-style-type: none"> • PBDE levels an order of magnitude higher that reported for Europe, Asia and other Sub-Saharan African countries • Mothers taking a clay product, used as mineral supplement and anti-emetic for pregnancy related nausea had higher PBDE levels 	(Müller <i>et al.</i> , 2016)

References

- Abafe, O.A., Martincigh, B.S., 2014. Polybrominated diphenyl ethers and polychlorinated biphenyls in indoor dust in Durban, South Africa. *Indoor Air* 25, 547–556. doi:10.1111/ina.12168.
- Abafe, O.A., Martincigh, B.S., 2015. An assessment of polybrominated diphenyl ethers and polychlorinated biphenyls in the indoor dust of e-waste recycling facilities in South Africa: implications for occupational exposure. *Environ. Sci. Pollut. Res.* 22, 14078–86. doi:10.1007/s11356-015-4627-z.
- Alabi, O.A., Bakare, A.A., Xu, X., Li, B., Zhang, Y., Huo, X., 2012. Comparative evaluation of environmental contamination and DNA damage induced by electronic-waste in Nigeria and China. *Sci. Total Environ.* 423, 62–72. doi:10.1016/j.scitotenv.2012.01.056.
- Arinaitwe, K., Muir, D.C.G., Kiremire, B.T., Fellin, P., Li, H., Teixeira, C., 2014. Polybrominated diphenyl ethers and alternative flame retardants in air and precipitation samples from the Northern Lake Victoria Region, East Africa. *Environ. Sci. Technol.* 48, 1458–1466. doi:10.1021/es403600a.
- Asante, K.A., Adu-Kumi, S., Nakahiro, K., Takahashi, S., Isobe, T., Sudaryanto, A., Devanathan, G., Clarke, E., Ansa-Asare, O.D., Dapaah-Siakwan, S., Tanabe, S., 2011. Human exposure to PCBs, PBDEs and HBCDs in Ghana: Temporal variation, sources of exposure and estimation of daily intakes by infants. *Environ. Int.* 37, 921–928. doi:10.1016/j.envint.2011.03.011.
- Asante, K.A., Takahashi, S., Itai, T., Isobe, T., Devanathan, G., Muto, M., Agyakwah, S.K., Adu-Kumi, S., Subramanian, A., Tanabe, S., 2013. Occurrence of halogenated contaminants in inland and coastal fish from Ghana: Levels, dietary exposure assessment and human health implications. *Ecotoxicol. Environ. Saf.* 94, 123–130. doi:10.1016/j.ecoenv.2013.05.008.
- Bodin, N., N’Gom Ka, R., Le Loc’h, F., Raffray, J., Budzinski, H., Peluhet, L., Tito de Morais, L., 2011. Are exploited mangrove molluscs exposed to Persistent Organic Pollutant contamination in Senegal, West Africa? *Chemosphere* 84, 318–327. doi:10.1016/j.chemosphere.2011.04.012.
- Bouwman, H., Kylin, H., Choong Kwet Yive, N.S., Tatayah, V., Løken, K., Utne Skaare, J., Polder, A., 2012. First report of chlorinated and brominated hydrocarbon pollutants in marine bird eggs from an oceanic Indian Ocean island. *Environ. Res.* 118, 53–64. doi:10.1016/j.envres.2012.05.009.
- Bouwman, H., Viljoen, I.M., Quinn, L.P., Polder, A., 2013. Halogenated pollutants in terrestrial and aquatic bird eggs: Converging patterns of pollutant profiles, and impacts and risks from high levels. *Environ. Res.* 126, 240–253. doi:10.1016/j.envres.2013.06.003.
- Bouwman, H., Booyens, P., Govender, D., Pienaar, D., Polder, A., 2014. Chlorinated, brominated, and fluorinated organic pollutants in Nile crocodile eggs from the Kruger National Park, South Africa. *Ecotoxicol. Environ. Saf.* 104, 393–402. doi:10.1016/j.ecoenv.2013.12.005.
- Bouwman, H., Govender, D., Underhill, L., Polder, A., 2015. Chlorinated, brominated and fluorinated organic pollutants in African Penguin eggs: 30 years since the previous assessment. *Chemosphere* 126, 1–10. doi:10.1016/j.chemosphere.2014.12.071.
- Chokwe, T.B., Okonkwo, J.O., Sibali, L.L., Ncube, E.J., 2012. Optimization and simultaneous determination of alkyl phenol ethoxylates and brominated flame retardants in water after SPE and heptafluorobutyric anhydride derivatization followed by GC/MS. *Chromatographia* 75, 1165–1176. doi:10.1007/s10337-012-2293-6.
