Polybrominated diphenyl ethers (BDEs) in sediment, pore water, and infaunal invertebrates along a spatial gradient in an urban estuarine river receiving wastewater effluent in Baltimore, Maryland, USA.

Susan L. Klosterhaus[1], Heather M. Stapleton[2], and Joel E. Baker[1]

[1]Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, Maryland, USA.
[2]National Institute of Standards & Technology, 100 Bureau Drive, Mailstop 8392, Gaithersburg, MD 20899.

Introduction

Relatively high levels of polybrominated diphenyl ethers (BDEs) in fish, mussels, and sediment near wastewater treatment plants, BDE manufacturing plants, and textile manufacturing plants[1-4] have demonstrated that aquatic environments located near these facilities may be particularly vulnerable to BDE contamination. To date, only a few studies measured BDEs in invertebrates[1,2,5], and less have investigated the accumulation of BDEs from sediments by the invertebrates most closely associated with them, the infaunal deposit feeders[6,7]. Deposit feeders rely on the ingestion of organic carbon-rich sediment particles as a high quality food source, and may inadvertently expose themselves to large amounts of carbon-sorptive hydrophobic organic chemicals (HOCs) while feeding in contaminated sediment environments. Bioaccumulation experiments and model results have indeed suggested that the ingestion of contaminated sediment may often be the dominant HOC uptake pathway for deposit-feeding invertebrates in sediments[8]. Diffusion of dissolved HOCs in pore water across soft biological membrane surfaces (e.g. respiratory surfaces, integument) may result in an additional BDE exposure route that an invertebrate organism suspension-feeding from overlying water on the sediment surface would not experience. Thus, feeding strategy and sediment-dwelling lifestyle may be significant factors in the degree of accumulation of sediment-associated BDEs. Our objectives for this study were to (1) investigate the steady-state partitioning behavior of BDEs in bulk sediments by comparing relative congener abundances in sediment and pore water, and (2) compare these profiles with those found in the biota to provide insight into the relative importance of each exposure route in the accumulation of BDEs by organisms living in their natural habitat.

Methods

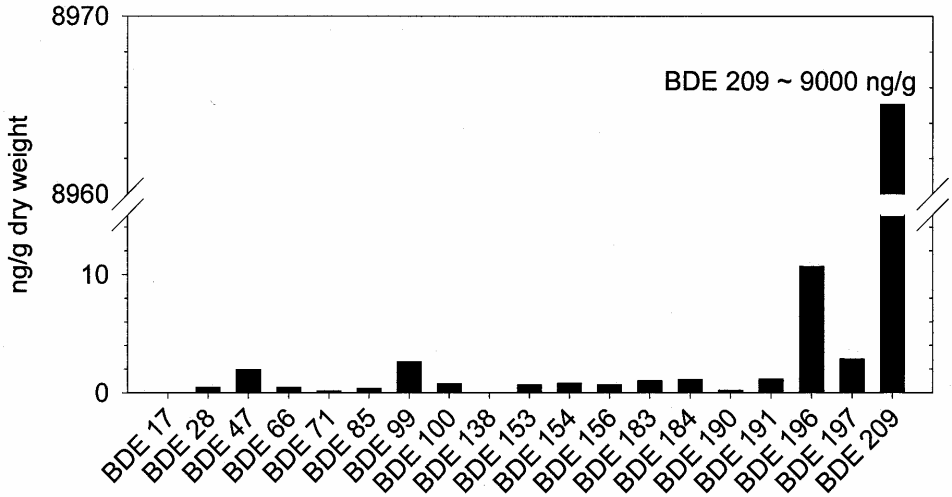
Bulk sediment and infaunal invertebrates, including amphipods and polychaete worms, were collected from sites along a spatial gradient downstream of a wastewater treatment facility in Back River and sites adjacent to Hart-Miller Island, a confined sediment

disposal facility at the mouth of Back River (Baltimore, Maryland, USA). Organisms were allowed to purge their gut contents in clean seawater for 5-8 hrs before sample processing. Pore water was separated from Back River bulk sediment via centrifugation and filtration under anoxic conditions, and BDEs were then extracted using a liquid:liquid extraction procedure. Following homogenization with sodium sulfate, BDEs were extracted from sediments using Soxhlet extraction (24 hrs) and from invertebrates via sonication, both using dichloromethane as the extraction solvent. Sample interferences were removed using alumina and Florisil column chromatography. A total of 19 BDE congeners (17, 28, 47, 66, 71, 85, 99, 100, 138, 153, 154, 156, 183, 184, 190, 191, 196, 197 and 209) were quantified in all samples using GC/MS with negative chemical ionization (NCI).

Results and Discussion

Sum BDE concentrations in Back River sediments ranged from ~2400-9000 ng/g dry weight, with BDE 209 accounting for more than 99% of the total. Relative concentrations among the remaining BDE congeners detected were 209>196,197>47, 99, 156 (Figure 1).

Figure 1. BDEs in sediment near wastewater effluent outflow in Back River



A spatial gradient of decreasing BDE 209 concentrations leading downstream from the wastewater facility was apparent. Compared to published literature values, concentrations of BDE 209 in Back River sediments are the highest measured to date[9]. Sum BDE concentrations in sediments at the Hart-Miller Island sites were more than an order of magnitude lower than Back River and ranged from ~50-160 ng/g dry weight. BDE 209 was the overwhelming predominant congener in sediment at these sites also, accounting for 93-99% of the total. Relative concentrations among the BDE congeners detected at Hart-Miller Island were 209>47, 99>others. Sum BDE concentrations in Back River pore

water ranged from 0.2-1.8 ng/liter. BDEs 47 and 99 were the only congeners detected in all pore water samples (0.1-1 ng/liter), and BDE 100 was detected at one site (0.2 ng/liter).

Clearly, BDEs were strongly sorbed to sediment particles, suggesting a very low exposure of BDEs to infaunal invertebrates via pore water in Back River. Ingestion of sediment particles, however, will result in an extremely high exposure of BDE 209 in the deposit-feeder gut, particularly organisms with high sediment ingestion rates such as polychaete worms. Invertebrate BDE concentrations, including congener profiles and biota-sediment accumulation factors, will be discussed in detail.

Acknowledgement
We thank Dan Liebert for assisting in field collections.

References

1. de Boer, J., Wester, P. G., van der Horst, A., Leonards, P. E. G. (2003). Environ. Poll. 122:63-74.
2. Voorspoels, S., Covaci, A., and Schepens, P. (2003). Environ. Sci. Technol. 37:4348-4357.
3. Hale, R. C., La Guardia, M. J., Harvey, E. P., Mainor, T. M., Duff, W. H., Gaylor, M. O. (2001). Environ. Sci. Technol. 35:4585-4591.
4. Sellstrom, U., Kierkegaard, A., de Wit, C., Jansson, B. (1998). Environ. Toxicol. Chem. 17: 1065-1072.
5. Booij, K., Zegers, B. N., Boon, J. P. (2002). Chemosphere. 46:683-688.
6. Leppanen, M.T., Kukkonen, J.V.K. (2004). Environ. Toxicol. Chem. 23: 166-172.
7. Stapleton, H.M., Baker, J.E. (2003). Arch. Environ. Contam. Toxicol. 45:227-234.
8. Forbes, T. L., Forbes, V. E., Giessing, A., Hansen, R., Kure, L. K. (1998). Environ. Toxicol. Chem. 17:2453-2462.
9. Hites, R. A. (2004). Environ. Sci. Technol. 38: 945-956.