The Uptake of PCBs by Zebra Mussels

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Abstract

The zebra mussel (*Driessena polymorpha*) is a bivalve mollusk detected in the Great Lakes about 1985 and has spread rapidly throughout the Great Lakes system and inland waterways. Their arrival in the Hudson River was inevitable and by 1991 the mussel was detected in the river. The impact of the zebra mussel on the Hudson River ecosystem remains unknown. Their high filtration rate, up to 200 mL of water per mussel per hour, is of particular interest. This filtering ability could cause restructuring of the food web in the Hudson River and alter the role of PCBs, of special concern in the highly contaminated Hudson River ecosystem.

This experiment was designed to measure the uptake rate of PCBs by the zebra mussel using tap water. However, chlorinated tap water was found to be lethal to zebra mussels. At the start of the experimental work, the Marist River Lab Facilities did not have access to non-chlorinated water so most of the time spent on this project was in designing and installing a continuous flow system using Hudson River water.

There were many delays and problems with the design. Cold weather led to frozen lines and the Aroclor drip used in the design was erratic. Data was inconclusive due to these influences. It is currently being improved and used by Dr. Thomas Lynch and Dr. Matthew Poslusny of Marist College in similar research for the Hudson River Foundation.

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Introduction

The zebra mussel (*Dreissena polymorpha*) is an exotic bivalve mollusk native to the drainage basins of the Black, Caspian, and Aral Seas. The mussel was first discovered in North America in Lake St. Clair in 1988 (Hebert et al., 1989). Since their detection they have spread rapidly throughout the Great Lakes system and connecting waterways. By way of natural and human influences, including the transient recreational boating activity, the mussel has spread to water systems having no physical contact with the Great Lakes (Marangelo and Johnson 1993). By September of 1991, zebra mussels were detected in the Hudson River between Albany and Red Hook (O'Neill and MacNeill 1991).

The full impact of the zebra mussel on North American aquatic ecology remains unknown. Data have suggested that zebra mussels have a high filtration rate, upwards of 5 to 200 mL/h (Dorgelo 1993; Fisher et al. 1993; Kinney et al. 1994). The estimated zebra mussel population in the Hudson River estuary has been calculated to filter 70 - 400 m^3/day during the summer, about 5 - 30% of the estuary's total volume (Strayer and Smith 1993). This percentage dramatically increases when only the areas of the river populated by zebra mussels are considered (Strayer and Smith 1993). It is this high filtration rate that is of concern within the Hudson River ecosystem. Predictions indicate that their filtering capacity will restructure the food web by diverting organic matter from the planktonic community to the benthic community. Casual observers have already noticed a remarkable increase in the river's clarity. Studies by the Institute of Ecological Studies in Millbrook, NY show a dramatic decrease in the concentrations of chlorophyll-a (Cole 1994). The effect of rapid filtration is compounded by the high fecundity of the mussels, estimated between 30,000 and 1,000,000 eggs per individual female spawning event. The lack of natural predators has also contributed to its rapid spread throughout the Great Lakes and adjacent water systems (Sprung 1993; Griffiths 1993).

The presence of polychlorinated biphenyls (PCBs) in the Hudson River has been of concern for a much longer time. Two General Electric plants on the Hudson River, one at Hudson Falls and the other at Fort Edward, have discharged massive amounts of PCBs into the river (Lee 1994). Recent evidence has shown that these two sites continue to leak PCBs into the river making them significant sources of contamination that continue to impact the Hudson (Lee 1994). PCB discharges into the Hudson by General Electric over a thirty-year period have been responsible for the closure of the upper Hudson to fishing,

closure of the important stripped bass fishery, and an "eat none" health advisory for women and children covering seventeen species of fish in the river (Lee 1994). Calculations indicate an economic loss of approximately $40 million per year for New York State (Lee 1994).

