LEAD ACCUMULATION IN SOFT TISSUES AND SHELLS OF ASIATIC CLAMS (*CORBICULA FLUMINEA*)

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Abstract. Bivalves bioaccumulate metals and are useful as sentinel organisms for assessing the bioavailability of metal contaminants in aquatic ecosystems. Frequently, tissue metal concentrations are used by environmental monitoring studies to evaluate potential exposure and effects scenarios. However, bivalves may accumulate certain metals, such as lead, to a significant extent in shells. The purpose of this study was to evaluate the uptake and distribution of lead in the Asiatic clam (*Corbicula fluminea*) to determine the utility of using shell lead concentrations in environmental monitoring studies. Clams were exposed to lead (5 and 10 mg/L) in a static-renewal system for three weeks. Tissue (adductor muscle and foot) and shell lead concentrations were quantified by atomic absorption spectroscopy after three weeks of exposure and one week post-exposure. Lead accumulation in shells and tissues increased with increasing exposure concentrations. Lead accumulation in shells was approximately 76 to 89% greater than accumulation in adductor muscle tissue and 48 to 70% greater than accumulation in foot tissue. Furthermore, shell lead concentrations were not altered in depurated clams. Together, these data indicate that shells represent a primary storage site for lead in Asiatic clams and suggest that shells may represent a valuable biological material to sample in environmental monitoring studies when lead is a contaminant of concern.

INTRODUCTION

Metal contamination of aquatic ecosystems has been extensive (Goyer, 1993). Elevated concentrations of metals in aquatic ecosystems can be caused by the release of sewage and industrial effluents, non-point source runoff from agricultural and urban areas, and atmospheric fallout. Once in aquatic environments, metals tend to accumulate in sediments (Salomons et al., 1987). As such, environmental monitoring programs routinely measure sediment metal concentrations as an indicator of potential biological and ecological stress. Metal toxicity is, however, an integrative process that depends on contaminant concentrations in the environment and on factors that affect bioavailability (Ankley et al., 1996). Therefore, to improve predictions of adverse effects during environmentally relevant exposure scenarios, many monitoring studies are beginning to incorporate tissue body burden data into analyses.

Bivalves are frequently used in biological monitoring studies because of their widespread distribution and abundance in study areas, sedentary habits, hardiness, and ability to bioaccumulate pollutants without excessive mortality (Farrington, 1983; Elder and Collins, 1991). The U.S. Mussel Watch Program has demonstrated that the use of bivalves as sentinel organisms can be beneficial for assessing the bioavailability of metal contaminants (Farrington, 1983; O'Conner and Beliaeff, 1995). Furthermore, many *in situ* studies on bivalves have found a significant correlation between tissue metal concentrations and adverse effects including inhibition of growth and impaired reproduction (Widdows et al., 1981; Widdows, 1985; Salazar and Salazar, 1991). Together, these studies suggest that tissue metal concentrations are valuable indicators of potential biological and ecological stress because they can account for factors that affect bioavailability.

In contrast, several studies on bivalves have noted a lack of correlation between tissue metal concentrations and adverse effects (Walkichuk, 1974; Black et al., 1996). One explanation for these inconsistencies is that certain metals are being preferentially accumulated in the shell matrix. Lead (Pb), in particular, is a metal whose environmental concentrations are often poorly correlated with tissue concentrations and adverse effects (Elder and Collins, 1991; Mason and Jenkins, 1996). Lead is also known to be deposited in the shells of bivalves as are cadmium, copper, manganese, mercury, and strontium

(Swinehart and Smith, 1975; Sturesson, 1976; Sturesson, 1978; Imlay, 1982).

The purpose of this study was to evaluate the uptake and distribution of Pb in the Asiatic clam (*Corbicula fluminea*) to determine the utility of using shell Pb concentrations in environmental monitoring studies. Asiatic clams are abundant and widely distributed in southeastern aquatic habitats. Therefore, Asiatic clams represent potentially valuable indicator species for assessing the biological and ecological integrity of water resources in Georgia.

METHODS

Test Organisms

Adult Asiatic clams were collected from an unpolluted reference site (Lake Chapman, Clarke County, GA), transported to the laboratory, and cleaned of debris. Clams were placed in 20-L aquaria containing aerated, dechlorinated tapwater and acclimated to laboratory conditions for 30 days. During acclimation and exposure periods, clams were fed a Microfeast Plus L-10 larval diet (Burns Philp Food Inc., Bartlesville, OK) dissolved in water at a concentration of 0.01 g/clam/day.

Exposures and Sample Preparation

Clams were exposed in 20-L aquaria to 5.0 or 10 mg/L Pb as $Pb(NO_3)_2$ (Fisher Scientific, Norcross, GA) for 3 weeks in a static-renewal system (16 clams in each replicate). Clams were sampled from aquaria after 3 weeks Pb exposure and after 1 week of depuration in Pb-free water. Tissue (adductor muscle and foot) and shells were collected for metal analyses. Tissues were frozen in liquid nitrogen, and stored at –80°C until analyzed. Shells were cleaned and stored at –20°C until analyzed.

