Accumulation of Polychlorinated Organic Contaminants from Sediment by Three Benthic Marine Species


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Abstract. A laboratory experiment was conducted to measure the accumulation of selected polychlorinated compounds by marine benthos exposed to environmentally contaminated sediment. Sandworms (Nereis virens), clams (Macoma nasuta), and grass shrimp (Palaemonetes pugio) were exposed to sediment collected from the Passaic River, New Jersey. All three species accumulated 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF) and polychlorinated biphenyls (PCBs) from the sediment. In addition, a recently identified sulfur containing analog of tetrachlorinated dibenzofurans, 2,4,6,8-tetrachlorodibenzothiophene (2,4,6,8-TCDT), accumulated in the three species.

Accumulation factors (AFs) were calculated (([organism]/lipid) / ([sediment]/total organic carbon)) and used to compare results among species and compounds. These comparisons showed that AFs measured for clams reached steady-state levels rapidly (10 days); however, steady-state AFs values were not achieved until 70-120 days in sandworms. Grass shrimp were exposed to test sediments for only 28 days; therefore, steady-state concentrations could not be determined for this species.

Although final contaminant concentrations were highest in the sandworms, AFs were generally higher for the clams and shrimp and lower for the sandworms. The AFs for 2,4,6,8-TCDT were significantly higher for shrimp than for sandworms and clams. PCB 153 showed higher AF values than those of the other compounds studied.

Clams showed preferential accumulation of lower molecular weight PCB congeners which may be due to the very low lipid content in this species. Sandworms and especially shrimp appeared to metabolize congeners 52, 101, and 151 which all contain vicinal hydrogens in the meta and para regions of the molecule.

Materials and Methods

Sediment Collection

Sediments for this study were collected from four stations in the Passaic River (PR) using a Smith-MacIntyre grab sampler. The sediments...
Experimental Design

Passaic River

North Jamestown (Control)

baskets

sediments

standpipes

Sampling Intervals

Passaic River

North Jamestown (Control)

baskets

sediments

standpipes

Fig. 1. Design of the experiment

Experimental Design

Organisms were exposed to bedded PR and NJ sediments in enclosed circular fiberglass tanks (92 cm diameter, 40 cm height) (Figure 1). Three tanks contained PR sediment and test organisms for replicate time series uptake measurements and a single tank containing NJ sediment served as the laboratory control. All tanks received filtered 20 (μm) Narragansett Bay seawater delivered at a rate of 300 ml/min. Temperature was maintained at 18–22°C and ambient salinity ranged from 30 to 32 ppt.

Infaunal organisms were placed in baskets buried in sediment to facilitate sampling for tissue analysis. Ten polyethylene baskets (2 mm mesh; 22 cm diameter; 10 cm height) were placed in each tank and covered with a 5 cm layer of homogenized PR or NJ sediment. Seawater (25 cm deep) was gently added and the system was maintained in a static condition for 48 hours to allow the sediment to settle and consolidate. Seawater flow was then initiated at a rate of 300 ml/min and the test species were loaded into the baskets. Each basket received 5 sandworms and 6 clams. In addition, each tank received 220 shrimp, which were allowed to swim freely in the tanks. Three replicate samples of each species, consisting of 5 sandworms, 6 clams, and 40 shrimp, were collected for chemical analyses prior to the initiation of the sediment exposures (Day 0) and at each sampling interval.

A single basket containing the sandworms and clams was removed from each replicate PR tank and the NJ tank at each sampling interval. The shrimp were collected using a dip net. The clams and sandworms were then placed in flowing seawater for 24 h to allow for purging residual sediment from their digestive systems prior to chemical analysis. Organisms were not fed during the experiment because it was felt that the addition of organic material may alter the partitioning of the contaminants.

The experiment was designed to run for 180 days and did so for the sandworms. This species was sampled on Days 10, 28, 42, 70, 120, and 180. The clams were sampled at the same times, except for Day 180, when sufficient amounts of this species were no longer available. Shrimp were only sampled after 10 and 28 days of exposure due to concerns that they would not receive adequate nutrition and would start to cannibalize each other.

Analytical Methods

Stable isotopes of 1,2,3,4-TCDD (13C9-1,2,3,4-TCDD and 13C12-
1,2,3,4-TCDD) were purchased from Cambridge Isotope Laboratories and unlabeled 2,3,7,8-TCDD and 2,3,7,8-TCDD standards were obtained from the US EPA Quality Assurance Materials Repository. Octachloronaphthalene (OCN) and PCB congeners were purchased from Ultra Scientific. This Company also synthesized the 2,4,6,8-TCDD standard, using procedures developed by Buser and Rappe (1991).

About 10 g (wet weight) of sediment or tissue were mixed with sodium sulfate (muffed at 650°C for 4 h) and the internal standards octachloronaphthalene and 13C9-1,2,3,4-TCDD were added. Each sample was Soxhlet extracted for eight h, using a 30:70 (v/v) acetone: pentane solvent mixture, allowed to sit in solvent overnight and then Soxhlet extracted for an additional 4 h. The extract was reduced in volume to approximately 15 ml using a Kudernack-Danish evaporator with a 3-ball Snyder column and then transferred to a concentrator tube and further reduced in volume to 5 ml using nitrogen blow down. Activated (treated with 8 N HCl) copper powder was added to sediment extracts to remove sulfur.

The sample was added to a 2.5 × 30 cm column containing a series of layers consisting of 2.5 cm of activated silica (155°C for 24 h), 2.5 cm of potassium silicate, 1.2 cm of sulfuric acid treated silica, 5 cm of activated silica, and 2.5 cm of sodium sulfate. The column was eluted with two-100 ml portions of a 50:50 ethyl chloride:pentane mixture. The column eluent was reduced in volume to 5 ml and added to a column containing a 6.3 cm layer of silver nitrate treated silica and a 1.2 cm layer of sodium sulfate. The silver nitrate:silica gel column was eluted with 50 ml of 20:80 ethyl chloride:pentane mixture which was solvent exchanged to isooctane and then added to a column of neutral alumina (Fischer Scientific). The column was eluted with 6 ml of 90:10, hexane:carbon tetrachloride which was collected and analyzed for PCBs by gas chromatography (GC). A second fraction (4 ml of ethyl chloride) was added directly onto a glass pipette containing 0.5 cm of silica and a 2.0 cm layer of 5% Amoco AX-21 activated...