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BIOACCUMULATION OF PCB CONGENERS BY BLUE MUSSELS (*MYTILUS EDULIS*) DEPLOYED IN NEW BEDFORD HARBOR, MASSACHUSETTS

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Abstract—Blue mussels (*Mytilus edulis*) were deployed to monitor the levels of bioavailable contaminants during a pilot dredging project in New Bedford Harbor (NBH), Massachusetts. Dissolved and particulate seawater samples also were collected periodically during these deployments. Polychlorinated biphenyl (PCB) congener concentrations in both mussel tissue and seawater samples were among the quantified contaminants. Large differences in the dissolved and particulate PCB concentrations in seawater and tissue residue concentrations in mussels were observed along a gradient from the upper harbor to Buzzards Bay. BCFs were calculated for six PCB congeners at two stations in NBH and a reference site in Buzzards Bay. Equations were generated relating the log BCF to the log octanol/water partition coefficient (K_{ow}) for these congeners. A consistent relationship was found between dissolved PCB congener concentrations and tissue concentrations in the mussels. This study demonstrates the utility of the blue mussel as a monitoring organism for quantifying bioavailable contaminants in seawater and for relating PCB tissue residues with seawater concentrations.

Keywords—Bioaccumulation PCB congeners *Mytilus edulis* Bioconcentration factors K_{ow}

INTRODUCTION

Many estuarine areas contain elevated concentrations of anthropogenic organic chemicals. Some organochlorine compounds are of particular environmental concern because of their large production rates, worldwide use, widespread occurrence, persistence, and bioaccumulative properties [1]. Of this group, polychlorinated biphenyls (PCBs) have been studied extensively because large quantities have been introduced into the environment [2]. Additionally, PCBs are present in the dielectric fluids of older transformers and capacitors [3] that possibly could have future adverse human health and ecological effects. Also, PCBs are useful as tracers of processes influencing the distribution of organic compounds because of the wide range of physicochemical properties among individual chlorobiphenyls and their slow rates of chemical and biological degradation [4]. Although direct discharges have been reduced [3], PCBs may be released back to other components of an ecosystem (e.g., through resuspension events) long after the initial input to the environment has ceased [5]. Therefore, methods for determining the movement, partitioning, and bioaccumulation of PCBs are important, especially in physically dynamic areas such as estuaries.

Blue mussels (*Mytilus edulis*) have been utilized in numerous monitoring programs to assess levels of bioavailable contaminants in marine systems [6–10]. Mussels concentrate many chemicals by factors of 10^2 to 10^5 above background seawater concentrations [11–12]. However, adequate information is lacking on the relationships between contaminant concentrations in bivalves and the surrounding seawater under field conditions. The fundamental problem is insufficient data on ambient contaminant concentrations in seawater [13]. Reasons for this include sampling difficulties, low background concentrations, and the variable nature of estuarine waters. These factors require that numerous samples be collected before an accurate assessment of chemical concentrations can be made. The result it that seawater PCB analysis is a costly and time-consuming process.

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The primary objective of this paper was to elucidate the relationship between seawater and mussel tissue residue PCB concentrations in the field over a wide range of environmental contamination levels. Data were collected in New Bedford Harbor (NBH), Massachusetts, an estuarine area characterized by elevated water-column concentrations of PCBs (low part-per-billion range), trace metals, and other contaminants [14–16]. The severely PCB-contaminated sediments in NBH have resulted in this location being placed on the National Priorities List as a Superfund site. A pilot study was initiated by the U.S. Environmental Protection Agency's (EPA's) Region I and the U.S. Army Corps of Engineers to assess the feasibility of removing these sediments by dredging [17]. A corresponding monitoring plan was designed and implemented by the EPA's Environmental Research Laboratory (Narragansett, RI) to assess possible environmental impacts of this dredging operation [18].

One element of the monitoring plan was quantifying PCBs in dissolved and particulate seawater samples collected at four locations in the harbor before, during, and after dredging. Five independent 28-d mussel deployments occurred at two of these stations during all phases of the project to monitor the levels of bioavailable PCBs and to serve as biological sentinels. A third station located in Buzzards Bay was utilized as a reference site. The subsequent data base was used to calculate concentration factors in mussels for six of the PCB congeners measured in the dissolved, particulate, and total phases of the seawater. Equations were determined relating these concentration factors to individual congener octanol/water partition coefficients (K_{ow}). This information was used to (a) provide a field assessment of the mussel for monitoring PCBs in seawater, (b) evaluate the relationship between mussel tissue and seawater PCB concentrations, and (c) compare this field study with similar studies conducted in the laboratory.