The concern over PCB contamination is based on the fact that PCBs are persistent chlorinated organic compounds that are both hydrophobic and lipophilic. Because of these characteristics, PCBs tend to accumulate in the lipid tissue of organisms that are in contact with it. PCBs were commercially produced under the tradename of Aroclor by the Monsanto Corporation. Aroclor is a mixture of PCB congeners that were used as coolants in transformers, ballasts for fluorescent lights, lubricants, some epoxy paints, and in the protective coatings used on woods and metals.

Because of the recent invasion and their high filtering capabilities, the impact of the mussel on the PCB concentration in the Hudson River should be better understood. The ability of the mussel to filter vast quantities of suspended particles from the water column has the possibility of redirecting the flux of these contaminants . The hydrophobic characteristics of PCBs cause them to adsorb readily onto suspended solids in the water column. The mussels may accumulate these contaminated solids as fecal pellets or pseudofeces, whose deposition on the river bottom could shift the PCB flux to the benthic community from the pelagic zone. The effect of such a change is unknown.

My objective in this experiment was to determine the rate of uptake of PCBs by zebra mussels. Aroclor 1254, a tradename PCB, was used as our source of PCB because of its prevalence in the Hudson River. Concentrations of 2.0 ppb and 0.50 ppb Aroclor 1254 plus a control were used. This was in the attempt to account for possible effects of depuration and maximum PCB load in the mussel tissue.

A continuous flow system was developed to minimize the fluctuations in Aroclor concentrations that would occur in a static system as the mussels filtered the PCB contaminated water throughout the day.

Procedures

Continuous Water System: The experiment was conducted in the River Laboratory at Marist College, Poughkeepsie, NY. Water used in these experiments was obtained directly from the Hudson River. A sand filter, as seen in Figure 1, was built in the lab to remove particles on which PCBs from the river could have adsorbed. Water was pumped from the river to the sand filter. A submersible pump was secured to two cement blocks

and placed in the river below the low tide mark and on level bottom. The sand filter consisted of an elevated 180 gallon galvanized stock tank located outside the lab. The tank was fitted at the bottom with two 3 inch diameter perforated pipes that collected and drained the water percolating through the filter sand into a second galvanized tank at ground level.

Water was pumped from the ground level collection tank outside the lab to a fiberglass tank inside the lab. The inside tank, with a capacity of approximately 392 liters, was supported on cement blocks 2 meters above the floor. Water levels in the indoor and outdoor tanks were automatically controlled by float switches.

Water was fed by gravity from the reservoir tank into mixing chambers at a rate of 400 mL/min . A combination of stop cocks and clamps were used to control the rates for this system. The mixing chambers were made from 20 liter glass aquaria. In the bottom of each aquaria a hole was drilled using a diamond bit. A concentrated solution of Aroclor 1254 was added to each mixing chamber at a rate of 1 mL/min to maintain the required concentration in the test tanks. Only pesticide grade acetone, used for Aroclor dilution, was added to the control tanks. The control tanks were processed like the exposure tanks.

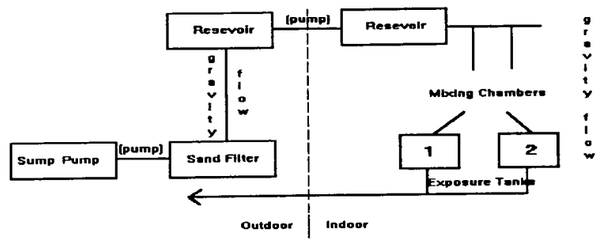

Figure 1: Schematic of continuous flow system

The Aroclor-contaminated water drained into a 8"x14"x3" Plexiglas box which distributed the water to replicate test aquaria at a rate of 200 mL/min/tank. In each test tank a hole was drilled and a stopper with glass tubing was used to regulate the water level and to control the retention time of the water in the tank.

Mussels were obtained from Oneida Lake by Dr. Edward Mills from Cornell University. These mussels were used in the hope that they would be relatively

uncontaminated by PCBs. As our mussel supply decreased from death, we were forced to use mussels collected from the Hudson at the Marist College dock site.

