Fate of Decabromodiphenyl Ether and Decabromodiphenyl Ethane in Pond Mesocosms

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Fließ- und Stillgewässer-Simulationsanlage

Introduction

Decabromodiphenyl ether (BDE-209) and decabromodiphenyl ethane (DBDPE) are high-production volume brominated flame retardants frequently used in a great variety of polymeric applications. It is still under debate whether the PBT criteria can be applied to BDE-209. Little is known about the fate of DBDPE, which was introduced in the early 90's and marketed as alternative to BDE-209.
Up to now, no fate data for these compounds from aquatic micro- or mesocosm studies have been published. Reasons for this may be their extreme sorption properties, which pose a challenge with regard to application, sampling and difficulties in analysis.

Application and sampling techniques for handling these extremely lipophilic substances were tested in small indoor mesocosm systems (1000 L water volume) of the artificial pond and stream mesocosm system (FSA) of the Federal Environment Agency (UBA). In 2006, both DBDPE and BDE-209 were dosed once resulting in an initial concentration of appr. 100 ng/L in two pond mesocosms with and without sediment respectively. In addition, a pond without sediment was used as control. BDE-209 and DBDPE concentrations in water were analysed over a period of 52 days by use of HRGC/ECNI-LRMS. At the end of the study concentrations in sediment and biofilms were measured.

Fig. 1: Indoor pond segments of the artificial stream and pond system (FSA) of the UBA. After application of test substances, air was blown across the water surface for 30 min to ensure homogeneous distribution

Materials & Methods

Pond design

Size: Length 2,5 x width 1.0 x height 1,0 cm
Material: Gel-coated fibre-reinforced composite material
Water volume: 1000 L
Light: Indirect light (indoor situation)
Ground (only Pond 3): Sand, natural fine sediment (groundwater lake "Britzer Garten", Berlin)
Biofilms: Naturally grown biofilms
Mixing: 30 min ventilation on water surface after application

Experimental design

Pond 1 - Control: no sediment, adding of acetone (dissolving intermediary) and LiBr as tracer.
Pond 2: - Test 1: no sediment, adding of BDE-209 and DBDPE in acetone solution (final concentration 102 ng/L) and LiBr as tracer.
Pond 3 - Test 2: sediment as described above, adding of 102 mg BDE-209 and DBDPE in acetone solution (final concentration 102 ng/L) and LiBr as tracer.

Analysis

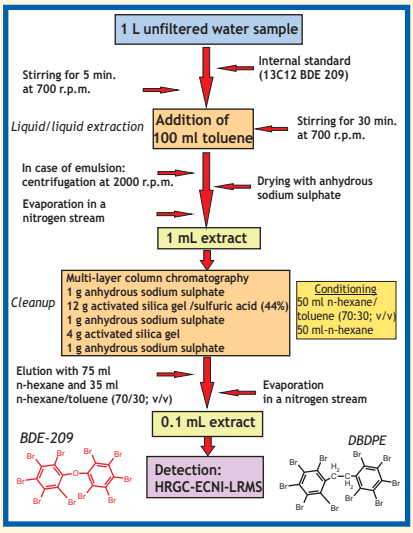

Fig. 2: Analytical scheme for the determination of BDE-209 and DBDPE in water

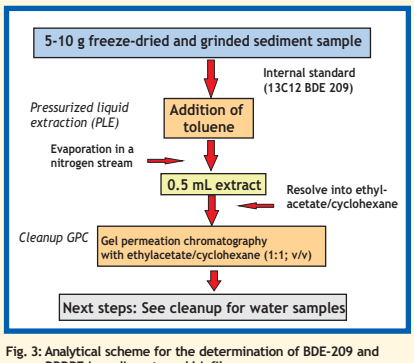

Fig. 3: Analytical scheme for the determination of BDE-209 and DBDPE in sediments and biofilms