MATERIALS AND METHODS

Sample collection

A detailed description of the monitoring program, sample collection, and station selection strategies was presented by Nelson and Hansen [18]. Briefly, mussels (*Mytilus edulis*) were collected from a reference area in East Sandwich, Massachusetts, and sorted to include organisms 5 to 7 cm in length to reduce potential variability associated with size differences. Twenty-five mussels were placed into polyethylene baskets and deployed at three stations: NBH-2 (Coggeshall St. Bridge), NBH-4 (Hurricane Barrier), and NBH-5 (West Island) (Fig. 1). In all, five independent 28-d deployments were conducted intermittently between June 1987 and October 1990 at stations NBH-2 and NBH-4 and four deployments at station NBH-5. Each station consisted of four replicate substations (one basket per substation) suspended 1 m above the bottom. Upon collection, mussels were returned to the laboratory, and animals from each basket were combined to create one sample for each basket. The samples were wrapped in combusted (muffled for 6 h at 450°C) aluminum foil and frozen at −20°C. Three of the four replicate samples from each station were analyzed; the fourth was archived.

At stations NBH-2 and NBH-4, 1 L of seawater was pumped manually from each of three depths (1 m below the surface, middepth, 1 m above the bottom) and composited into one sample. This sampling occurred at five equally spaced time intervals over each tidal cycle. Immediately after each collection, a 200-ml subsample was filtered through a 47-mm Gelman (Ann Arbor, MI) type A/E glass-fiber filter (approximately 1 μm particle size retention), and the five filtrates were composited and stored in combusted glass bottles at 4°C. The filter was placed in combusted aluminum foil and stored at 4°C.

As a result of lower PCB concentrations at station NBH-5, a high-volume seawater sampling device was utilized [19]. Thirty-six liters of seawater was pumped from a depth of 3 m (middepth), then passed through a 293-mm Gelman type A/E glass-fiber filter and a cartridge containing polyurethane foam plugs.

Dissolved and particulate samples were collected for OC analysis at the three stations during the summer of 1990. Fifty milliliters of water was drawn into clean syringes, passed through combusted 13-mm Gelman type A/E glass-fiber filters into combusted 100-ml brown glass bottles, then stored at 4°C. Filters were placed in scintillation vials, dried in a desiccator, and stored at −20°C. Deionized water blanks were collected in the field with every sample.

Sample extraction

Mussel samples were analyzed using a method described by Bergen [20]. Frozen mussels were shucked and homogenized using a Polytron® (Brinkmann Instruments, Westbury, NY) tissue homogenizer. Samples of 2 to 5 g were weighed into an acetone-rinsed 100-ml centrifuge tube. One gram of homogenate was dried at 120°C overnight for wet-to-dry ratio determination. Octachloronaphthalene (OCN)

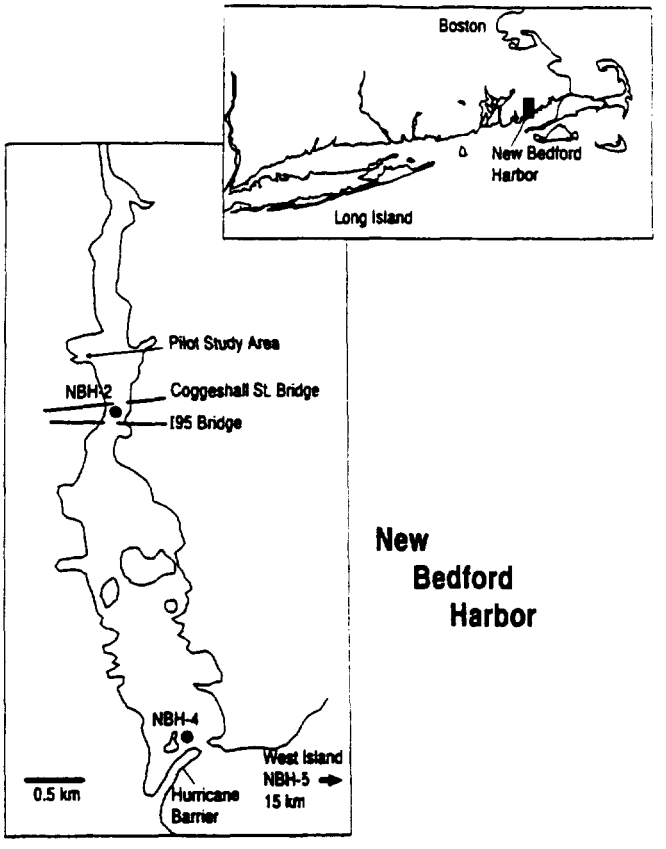

Fig. 1. Map of New Bedford Harbor and Buzzards Bay, showing the locations of the three stations used in this study.