Preliminary uptake rates by the mussels were quantified in a static water experiment. A volume of 10 liters of filtered river water was placed in 20 liter glass aquaria and sufficient Aroclor was added to the water to produce the needed concentrations. The concentrations used were 2.0 ppb and 0.50 ppb. The water and Aroclor were replaced at the same time daily to minimize the effect of concentration fluctuations. Approximately 30 to 50 mussels, depending on size, were placed in each exposure tank. The experiment was run for 10 days with samples of mussels collected on day 0, 3, 6, and 10. To assure that the mussels were exposed for the full duration, only mussels that were still alive at the time of collection were kept. Each mussel sample was frozen until processed.

PCB Analysis: The mussels were thawed and the tissue was removed from the mussel shell and placed on paper toweling to adsorb extra water. The mussel tissue was then weighed in a homogenizing container. The mussel was homogenized using a Virtis "23" Homogenizer for approximately 5 minutes in hexane. The tissue, including the hexane, was collected and analyzed using a variation of Method 608 from the Federal Register (1979). A drafted copy of this variation can be found at Marist College (Poslusny 1994). All solvents used in these experiments were of pesticide grade. Variations of the technique included the use of hexane instead of methylene chloride in extraction, the use of aluminum foil around the Kuderna-Danish (K-D) to effectively retain more heat, and the extract was condensed to less than 10 mL.

The concentration of the unknown was calculated using the equation Cunk= Area of Sample x Concentration of the Internal Standard (IS)/ Area of IS x Response Factor (RF). The RF= Area of the Sample x Concentration of IS/ Area of IS x Concentration of the Standard. Before each day of injections, a set of three standards was run to calculate a new response factor to account for changes in the GC's sensitivity. The calculated concentrations for the day were based on that day's response factor.

Results and Discussion

Figure 2 shows the concentrations of Aroclor found in the wet weight mussel tissue after static exposure. There is an obvious increase in PCB levels for both exposure concentrations on Day 2 and a decrease again on Day 3.

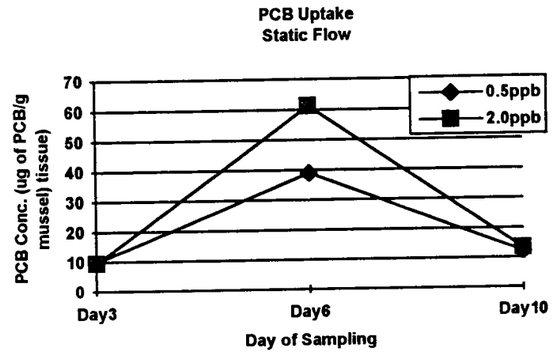

Figure 2: Tissue Conc. in static flow system

The continuous flow exposure concentrations are seen in Figure 3. Both exposure concentrations show a decrease in tissue concentration over time. The control also showed a decrease in tissue concentrations from Day 0 to Day 3, but concentrations increased again from Day 3 to Day 6 and then appear to even out.

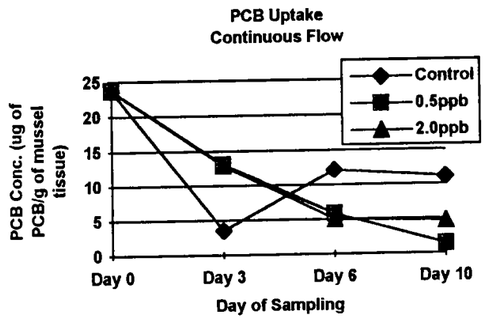

Figure 3: Tissue conc. in continuous flow system

The concentration of PCBs on Day 0 for the continuous flow system was high. It should be noted that water temperatures taken for the continuous flow system indicated temperature lows of 8.9°C to 14.8° C. Decreased mussel filtration due to the low

temperatures or depuration of PCB by the mussels may have contributed to the lower concentrations seen after Day 0. High mussel mortality and low mussel weight in both the static and continuous flow systems led to many smaller sample sizes with the range being 0.686 g to 2.985 g per sample. The ideal sample size is 1.0 g.

