Trophic Transfer of Polychlorinated Organic Contaminants in a Simple Marine Food Chain

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INTRODUCTION

A wide variety of polychlorinated organic compounds have been found in nearshore marine sediments[1,2] and biota[3]. Several recent studies[4,5,6] have shown that there is a relatively constant relationship between the concentrations of polychlorinated hydrocarbons in lower trophic level biota (normalized to lipid content) and sediments (normalized to total organic carbon concentration). Less is known, however, about how contaminant concentrations and ratios change as these compounds are transferred to higher trophic levels; yet, both the extent of biomagnification and changes in contaminant ratios may have important implications for ecological and human health risk assessments.

This laboratory study was designed to investigate the bioaccumulation of organic contaminants from sediments and their subsequent transfer through a simple two-step marine food chain. The species involved included the infaunal polychaete, Nereis virens, and a crustacean, the American lobster, Homarus americanus. These organisms were selected because this polychaete is a natural component of the diet of the American lobster and a previous laboratory study[7] showed that this species readily accumulated sediment-associated polychlorinated organic contaminants. Also, the lobster is of commercial importance and has been shown to accumulate high concentrations (especially in the hepatopancreas) of polychlorinated contaminants[8,9]. In addition, the PCB patterns found in lobster are highly altered when compared with those of other species or sediments from a given area[10] and preliminary data indicate that these alterations include the relative enrichment of the more toxic coplanar congeners[11]. The specific questions that the experiment was designed to address include the following:

(1) What is the relative importance of diet vs sediment as contaminant sources to the American lobster?
(2) What changes occur in the relative distributions of contaminants between the trophic levels of this experiment?
(3) Can lipid class measurements be used to normalize contaminant distributions between tissues of the American lobster?
(4) How does lipid class normalization influence trophic level comparisons?

Sediments from the Passaic River, NJ were used for this experiment because of the high concentrations of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) that have previously been reported[9,12]. The design selected for this experiment was similar to a trophic transfer study[13] that involved polychaetes and fish. In the present experiment, polychaete worms (Nereis virens) were exposed to Passaic River and clean Reference sediment for 70 days to allow steady-state concentrations to be achieved. American lobster (Homarus americanus) were then fed polychaetes that had been exposed to either the Passaic River or Reference sediment. The lobsters used for this study were approximately 1 1/2 years old and had been reared in the laboratory from eggs obtained from three females.

Lobsters were placed in glass aquaria which were divided into six chambers (one lobster per chamber) and contained a 4.5 cm layer of bedded sediment. Four exposure scenarios were examined: Reference sediment/Reference food, Reference sediment/Passaic food, Passaic sediment/Reference food and Passaic sediment/Passaic food. Lobster samples were collected on days 0, 7, 28 and 56 of the exposure period. The remaining lobsters were then transferred to aquaria containing Reference sediment in order the determine the depuration rates of the accumulated contaminants. Samples were collected after lobsters were held in the depuration tanks for 19, 38 and 56 days.

Triplicate chemical analyses were conducted on lobster samples collected at each sampling interval. Muscle and hepatopancreas samples were analyzed separately. Replicate sediment and polychaete samples were also analyzed. All of the tetra - octa, 2,3,7,8-substituted PCDDs and PCDFs as well as numerous PCB congeners, including the coplanar congeners 3,3',4,4'-TeCB, 3,3',4,4',5-PeCB and 3,3',4,4',5,5'-HxCB, were measured. In addition, detailed lipid class measurements were conducted on each tissue type.

METHODS

PCDDs, PCDFs and PCBs were measured using methods similar to those described previously[7]. These included the use of a column containing acid-, base- and silver-nitrate treated silica, a second column of neutral alumina and an activated carbon column. PCDDs, PCDFs and the coplanar PCB congeners (3,3',4,4'-TeCB, 3,3',4,4',5-PeCB and 3,3',4,4',5,5'-HxCB) were quantitated using a Hewlett Packard 5890 gas chromatograph (GC) - mass selected detector (Hewlett Packard 5971A) system. The GC was equipped with a 60 m DB-5 fused silica capillary column (J & W Scientific, Inc.). All of the other PCB congeners that are reported were measured using a Hewlett-Packard 5890 gas chromatograph equipped with a 60 m DB-5 fused silica capillary column and an electron capture detector. The detailed lipid determinations were made using an Iatroscan TLC/FID Analyzer System.

RESULTS

The Passaic River sediments used in this study contained high concentrations of tetra - octa PCDDs and PCDFs. The concentrations and distributions of these compounds were

very similar to those previously reported[12] for sediments from this area. Numerous PCB congeners were also detected in this sediment including the coplanar congeners, 3,3',4,4'-TeCB and 3,3',4,4',5-PeCB.

No differences in mortality were observed among treatments for polychaetes or lobsters. In addition, no significant differences were observed in the growth rates of lobsters from the four treatment groups.

Polychaetes exposed to Passaic River sediment accumulated PCDDs, PCDFs and PCBs in ratios similar to those found in the sediment. High concentrations of these compounds were also found in the lobster hepatopancreas samples. As expected, significantly lower levels were observed in the lobster muscle samples. Additional lobster muscle and hepatopancreas samples are now being analyzed to complete the uptake and depuration curves. This information will be used to estimate steady-state concentrations for each treatment group and, thereby, determine the relative importance of sediment and food exposure routes.

The contaminant results will be combined with the detailed lipid class measurements to compare accumulations among tissues and species. This information will be used to determine if these contaminants were biomagnified by the lobsters. Toxic equivalency factors (TEFs) will also be calculated for the contaminant mixtures (PCDDs, PCDFs and PCBs) measured in each sample. These values will be used to determine if the more toxic congeners were enriched relative to total contaminant levels with passage from sediments through a marine food chain.

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