(powder, Ultra Scientific, North Kingston, R.I.) was added as an internal standard, and samples were extracted with 25 ml of acetone by homogenizing for 20 s with a Polytron. The sample was centrifuged and the supernatant poured into a 1-L separatory funnel containing 300 ml of Freon®-(1,1,2-trichlorofluoroethane-) rinsed deionized water. This Polytron extraction was repeated twice, and the extracts were combined in the separatory funnel. The solution in the separatory funnel was extracted three times with 25 ml of Freon each time. Freon extracts were combined, dried with sodium sulfate, reduced in volume, and exchanged to 10 ml of hexane. One milliliter was removed for a gravimetric total lipid determination, and the remaining 9 ml was partitioned with concentrated sulfuric acid to remove organic interferences. The sample was removed from the acid, reduced in volume, and exchanged to 1 ml of heptane.

Seawater samples were analyzed using a method described by Bergen [20]. Exact volumes were recorded for the dissolved-phase water samples, OCN was added as an internal standard, and the samples were extracted three times with 50 ml of Freon. Freon extracts were combined, dried with sodium sulfate, volume reduced, and solvent exchanged to 1 ml of heptane. Extracts then were partitioned with concentrated sulfuric acid overnight. The heptane layer was removed from the acid and stored.

Foam plug samples were extracted twice with 50 ml of acetone, then twice with 50 ml of hexane. Extracts were combined in a 1-L separatory funnel containing 300 ml of hexane-rinsed deionized water and OCN added as an internal standard. The aqueous phase was drawn off and the hexane layer removed. The aqueous phase was returned to the funnel and extracted with 100 ml of hexane; this hexane layer was removed and combined with the first. Combined extracts were dried with sodium sulfate, reduced in volume, solvent exchanged to heptane, and partitioned with concentrated sulfuric acid overnight. The heptane layer was removed from the acid and stored.

The OCN internal standard was added directly

to the filter samples. Each filter was extracted twice with acetone and once with Freon (25 ml each time) using a Polytron homogenizer. After each of these three extractions, the sample was centrifuged and the supernatant decanted into a 1-L separatory funnel containing 300 ml of Freon-rinsed deionized water. The resultant Freon layer then was transferred to an Erlenmeyer flask. The Freon extraction of the separatory funnel was repeated twice more, using 25 ml of Freon each time. The three Freon extracts were combined, dried with sodium sulfate, reduced in volume, solvent exchanged to 1 ml of heptane, and treated with concentrated sulfuric acid. The heptane layer was removed and stored.

Sample analysis

PCBs in the heptane extracts were analyzed by electron-capture gas chromatography (EC-GC). One microliter of each sample was injected into a Hewlett Packard (Avondale, PA) 5890 GC equipped with a splitless injector, 30-m DB-5 fused-silica capillary column (0.25-μm film thickness, 0.25-mm i.d., J & W Scientific, Folsom, CA), and an electron-capture detector. Injector port temperature was set at 270°C. Column temperature was held at 60°C for 1 min, then heated at a rate of 10°C min^{-1} to 315°C and held for 13.5 min. The detector temperature was 325°C. Analog data from the GC were digitized using a Perkin Elmer (Norwalk, CT) 3200 computer equipped with Perkin Elmer LIMS/CLAS software. Thirteen individual congeners were quantitated against the OCN internal standard. PCB standards were obtained as powders in pure form from Ultra Scientific (North Kingston, RI).

The dissolved OC in the water samples was analyzed with an O.I. Corp. (College Station, TX) model 700 total organic carbon analyzer. Analysis consisted of inorganic carbon digestion with 5 N phosphoric acid for 3.5 min, followed by a nitrogen gas purge to remove carbon dioxide from inorganic sources. The remaining sample was subject to persulfate oxidation for 10 min at 100°C for OC analysis. Carbon dioxide that evolved was trapped on a molecular sieve, then released to an IR detector for quantitation using calibration standards. Detection limits for this method were approximately 1 mg/L. The DOC values were corrected for blank values.

For PCB measurements, laboratory blank analyses were conducted with each sample type and for every second set of six samples analyzed. In addition, field blanks were collected for dissolved water and filter analyses each sampling day. In all cases, results for blanks showed no or trace levels of PCB congeners. Reported concentrations have not been corrected for blank values. An in-house mussel homogenate was analyzed as a reference material to provide information on the precision and accuracy of the PCB determinations in mussels. PCB congener concentrations in the homogenate ranged from 50 to 115 ng/g dry weight. Triplicate analyses of this sample indicated that relative standard deviations from known values were <12% for the 13 measured congeners. Spike and recovery experiments indicated that analyte recovery averaged 85 to 100% for water and filter samples. Mussel sample recoveries ranged from 75 to 100%.