Lead Analyses

Pooled tissue samples (from 9 to 12 individuals, necessitated by tissue weights) and individual shells were analyzed for Pb content by U.S. EPA method 3050 with slight modifications (U.S. EPA, 1986). Samples were digested in concentrated nitric acid at 60°C for 75 minutes. Hydrogen peroxide (30%) was then added to remove any remaining organic material and samples were allowed to evaporate to 5 ml. Samples were diluted to 100 ml with H_2O and analyzed for Pb content by atomic absorption spectrometry with graphite furnace atomization.

RESULTS

Lead accumulation in clams exposed for three weeks increased with increasing Pb exposure concentrations and was consistently higher in shells than soft tissues (Figure 1). Lead accumulation in shells was approximately 76 to 89% greater than accumulation in adductor muscle tissue and 48 to 70% greater than accumulation in foot tissue. Exposed clams, at one week of depuration in Pb-free water, still contained elevated concentrations of Pb in shells and tissues (Figure 2). At the highest Pb exposure concentration (10 mg/L), Pb in adductor muscle tissue decreased, while concentrations in foot tissue and shells remained constant.

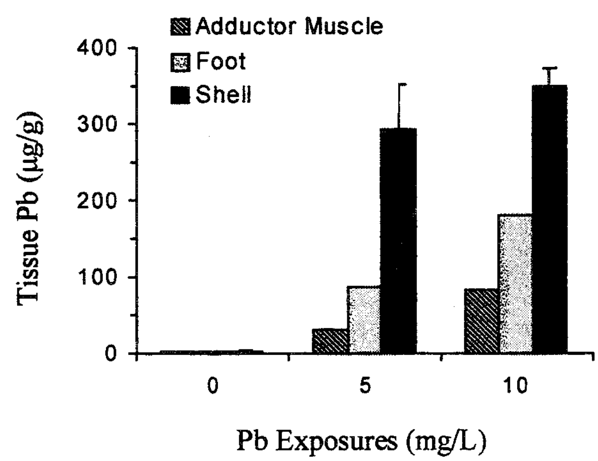

Figure 1. Lead concentrations in soft tissues and shells of Asiatic clams exposed for three weeks. Data are means ± SD (n=3 or 4) for shells and represent pooled samples (n=1) for soft tissues.

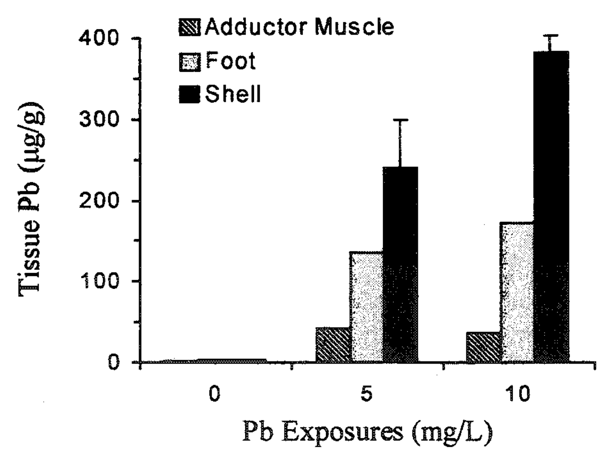

Figure 2. Lead concentrations in soft tissues and shells of Asiatic clams after one week of depuration. Data are means ± SD (n=3 or 4) for shells and represent pooled samples (n=1) for soft tissues.

DISCUSSION

Many studies on aquatic invertebrates have demonstrated that Pb accumulates in shells and other skeletal material (Sturensson, 1976; Brown, 1977; Imlay, 1982). In this study, it was found that shells represent a primary storage site for Pb in Asiatic clams. It has been proposed that bivalves accumulate Pb in the shell by two processes, an active process whereby Pb accumulated in soft tissues is transported to the mantle and deposited in the shell and a passive process whereby Pb from the surrounding environment physically adsorbs on to shell material (Sturensson, 1976). Once in the shell, the majority of Pb associates with the periostracum and calcium carbonate fractions (Sturensson, 1976).

The use of shell Pb concentrations in environmental monitoring studies would be advantageous for many reasons. Sturensson (1978) notes that bivalve shells are easier to preserve than soft tissues and may also release metals at a slower rate during depuration periods. Hence, shell Pb concentrations would be useful for predicting environmental exposures from single point in time measurements. Findings from this study support this notion in that shell Pb concentrations in Asiatic clams remained stable during depuration.

Shell Pb concentrations may also be valuable in environmental monitoring studies because of their toxicological relevance. Bivalves have been shown to resorb shell material during times of stress (Frazier, 1976). During these resorption periods, Pb present in shells can become mobilized and may have detrimental affects on organismal health. Lead present in shells may also act to weaken the calcium carbonate matrix. Future studies aimed at evaluating the toxicological relevance of Pb in bivalve shells will be important for using and interpreting shell Pb concentrations in environmental monitoring.

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