Application

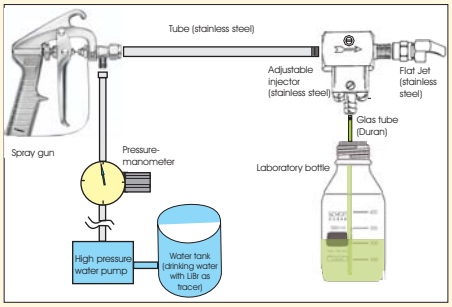

Fig. 4: Scheme of the water injection system: The test substance/acetone solution was aspirated by low pressure, pre-admixed in the water jet and sprayed through a flat nozzle in the water body

Fig. 5: Application of BDE-209 and DBDPE acetone solution in a water jet with a low pressure water injection system

Sampling

Fig. 6: Water sampling using pre-cleaned 1 L narrow-necked glass bottles

Fig. 7: Sampling of biofilms with toluene saturated cotton cloth at the end of the experiment (left) and sediment sampling using core sampler made of acrylic glass or stainless steel (right)

Results

- Measured Li-tracer concentrations indicated a homogenous distribution one hour after application (Fig. 8, 9).
- The concentrations of BDE-209 and DBDPE in water decreased with time. The decline in DBDPE levels was faster than that in BDE-209 according to its higher logPow.
- Concentrations of DBDPE and BDE-209 decreased fastest in the pond with sediment. The elimination of the both compounds was described in all cases by double first order kinetic (Fig. 8, 9).
- At the end of the study 0.27 ± 0.14 µg/kg DBDPE were detected in the sediment. There was no detectable increase in BDE-209 levels in the sediment due to high background BDE-209 concentrations.
- BDE-209 and DBDPE levels in biofilms were 1.8 µg/m² and 3.2 µg/m², respectively.

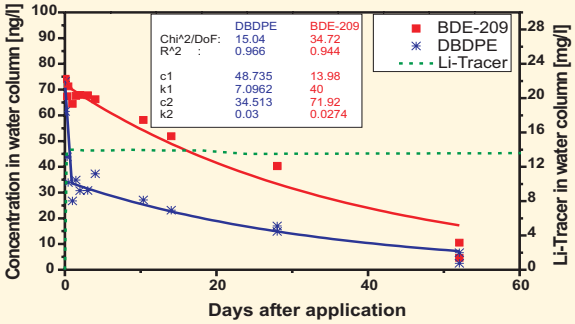

Fig. 8: Water concentrations of BDE-209 and DBDPE in the pond without sediment at different times after application

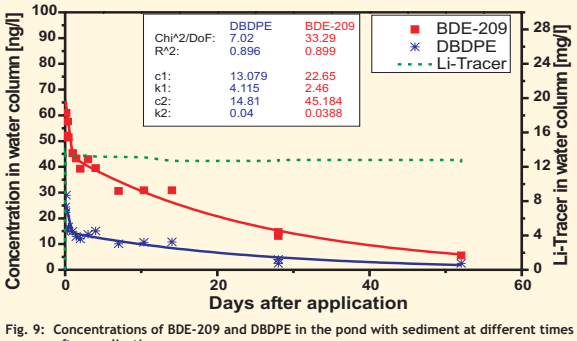

Fig. 9: Concentrations of BDE-209 and DBDPE in the pond with sediment at different times after application

Discussion

- The applied injection method was well-suited to introduce BDE-209 and DBDPE into the aquatic system
- Even though log Pow of the test compounds are extremely high, double first order decrease curves were obtained.
- The absence of natural water mixing represents a worst-case scenario (low exchange between the compartments water and sediment).
- It is a serious problem to find uncontaminated natural sediments for mesocosm studies.
- The mass balance indicated a loss of appr. 70% of either substances. This may be caused by a patchy dispersion (few replicates), problems in sediment and biofilm sampling strategies (high variance of data).
- The influence of natural water turbulence and the mass losses will be studied in further large mesocosm (25,000 L) experiments.