Data analysis

Mussel deployments of 7, 14, and 28 d were conducted at NBH-2, -4, and -5 during the NBH pilot dredging project. However, only data from the 28-d deployments were utilized in this study because the data indicated that mussels deployed in <28 d were not at steady-state concentrations. Other studies also have indicated that concentrations of PCBs in bivalves reach approximate steady-state concentrations in 28 d [21-22].

Mussel tissue residue data were analyzed initially to determine whether seasonal differences in PCB bioaccumulation occurred among the five independent deployments. No statistically significant differences were observed in mussel PCB accumulation over time, even when the data were normalized to lipid values. This does not imply that temporal effects would not have occurred if deployments had been conducted continuously throughout the year. Rather, the data indicate that seasonal effects did not occur during those times when mussels were deployed in this project. Therefore, data from all deployments were combined for subsequent analyses.

Additional water samples were collected at other locations in NBH during this study. However, only those water samples collected at stations NBH-2, -4, and -5 are discussed here because mussels were deployed only at these sites (Fig. 1). Thirteen individual congeners were quantitated in each sample; however, only six congeners were chosen for consideration in this paper (Table 1). Selection was based on the fact that only these six congeners were present in detectable amounts in all the 1-L dissolved-phase seawater samples. All thirteen congeners were present in the particulate-phase seawater and mussel tissue samples. The studied congeners included a range of chlorination levels (two each of tetra-, penta-, and hexachlorobiphenyls) and log K_{ow} values (5.84-6.92).

Table 1. PCB congeners selected for use in this study

	PCB congener identification[a]	Log K_{ow}[b]
52	2,2',5,5'-TCB	5.84
47	2,2',4,4'-TCB	5.85
101	2,2',4,5,5'-PeCB	6.38
118	2,3',4,4',5-PeCB	6.74
153	2,2',4,4',5,5'-HxCB	6.92
138	2,2',3,4,4',5'-HxCB	6.83

[a]Numbering system from Ballschmiter and Zell [37].
[b]Hawker and Connell [38].

RESULTS AND DISCUSSION

Water – PCBs

Mean seawater PCB congener concentrations at each station are shown for the dissolved (Fig. 2a) and particulate (Fig. 2b) phases, as well as the total (Fig. 2c) concentration (sum of dissolved and particulate concentrations). Quantitatively, over the distance from station NBH-2 to station NBH-5, the mean particulate and total PCB concentrations decreased twice as much as the mean dissolved PCB concentration. This point will be elaborated further in the discussion of PCB concentration factors in mussels.

To examine qualitative trends between stations, the relative distribution of each congener was calculated as a percentage of the total six (Fig. 3). The dissolved phase (Fig. 3a) showed a decrease in the predominance of lower molecular weight compounds from the upper harbor to the lower harbor to Buzzards Bay, which agrees with observed patterns for sediments in NBH [16]. For example, congener 52 decreased significantly ($P < 0.05$), from 40% of the total at station NBH-2 to 25% at station NBH-5. There was a corresponding relative increase in the higher molecular weight congeners; 118 comprised 12% at station NBH-2 and 20% at station NBH-5. The standard deviation for each congener distribution was <5% among all stations.

Particulate-phase samples were dominated by pentachlorobiphenyls at stations NBH-2 and NBH-4, and penta- and hexachlorinated compounds at station NBH-5 (Fig. 3b). At all three stations, the relative percentages of the two pentachlorobiphenyls, congeners 101 and 118, remained about the same. There was a decrease in the proportion of congener 52 from 17% at station NBH-2 to 6% at station NBH-5, with an increase in congener 138 from 10% at station NBH-2 to 21% at station NBH-5. The congener distributions in the total samples (not shown) were similar to the particulate-phase distributions. At a given station, absolute PCB congener concentrations in the dissolved and particulate phases varied by 20 to 50%, whereas the relative percentage of distribution varied <5%. These data suggest that a relatively stable condition existed with respect to congener distribution at each station, even though the absolute concentrations varied.

