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Bioaccumulation of Four Heavy Metals in Two Populations of Grass Shrimp, *Palaemonetes pugio*

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Bioaccumulation can occur only if the rate of uptake of a chemical by an organism exceeds its rate of elimination. Bioaccumulation of pollutants first gained public attention in 1960s with the discovery of DDT, DDD, and methylmercury residues in fish and wildlife (Rand & Petrocelli, 1985). Several authors reported that organisms living in contaminated areas accumulated higher concentrations of metals than uncontaminated areas. Gale et al. (1973) found higher concentration of metals in aquatic organisms from a contaminated area than those from an uncontaminated area. Similarly, Anderson and Brower (1978) found higher concentrations of Cd and Pb in crayfish, *Orconectes virilis* collected from a contaminated site than those from an uncontaminated site.

Many aquatic animals are able to excrete a greater proportion of their intake under contaminated conditions and thus maintain trace metal concentration in the body at an approximately normal level. Johnels et al. (1967) reported that pike (*Esox lucius)* collected from highly contaminated and slightly contaminated lakes accumulated comparable levels of Hg. Similarly, Blanton et al. (1972) found low levels of Hg in mullet collected from a contaminated area. The biological activity or the metabolic rate of an organism often changes due to natural seasonal variations causing the rate of incorporation and release of heavy metals to change. Hardisty et al. (1974) found seasonal variations of Zn concentrations in flounder. Weis et al. (1986) also found higher Hg concentration in killifish *(Fundulus heteroclitus)* collected from Berry's Creek, New Jersey during the summer than in other times of the year. This paper reports on the comparative bioaccumulation of Hg, Cd, Cu, and Zn in two populations of grass shrimp, *Palaemontes pugio*, one of the few species surviving in highly contaminated estuaries in northern New Jersey. One population we studied was from Piles Creek(PC),a tributary of the Arthur Kill in heavily industrialized

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Linden, New Jersey, and the other population was from Big Sheepshead Creek (BSC), a relatively pristine creek near non-industrialized Tuckerton, New Jersey.

MATERIALS AND METHODS

To find out the bioaccumulation of Hg, Cd, Cu, and Zn in PC and BSC shrimp, adult shrimp were collected during the summer of 1986 from both PC and BSC by minnow traps and seine nets. Sediment samples were also collected at the same time. Sediment samples and shrimp were stored at -20°C. Later shrimp were dissected and exoskeleton and muscle were used for Hg, Cd, Cu, and Zn analysis. Due to the small sizes of hepatopancreas, the whole body tissues of the shrimp was selected; it would be eaten by a predator in the food chain. Total Hg was analyzed by the Hatch and Ott (1968) cold vapor atomic absorption method in Coleman Mas-50 mercury analyzer. US EPA quality control samples, "Metals in Fish" were analyzed for Hg along with the shrimp samples and 90% of the Hg was recovered. Cd, Cu, and Zn were analyzed by direct aspiration of HCl_4/HNO_3 (3:1) in wet ashed acetylene flame of a Perkin-Elmer 403 atomic absorption Spectophotometer. For each metal 5-10 samples were analyzed. Oyster powder (National Bureau of standards) samples were analyzed for Cd, Cu and Zn along with the shrimp samples. The recovery were 85, 90, and 80 % for Cd, Cu, and Zn, respectively. Data were analyzed by t-test (Zar, 1984). Concentration factors were calculated by dividing the concentration of metals in the shrimp by the concentration of metals in the sediments. Results were significant at alpha=0.05.

RESULTS AND DISUCSSIONS

Piles Creek sediment contained higher concentrations of Hg, Cd, Cu, and Zn (11.2 µg/g Hg, 5.9 µg/g Cd, 623.5 µg/g Cu, and 627.0 µg/g Zn) than BSC sediment (0.054 µg/g Hg, 0.13 µg/g Cd, 12.9 µg/g Cu, and 7.7 µg/g Zn).

Piles Creek shrimp also showed significantly higher levels of Hg, Cu, and Zn in exoskeleton and muscle than BSC shrimp (Figs. 1 & 2). However, Cd levels did not show any significant difference between PC and BSC (Fig. 1). In both PC and BSC shrimp, there were no significant difference in concentration of Hg, Cu, and Zn between exoskeleton and muscle. (Figs. 1 & 2). However, exoskeleton of both populations showed significantly higher levels of Cd than muscles.

Piles Creek shrimp showed concentration factors of 0.32, 0.13, 0.07, and 0.08 of Hg, Cd, Cu, and Zn, respectively; whereas BSC shrimp showed 1.73, 0.8, 1.1, and 4.2 of Hg, Cd, Cu, and Zn, respectively. Although PC shrimp had higher concentration of these metals, their concentration factors were much lower than BSC shrimp.