PCB studies in connection with biota accumulation has occurred worldwide. Samples of zooplankton and phytoplankton, in a Japanese study, were observed to reach their maximum PCB adsorption capacity within 100 to 200 minutes, but show a low desorption rate(Hiraizumi et al. 1979).

Studies have indicated that deviations from expected results when using PCB compounds may be attributed to the influence of stereochemistry (Shaw and Connell 1984). The accumulation of PCBs involve not only the partition between tissue lipids and the surrounding water but also surface adsorption. The accumulations of organic chemicals by fish has been compared to the interactions of the chemical and fish tissue by hydrogen bonding and van der Waals forces. Expected results were the increase in accumulation with the increase in the degree of chlorination. Deviations occurred when some of the PCB molecules, especially those with more chlorine, twist out of the plane of their biphenyl ring. It is determined that this twist out of plane would reduce the amount of interaction and therefor adsorption at the tissue surface. This must be a consideration with further uptake models (Shaw and Connell 1984).

Figures 4 and 5 compared the results in the continual versus the static uptake systems. In both exposure concentrations, the static system showed an increase in PCB concentration on Day 2 and a decrease on Day 3. For the continuous system there was a decrease from Day 1 to Day 3. The trend in both systems seem to indicate that the system itself had influenced the uptake and possibly the depuration processes of the mussels.

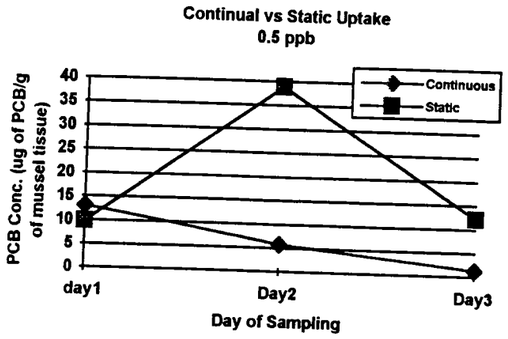

Figure 4: Comparison of tissue conc. in mussels exposed to 0.5 ppb Aroclor in both static and continuous flow systems

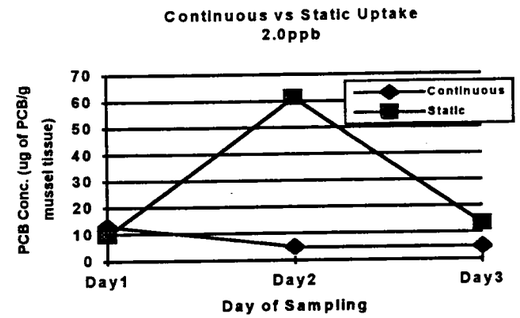

Figure 5: Comparison of tissue conc. in mussels exposed to 2.0 ppb Aroclor in both static and continuous flow systems

The water used in the systems was most likely low in organic matter due to the sand filter system, although no test was done to determine the amount of organic matter. It may have also been high in suspended inorganic particles from the sand used to filter the water. Since the nature of PCB is hydrophobic, PCBs tend to accumulate on suspended particles. If the water contained high levels of suspended matter, including organic and inorganic matter, the mussels are much more likely to accumulate the PCB as they filter bringing the matter into direct contact. On the other hand, if the concentrations were low that would lower the contact with PCB-laden particles. Deviations in PCB tissue concentrations may have occurred as changes in the suspended solids occurred.

Recommendations

More extensive studies must be done in order to determine the zebra mussels possible impact on the Hudson River and its ecology. The PCBs in the Hudson are of special concern. With the mussel's invasion our limited understanding of the Hudson River's ecology and PCBs role in the ecosystem is further jeopardized. Experimental designs are hard to use as indicators of true interactions in the environment, but they can give us a guide from which to work. A revised design should be devised using water free of suspended solids and of constant temperatures. From there, studies could be done that vary the suspended solid concentration, type of suspended solids, and water temperature.

As seen in Figures 4 and 5, the system used may influence the mussel processes. Further studies into the process of uptake and depuration of contaminants by the mussels may increase the understanding of these processes.

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