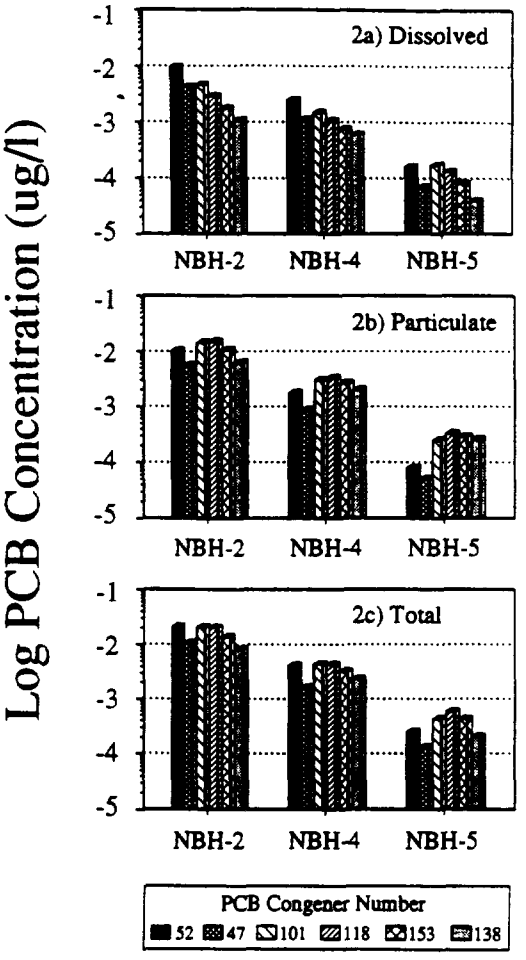

Fig. 2. Mean concentrations of six PCB congeners in the dissolved (**2a**), particulate (**2b**), and total (**2c**) phases of seawater collected at two stations in New Bedford Harbor (NBH-2, -4) and a reference site in Buzzards Bay (NBH-5). Total concentration is defined as the sum of the dissolved and particulate concentrations.

Mussels – PCBs

Mussel PCB tissue residue concentration data are summarized in Figure 4. The day 0 mussels (not shown) had initial individual congener concentrations ranging from 3 to 16 ng/g dry weight. At station NBH-2, mussels accumulated individual

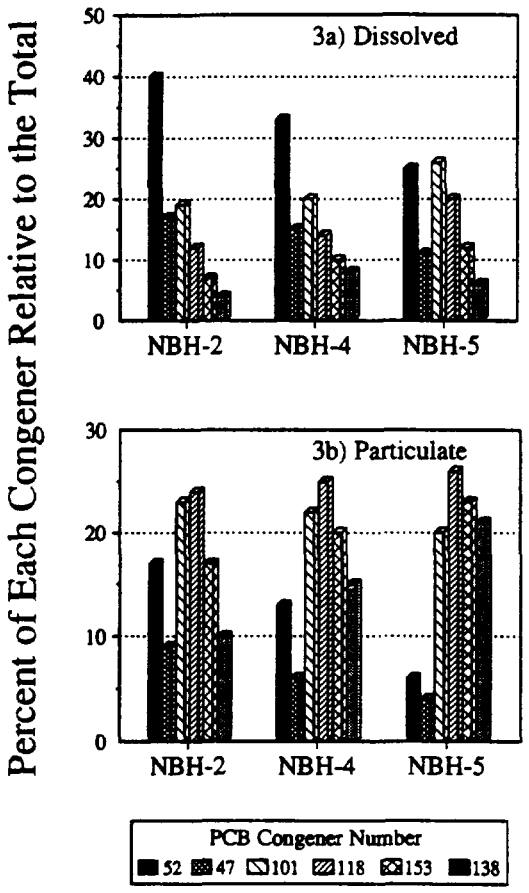

Fig. 3. Mean percentage of each PCB congener relative to the total of all six congeners in the dissolved (3a) and particulate (3b) phases of seawater at two stations in New Bedford Harbor (NBH-2, -4) and a reference site in Buzzards Bay (NBH-5).

congeners to approximately 3,000 ng/g dry weight, and the highest concentrations measured at stations NBH-4 and NBH-5 were about 900 and 150 ng/g dry weight, respectively. Of the measured congeners, mussels accumulated the pentachlorobiphenyls (congeners 101 and 118) to the highest concentrations at stations NBH-2 and -4. Mussels deployed at station NBH-5 exhibited elevated concentrations of penta- and hexachlorinated compounds (congeners 101, 118, 153, and 138.

The relative distributions of the PCB congeners also were calculated for mussels (Fig. 5). A least-squares means test indicated no statistical differences ($P > 0.05$) in the proportions of congeners 101 and 118 between the stations. However, the percentage of congener 52 decreased from 21% at station NBH-2 to 6% at station NBH-5. Also, there was a corresponding increase in the percentage of congener 138 from 9% at station NBH-2 to 21% at station NBH-5.