- Chokwe, T.B., Okonkwo, J.O., Sibali, L.L., Krüger, E., Preez, H., Hariram, R., Ncube, E.J., 2015a. A Simplified Analytical Procedure for Simultaneous Determination of Alkylphenol Ethoxylates and Brominated Flame Retardants in Fish Tissue Samples from Vaal River, South Africa. *Am. J. Anal. Chem.* 6, 422–428.
- Chokwe, T.B., Okonkwo, J.O., Sibali, L.L., Ncube, E.J., 2015b. Alkylphenol ethoxylates and brominated flame retardants in water, fish (carp) and sediment samples from the Vaal River, South Africa. *Environ. Sci. Pollut. Res.* 22, 11922–11929. doi:10.1007/s11356-015-4430-x.
- Chokwe, T.B., Okonkwo, J.O., Sibali, L.L., Ncube, E.J., 2015c. An integrated method for the simultaneous determination of alkylphenol ethoxylates and brominated flame retardants in

- sewage sludge samples by ultrasonic-assisted extraction , solid phase clean-up , and GC-MS analysis. *Microchem. J.* 123, 230–236. doi:10.1016/j.microc.2015.07.001.
- Darnerud, P.O., Aune, M., Larsson, L., Lignell, S., Mutshatshi, T., Okonkwo, J., Botha, B., Agyei, N., 2011. Levels of brominated flame retardants and other persistent organic pollutants in breast milk samples from Limpopo province, South Africa. *Sci. Total Environ.* 409, 4048–4053. doi:10.1016/j.scitotenv.2011.05.054.
- Daso, A.P., Fatoki, O.S., Odendaal, J.P., 2011. Development of analytical procedures for the simultaneous determination of tri- to heptabrominated diphenyl ethers and hexabrominated biphenyl (BB 153) in sediment samples. *Water SA* 37, 331–338. doi:10.4314/wsa.v37i3.68484.
- Daso, A.P., Fatoki, O.S., Odendaal, J.P., Olujimi, O.O., 2012. Occurrence of selected polybrominated diphenyl ethers and 2,2',4,4',5,5'-hexabromobiphenyl (BB-153) in sewage sludge and effluent samples of a wastewater-treatment plant in Cape Town, South Africa. *Arch. Environ. Contam. Toxicol.* 62, 391–402. doi:10.1007/s00244-011-9720-9.
- Daso, A.P., Fatoki, O.S., Odendaal, J.P., 2013a. Occurrence of polybrominated diphenyl ethers (PBDEs) and 2,2',4,4',5,5'-hexabromobiphenyl (BB-153) in water samples from the Diep River, Cape Town, South Africa. *Environ. Sci. Pollut. Res.* 20, 5168–5176. doi:10.1007/s11356-013-1503-6.
- Daso, A.P., Fatoki, O.S., Odendaal, J.P., Olujimi, O.O., 2013b. Polybrominated diphenyl ethers (PBDEs) and 2,2',4,4',5,5'-hexabromobiphenyl (BB-153) in landfill leachate in Cape Town, South Africa. *Environ. Monit. Assess.* 185, 431–439. doi:10.1007/s10661-012-2565-5.
- Daso, A.P., Okonkwo, J.O., Jansen, R., Forbes, P.B.C., Kotzé, A., Rohwer, E.R., 2015. Polybrominated diphenyl ethers (PBDEs) in eggshells of the Southern Ground-Hornbill (*Bucorvus leadbeateri*) and Wattled Crane (*Bugeranus carunculatus*) in South Africa. *Chemosphere* 118, 284–292. doi:10.1016/j.chemosphere.2014.09.063.
- Daso, A.P., Fatoki, O.S., Odendaal, J.P., 2016. Evaluation of polybrominated diphenyl ethers (PBDEs) and 2,2',4,4',5,5'- hexabromobiphenyl (BB-153) burdens of sediment samples from the Diep and Kuils Rivers, Cape Town, South Africa. *Int. J. Sediment Res.* 31, 61-70. doi:10.1016/j.ijsrc.2013.10.001.
- Hassan, Y., Shoeib, T., 2015. Levels of polybrominated diphenyl ethers and novel flame retardants in microenvironment dust from Egypt: An assessment of human exposure. *Sci. Total Environ.* 505, 47–55. doi:10.1016/j.scitotenv.2014.09.080.
- Hassine, S. Ben, Ameur, W. Ben, Gandoura, N., Driss, M.R., 2012. Determination of chlorinated pesticides, polychlorinated biphenyls, and polybrominated diphenyl ethers in human milk from Bizerte (Tunisia) in 2010. *Chemosphere* 89, 369–377. doi:10.1016/j.chemosphere.2012.05.035.