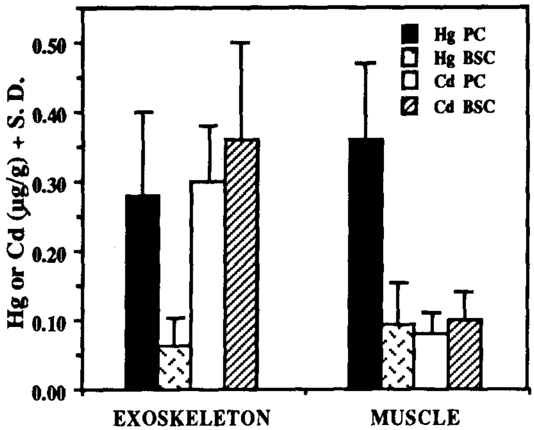

Figure. 1. Bioaccumulation of Hg and Cd in exoskeleton and muscle (wet weight) of two populations of grass shrimp [(Piles Creek (PC), Big Sheepshead Creek(BSC)].

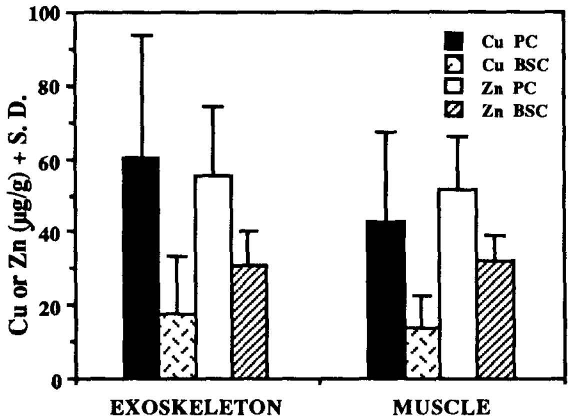

Figure. 2. Bioaccumulation of Cd and Zn in exoskeleton and muscle (wet weight) of two populations of grass shrimp [(Piles Creek (PC), Big Sheepshead Creek(BSC)].

The occurence of higher concentrations of Hg, Cu and Zn in PC shrimp than BSC shrimp was related to the levels of these metals in their habitat. This association of higher concentrations of metals in organisms and greater concentration in their environment has been reported by Gale et al. (1973) in aquatic organisms, and Anderson and Brower (1978) in crayfish, *O. virilis* and Frazer and George (1983) in oyster *Ostrea edulis*.

Hg, Cu and Zn concentrations were higher in the soft body parts than the exoskeleton. The increase in these concentrations in the soft body tissue is possibly due to the binding of the metals to metallothionein proteins. However, the lower exoskeleton concentration reflects the fact that few metabolic processes occur in this hard body tissue and that it was not acting as a reservoir for metabolic Hg, Cu, and Zn. Similar findings were reported by Bryan (1968) in decapod crustaceans, and Anderson and Brower (1978) in crayfish, *O. virilis*.

Higher Cd concentrations were recorded in the exoskeleton than the muscle of both populations of shrimp. This may be due to the accumulation of Cd in the exoskeleton. Long term accumulation of potentially toxic concentrations may not occur due to the periodic molt of the exoskeleton. The exoskeleton thus could be a potential sink for the Cd and a method of eliminating the body burden of Cd. Similarly, MacDonald (1951) reported that the vertebrate bone was the site of Pb deposition, and Wiser and Nelson (1964) reported a higher concentration of Co^{60} in the integument of crayfish, *cambarus longulus,* and Bertine and Goldberg (1972) found a Zn level in exoskeleton double than in internal tissues of shrimp. However, in our study we have not found higher concentration of Zn in the exoskeleton. Frenet and Alliot (1985) found higher concentrations of Cd, Cu, Fe, Mn, Pb, and Zn in the cephalothorax of *Palaemonetes varians* than in exoskeleton and abdomen. Ray (1981) also found higher concentration of these metals in the cephalothorax of *Homarus vulgaris.* In crustaceans the hepato-pancreas and reproductive organs situated in cephalothorax can accumulate higher concentrations of these metals.

During molting crustaceans can depurate some of their body burden of toxic metals such as Cd and Zn. Bertine and Goldberg (1972) recorded a large portion of Zn body burden was lost at molting by shrimp. Although PC is highly polluted with heavy metals, the shrimp living in this creek showed lower concentration factors than BSC shrimp. Frazer and George (1983) investigated the uptake of Cd in the oyster *Ostrea edulis* and showed that oysters from a contaminated site accumulated Cd at a slower rate than oysters from an uncontaminated site. Similarly, Abdullah and Ireland (1986) found a reduced rate of uptake in dog whelks *Nucella* from a contaminated site than in those from less contaminated sites. Population living in polluted areas can accumulate lower amounts of toxic chemicals by reducing permeability or excreting more. This is a type of adaptation for organisms to survive in polluted areas.

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