Seawater-mussel comparison

Examination of mussel and water PCB distributions indicated that the relative abundances of PCB congeners in the mussels were similar to those of the particulate phase of seawater at each station (Figs. 3b and 5). The relative distribution of all six congeners was nearly identical in mussel tissues and the seawater particulate phase. In contrast, large differences were observed between the congener distributions in the mussels and particles and the congener distributions in the dissolved phase of the seawater (Figs. 3a and 5). For example, at station NBH-5, congener 52 made up 6% of the six congeners in the mussel and the seawater particulate phase compared to 25% in the dissolved phase. Congener 138 constituted 21% of the total six congeners in the mussels and the particulates compared to 6% in the dissolved phase. These findings suggest that the mussels and the particles were accumulating PCBs in a similar manner and that both were in steady state relative to dissolved-phase PCB concentrations.

Concentration factors in mussels

Various studies have utilized concentration factors to describe the behavior of organic compounds in marine and freshwater environments [21,23–25]. These and other authors have stated that the relationship between the BCF and the K_{ow} can be represented by a linear equation:

$$\log \text{BCF} = m \log K_{ow} + b \qquad (1)$$

where

$$\text{BCF} = \frac{[\text{contaminant}]_{\text{organism}}}{[\text{contaminant}]_{\text{water}}\ (\text{dissolved})}$$

To characterize further the seawater-mussel PCB relationship in NBH, concentration factors for the dissolved, particulate, and total phases were calculated for the six PCB congeners in mussel tissues at each station. The wet-weight congener concentration in mussel tissue was divided by the concentration in the dissolved (concentration factor – dissolved, or BCF), particulate (concentration factor – particulate), and total (concentration factor – total)

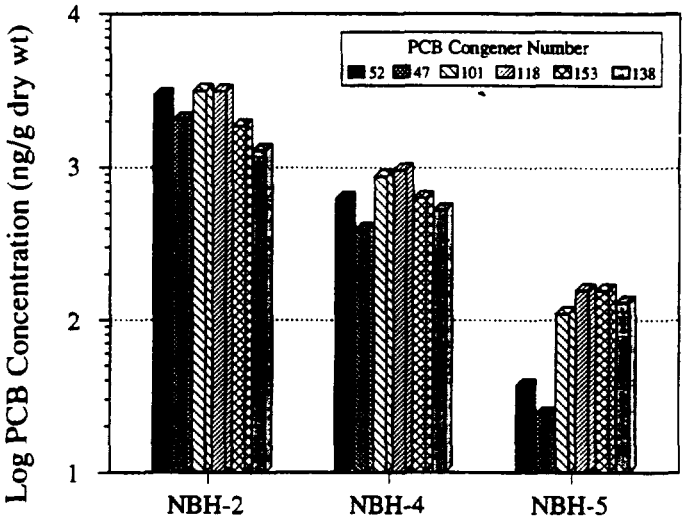

Fig. 4. Mean PCB congener concentrations in blue mussel (*Mytilus edulis*) tissue (ng/g dry wt.) from five 28-d deployments at two stations in New Bedford Harbor (NBH-2, -4) and four 28-d deployments at a reference site in Buzzards Bay (NBH-5). Day 0 concentrations ranged from 3 to 16 ng/g dry weight and are not shown.

phases of the seawater. These three concentration factors were calculated for each replicate sample at each station.

Analysis of covariance (ANCOVA) was used to test the equality of the linear regression equations among stations for the dissolved, particulate, and total concentration factors. Stations NBH-4 and -5 were statistically similar ($P > 0.05$) for concentration factors calculated against the dissolved phase (BCF); however, station NBH-2 was different (Fig. 6). The mean PCB congener concentration decreased by an order of magnitude between stations NBH-4 and NBH-5. The data from stations NBH-4 and -5 were combined, and one equation was calculated

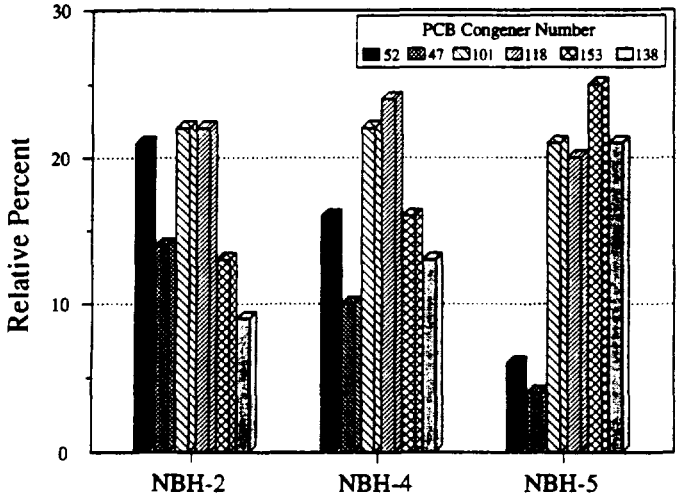

Fig. 5. Mean percentage of each PCB congener relative to the total of the six congeners in blue mussel (*Mytilus edulis*) tissue from five 28-d deployments at two stations in New Bedford Harbor (NBH-2, -4) and a reference site in Buzzards Bay (NBH-5).