- Hellar-Kihampa, H., De Wael, K., Lugwisha, E., Malarvannan, G., Covaci, A., Van Grieken, R., 2013. Spatial monitoring of organohalogen compounds in surface water and sediments of a rural–urban river basin in Tanzania. *Sci. Total Environ.* 447, 186–197. doi:10.1016/j.scitotenv.2012.12.083.
- Kefeni, K.K., Okonkwo, J.O., 2014. Distribution of polybrominated diphenyl ethers and dust particle size fractions adherent to skin in indoor dust, Pretoria, South Africa. *Environ. Sci. Pollut. Res.* 21, 4376–4386. doi:10.1007/s11356-013-2312-7.
- Kefeni, K.K., Okonkwo, J.O., Botha, B.M., 2011. Influence of gas chromatographic parameters on determination of decabromodiphenyl ether. *Chromatographia* 73, 965–973. doi:10.1007/s10337-010-1843-z.
- Kefeni, K.K., Okonkwo, J.O., 2012. Analysis of major congeners of polybromobiphenyls and polybromodiphenyl ethers in office dust using high resolution gas chromatography – mass spectrometry. *Chemosphere* 87, 1070–1075. doi:10.1016/j.chemosphere.2012.02.014.
- Kefeni, K.K., Okonkwo, J.O., 2013. Trace metals, anions and polybromodiphenyl ethers in settled indoor dust and their association. *Environ. Sci. Pollut. Res.* 20, 4895–4905. doi:10.1007/s11356-013-1469-4.

- Kefeni, K.K., Okonkwo, J.O., Botha, B.M., 2014. Concentrations of polybromobiphenyls and polybromodiphenyl ethers in home dust: Relevance to socio-economic status and human exposure rate. *Sci. Total Environ.* 470-471, 1250–1256. doi:10.1016/j.scitotenv.2013.10.078.
- La Guardia, M.J., Hale, R.C., Newman, B., 2013. Brominated flame-retardants in sub-saharan Africa: Burdens in inland and coastal sediments in the eThekweni metropolitan municipality, South Africa. *Environ. Sci. Technol.* 47, 9643–9650. doi:10.1021/es4020212.
- Linderholm, L., Biague, A., Månsson, F., Norrgren, H., Bergman, Å., Jakobsson, K., 2010. Human exposure to persistent organic pollutants in West Africa - A temporal trend study from Guinea-Bissau. *Environ. Int.* 36, 675–682. doi:10.1016/j.envint.2010.04.020.
- Müller, M.H.B., Polder, A., Brynildsrud, O.B., Lie, E., Løken, K.B., Manyilizu, W.B., Mdegela, R.H., Mokiti, F., Murtadha, M., Nonga, H.E., Skaare, J.U., Lyche, J.L., 2016. Brominated flame retardants (BFRs) in breast milk and associated health risks to nursing infants in Northern Tanzania. *Environ. Int.* 89-90, 38–47. doi:10.1016/j.envint.2015.12.032.
- Mwevura, H., Amir, O.A., Kishimba, M., Berggren, P., Kylin, H., 2010. Organohalogen compounds in blubber of Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) and spinner dolphin (*Stenella longirostris*) from Zanzibar, Tanzania. *Environ. Pollut.* 158, 2200–2207. doi:10.1016/j.envpol.2010.02.027.
- Nomngongo, P.N., Catherine Ngila, J., Msagati, T.A.M., Gumbi, B.P., Iwuoha, E.I., 2012. Determination of selected persistent organic pollutants in wastewater from landfill leachates, using an amperometric biosensor. *Phys. Chem. Earth* 50-52, 252–261. doi:10.1016/j.pce.2012.08.001.
- Odusanya, D.O., Okonkwo, J.O., Botha, B., 2009. Polybrominated diphenyl ethers (PBDEs) in leachates from selected landfill sites in South Africa. *Waste Manag.* 29, 96–102. doi:10.1016/j.wasman.2008.02.011.
- Olukunle, O.I., Okonkwo, O.J., 2015. Concentration of novel brominated flame retardants and HBCD in leachates and sediments from selected municipal solid waste landfill sites in Gauteng Province, South Africa. *Waste Manag.* 43, 300–306. doi:10.1016/j.wasman.2015.07.009.
- Olukunle, O., Okonkwo, J., Kefeni, K., Lupankwa, M., 2012. Concentrations of polybrominated diphenyl ethers in sediments from Jukskei River, Gauteng, South Africa. *Bull. Environ. Contam. Toxicol.* 88, 461–466. doi:10.1007/s00128-011-0481-y.