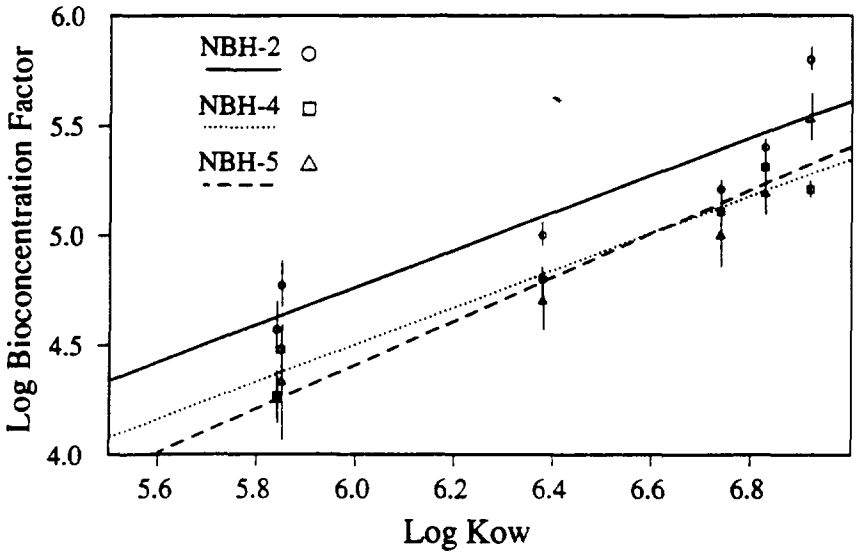

Fig. 6. Linear regression lines relating log BCF and log K_{ow} for two stations in New Bedford Harbor (NBH-2, -4) and a reference site in Buzzards Bay (NBH-5). Also shown are the mean and ±1 SD of log BCF for the six congeners at each station.

to describe the relationship between log BCF and log K_{ow}:

$$\log \text{BCF} = 0.82 \log K_{ow} - 0.52 \quad (R^2 = 0.74) \tag{2}$$

ANCOVA of concentration factors calculated from the particulate and total phases indicated statistical differences among all stations. These results suggest that the bioaccumulation of PCB congeners by the mussels can best be modeled as if these compounds were accumulated from the dissolved phase of the seawater. This hypothesis is supported further by the observation that the ratio of the mean dissolved seawater PCB congener concentrations between stations NBH-2 and NBH-5 was nearly identical to the ratio of the mean mussel tissue residue concentrations (36 and 37, respectively). In contrast, the ratio of particulate PCB congener concentrations between stations NBH-2 and NBH-5 was greater by a factor of approximately two compared to the ratio of the mussel tissue residue concentrations.

Binding of PCBs by DOM

One possible explanation for the difference in log BCF vs. log K_{ow} between station NBH-2 and stations NBH-4 and -5 may be the association of PCBs with dissolved organic matter (DOM) at the sites. Reports have indicated that the selective binding of contaminants to macromolecular DOM decreases their bioavailability [26–29].

In the present study, samples were collected and analyzed to determine the amount of DOC at all three stations. Using a relationship described by Eadie et al. [30] and the measured DOC concentrations, the "fraction *d*" was calculated for each congener at each station. Fraction *d* is that portion of the total contaminant bound to organic matter. Based on these calculations, 2 to 8% of the PCB congeners measured in the dissolved phase in NBH are likely bound to DOM (Table 2). Eadie et al. [30] found that <10% of the total dissolved contaminants were bound to DOM in the Great Lakes. The BCF equations were recalculated after subtracting the amount of PCB congener expected to be bound to DOM in the dissolved phase. This operation slightly changed the equations at the three stations; however, it did not account for the difference in the relationship between log BCF and log K_{ow} observed between station NBH-2 and stations NBH-4 and -5.

The exact reason for the differences between stations cannot be determined from the current data set. It is possible that at station NBH-2 (a) the high PCB concentrations may be affecting the physiology and biochemistry of the mussels, (b) the nature of PCB-DOM associations is different, or (c) the observed differences could be accounted for by nor-

Table 2. Calculated percentage (fraction d) of six PCB congeners bound to dissolved organic matter (DOM) in seawater samples collected at two stations in New Bedford Harbor (NBH-2 and NBH-4), and a third reference site in Buzzards Bay (NBH-5)

Station	Avg. DOC (g/ml)	Congener	Fraction d (%)[a]
NBH-2	2.44×10^{-6}	52	3
		47	3
		101	5
		118	7
		153	8
		138	7
NBH-4	2.05×10^{-6}	52	2
		47	3
		101	4
		118	6
		153	7
		138	7
NBH-5	1.65×10^{-6}	52	2
		47	2
		101	3
		118	5
		153	6
		138	5

[a]From Eadie et al. [30]:

$$\text{fraction } d = \frac{\log^{-1}Q \cdot \text{WFC} \cdot \text{DOC}}{(1 + \log^{-1}Q \cdot \text{DOC})}$$

where WFC = avg. dissolved PCB and $Q = 0.43 \log K_{ow} + 1.6$.

malizing to particulate organic carbon, which was not measured.