- Olukunle, O.I., Sibiyi, I. V., Okonkwo, O.J., Odusanya, A.O., 2014. Influence of physicochemical and chemical parameters on polybrominated diphenyl ethers in selected landfill leachates, sediments and river sediments from Gauteng, South Africa. *Environ. Sci. Pollut. Res.* 22, 2145–2154. doi:10.1007/s11356-014-3443-1.
- Olukunle, O.I., Okonkwo, O.J., Sha'ato, R., Wase, G.A., 2015a. Levels of polybrominated diphenyl ethers in indoor dust and human exposure estimates from Makurdi, Nigeria. *Ecotoxicol. Environ. Saf.* 120, 394–399. doi:10.1016/j.ecoenv.2015.06.023.
- Olukunle, O.I., Okonkwo, O.J., Wase, A.G., Sha'ato, R., 2015b. Polybrominated diphenyl ethers in car dust in Nigeria: Concentrations and implications for non-dietary human exposure. *Microchem. J.* 123, 99–104. doi:10.1016/j.microc.2015.05.023.
- Parolini, M., Guazzoni, N., Comolli, R., Binelli, A., Tremolada, P., 2013. Background levels of polybrominated diphenyl ethers (PBDEs) in soils from Mount Meru area, Arusha district (Tanzania). *Sci. Total Environ.* 452-453, 253–261. doi:10.1016/j.scitotenv.2013.02.069.
- Polder, A., Venter, B., Skaare, J.U., Bouwman, H., 2008. Polybrominated diphenyl ethers and HBCD in bird eggs of South Africa. *Chemosphere* 73, 148–154. doi:10.1016/j.chemosphere.2008.03.021.
- Polder, A., Müller, M.B., Lyche, J.L., Mdegela, R.H., Nonga, H.E., Mabiki, F.P., Mbise, T.J., Skaare, J.U., Sandvik, M., Skjerve, E., Lie, E., 2014. Levels and patterns of persistent organic pollutants (POPs) in tilapia (*Oreochromis sp.*) from four different lakes in Tanzania: Geographical differences and implications for human health. *Sci. Total Environ.* 488-489, 252–260.

doi:10.1016/j.scitotenv.2014.04.085.

- Polder, A., Müller, M.B., Brynildsrud, O.B., de Boer, J., Hamers, T., Kamstra, J.H., Lie, E., Mdegela, R.H., Moberg, H., Nonga, H.E., Sandvik, M., Skaare, J.U., Lyche, J.L., 2016. Dioxins, PCBs, chlorinated pesticides and brominated flame retardants in free-range chicken eggs from peri-urban areas in Arusha, Tanzania: Levels and implications for human health. *Sci. Total Environ.* 551-552, 656–667. doi:10.1016/j.scitotenv.2016.02.021.
- Sindik, O., Babayemi, J., Osibanjo, O., Schlummer, M., Schluep, M., Watson, A., Weber, R., 2014. Polybrominated diphenyl ethers listed as Stockholm Convention POPs, other brominated flame retardants and heavy metals in e-waste polymers in Nigeria. *Environ. Sci. Pollut. Res.* 22, 14489–14501. doi:10.1007/s11356-014-3266-0.
- Ssebugere, P., Sillanpää, M., Wang, P., Li, Y., Kiremire, B.T., Kasozi, G.N., Zhu, C., Ren, D., Zhu, N., Zhang, H., Shang, H., Zhang, Q., Jiang, G., 2014. Polychlorinated biphenyls in sediments and fish species from the Murchison Bay of Lake Victoria, Uganda. *Sci. Total Environ.* 482-483, 349–357. doi:10.1016/j.scitotenv.2014.03.009.
- Sun, H., Qi, Y., Zhang, D., Li, Q.X., Wang, J., 2016. Concentrations, distribution, sources and risk assessment of organohalogenated contaminants in soils from Kenya, Eastern Africa. *Environ. Pollut.* 209, 177–185. doi:10.1016/j.envpol.2015.11.040.
- Verhaert, V., Covaci, A., Bouillon, S., Abrantes, K., Musibono, D., Bervoets, L., Verheyen, E., Blust, R., 2013. Baseline levels and trophic transfer of persistent organic pollutants in sediments and biota from the Congo River Basin (DR Congo). *Environ. Int.* 59, 290–302. doi:10.1016/j.envint.2013.05.015.
- Wepener, V., van Dyk, C., Bervoets, L., O'Brien, G., Covaci, A., Cloete, Y., 2011. An assessment of the influence of multiple stressors on the Vaal River, South Africa. *Phys. Chem. Earth* 36, 949–962. doi:10.1016/j.pce.2011.07.075.