Comparison of lab and field data

Most studies that have investigated the factors controlling the bioaccumulation of xenobiotic compounds have been conducted in the laboratory. Bioaccumulation has been related to solubility [23,31], fugacity [32], and the n-octanol/water partition coefficient [21,33-34] of chemicals. Laboratory studies often contain levels of suspended particulate matter substantially lower than those found in natural marine systems. Such conditions may produce results significantly different from those in the field, where contaminants occur freely dissolved, bound to particulate material, and associated with DOM [35]. Given these factors, it is interesting to note that Equation 2 relating log K_{ow} and log BCF in this field study is very similar to relationships reported from two laboratory studies with *M. edulis* [24] and fathead minnows [36] (Fig. 7). In contrast, Pruell et al. [21] exposed *M. edulis* to suspended contaminated sediment in the laboratory and found that the relationship between log BCF and log K_{ow} (not shown) produced an equation with a lower slope and higher intercept than this field research or the other two referenced laboratory experiments.

The present study indicated a consistent relationship between mussel PCB concentration and the dissolved-phase PCB concentration (Eqn. 2) along a

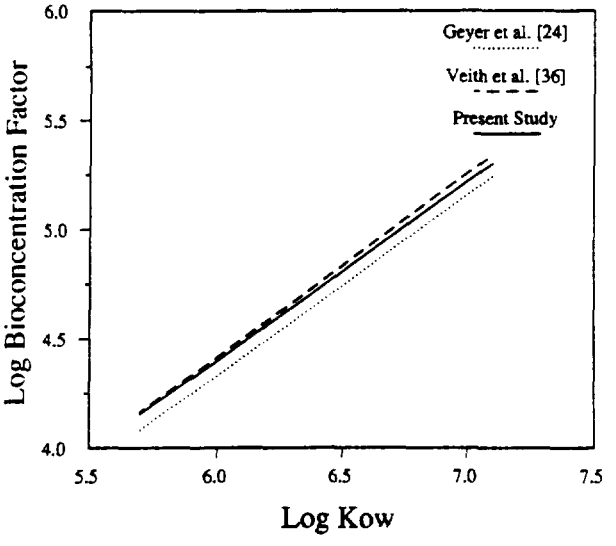

Fig. 7. Linear regression lines relating log BCF and log K_{ow} for the combined data collected from stations NBH-4 (located inside New Bedford Harbor) and NBH-5 (located in Buzzards Bay). Similar relationships derived from laboratory experiments described by Veith et al. [36] and Geyer et al. [24] are shown also.

contamination gradient from station NBH-4 to station NBH-5. However, at the elevated PCB concentrations observed at NBH-2, this relationship was different. Therefore, different processes affecting PCB partitioning and bioaccumulation may be operating at this station. Because the relationship observed between BCF and K_{ow} in this field study was similar to that demonstrated in at least two laboratory experiments, Equation 2 may be applicable in other situations in which PCB seawater concentrations are within this range. This study demonstrates the utility of the blue mussel for assessing PCB bioavailability and provides information useful for relating PCB concentrations in mussels to ambient seawater concentrations.

CONCLUSIONS

1. A large concentration gradient of PCB congeners existed in the seawater of NBH.

2. The relative concentrations of the less chlorinated PCB congeners in both the dissolved and the particulate phases of seawater decreased rapidly with distance south in the estuary.

3. Although absolute concentrations of PCB congeners measured in seawater at any one station were variable, the relative congener distributions were very consistent.

4. PCB concentrations in deployed blue mussels, *M. edulis*, and the dissolved phase of the seawater decreased by the same amount over the study area. Concentration factor analysis revealed that PCB concentrations in mussels was best modeled as if these compounds had been accumulated from the dissolved phase of the seawater.

5. Uptake of PCB congeners in mussels from the dissolved phase of the seawater was predictable from the log of the BCF and the log K_{ow} of the congeners.

6. The relationship described between dissolved contaminant concentrations in seawater and mussels in this field study was consistent with and similar to those previously observed in two laboratory experiments.

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