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Influences of salinity on the biokinetics of Cd, Se, and Zn in the intertidal mudskipper *Periophthalmus cantonensis*

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Abstract

The biokinetics (aqueous uptake, dietary assimilation, and elimination) of Cd, Se, and Zn in the intertidal mudskipper, *Periophthalmus cantonensis*, were examined at different acclimated salinities using the radiotracer technique. The dietary assimilation efficiency from ingested radiolabeled polychaetes was the highest for Se (32–40%), followed by Zn (5–7%) and Cd (2–3%), and was not influenced by salinity within a range of 10–30 psu. Uptake from the dissolved phase typically exhibited a linear pattern within the first 12 h of exposure, followed by a second slower uptake. The highest concentration factor (CF) was found for Zn, followed by Cd and Se. Differences in salinity did not significantly affect the CF of the three metals within the first 12 h, but the CFs were significantly higher at lower salinities (10–20 psu) than at the highest salinity (30 psu) by the end of 48 h exposure. Because the degrees to which the uptake of Se (a metalloid) and Cd/Zn were affected by salinity were comparable, we concluded that metal speciation as a result of salinity change was not important in leading to a change in metal CF. Physiological changes may be responsible for the increasing uptake at lowered salinity. The elimination rates of the three metals (0.01–0.06 d^{-1}) were not significantly affected by salinity, but Se was eliminated at a faster rate following aqueous uptake than following dietary ingestion. There was no consistent influence of exposure routes on Cd and Zn elimination. The accumulated Cd was mainly associated with the gut, whereas the muscle was the dominant target site for Se and Zn accumulation.

Keywords: Mudskipper; Polychaete; Bioaccumulation; Trophic transfer; Cadmium; Selenium; Zinc

1. Introduction

Coastal pollution has been increasingly recognized as a significant and expanding environmental problem in many developing nations. In Hong Kong, the discharge of industrial wastes have resulted in high metal concentrations in the local marine environment, particularly in the coastal sediments. Aquatic animals are exposed to chemicals in both the dissolved (ambient water) and dietary (sediment or prey) phases. Typically, water quality criteria are defined based on the measurements of metal concentrations in the seawater. However, given the recent recognition of the quantitative importance of

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dietary metals as sources for metal accumulation in marine animals (Wang and Fisher, 1999a; Wang, 2002), it is desirable to consider metal dietary exposure when developing realistic water quality criteria.

Numerous environmental conditions can affect trace metal accumulation in aquatic organisms (for a review, see Phillips and Rainbow, 1993). Among the many environmental factors, salinity affects metal accumulation by directly causing changes in metal speciation and the animal's physiology such as membrane permeability. Such changes may in turn affect trace metal biokinetics, including the aqueous uptake rate, the dietary assimilation efficiency, and the efflux (or elimination) rate (Wang, 2002). Most previous studies on the influences of salinity on metal accumulation focused on the dissolved uptake, whereas there have essentially been no studies on the influences of salinity on dietary assimilation efficiency and efflux rate constant (Blackmore and Wang, 2003; Ng and Wang, 2005).

The mudskipper, *Periophthalmus cantonensis* (Gobiidae), a demersal fish limited to Japan, Korea, and China, is common in Hong Kong's marshy areas and tidal mudflats. Mudskippers are euryhaline and widely distributed in different areas in Hong Kong, including both the eastern side which is characterized by relatively high salinity, and the western side (e.g., Mai Po natural reserve) which is characterized by low salinity (especially during the summer). The mudskippers are also the important prey for many predators such as migrating birds, thus it is necessary to evaluate the bioaccumulation of coastal toxicants (including metals) in this fish. In an earlier study (Ni et al., 2000), the dietary assimilation efficiencies (AEs) of Cd, Cr, and Zn were determined in mudskippers feeding on two zooplankton prey (brine shrimp *Artemia salina* larvae and copepods). The mudskippers assimilated Cd, Cr, and Zn at an efficiency of 10–26%, 4–19%, and 11–31%, respectively, from the zooplankton prey. However, the influences of environmental conditions (such as salinity) and biological conditions (such as other prey types) on the AEs and other biokinetics parameters (dissolved uptake and metal elimination) remain unknown. All three parameters are critical in determining metal accumulation and concentration in the animals.

The objectives of this study were to examine the biokinetics of Cd, Se, and Zn in the intertidal mudskipper from both the aqueous and dietary phases under varying salinity conditions. Given the widespread distribution of mudskippers in different areas around Hong Kong with different salinity regimes, it is necessary to understand how the metal accumulation in fish varies between the environments. The three metals were chosen based on their essentiality (Se and Zn) and non-essentiality (Cd) and their contrasting chemical behaviors (e.g., Se is a metalloid and its speciation is least affected by salinity, whereas Cd and Zn speciation is dependent on salinity). We measured the dietary metal assimilation efficiencies by feeding the radiolabeled polychaete *Capitella capitata* to the fish. The polychaete was previously exposed in radiolabeled sediment in order to contrast the results with the previous measurements of metal assimilation in the fish when feeding on zooplankton prey (Ni et al., 2000).

2. Materials and methods

2.1. Mudskipper and food preparation

The intertidal mudskipper *Periophthalmus cantonensis* (Gobiidae) was chosen for this study. Mudskippers breathe through their skin by keeping their bodies moist when exposed to the air (Graham, 1997; Ni and Kwok, 1999). The mudskippers were collected from Lantau Island between December 2000 and February 2001, under typical salinity conditions of 30 psu. The fish were acclimated for 14 days in the laboratory in aerated seawater at 25 °C and at different salinities (10, 20, and 30 psu) before the biokinetic experiments. The fish were sequentially acclimated to the targeted salinity over a period of seven days. During the acclimation period, the fish were constantly fed the polychaete, *Capitella capitata*, at a daily ration of about 5% of their tissue dry weights, which was sufficient to sustain the fish.

The cosmopolitan *Capitella* sp. I is characterized by its rapid growth rate (up to 36% each day) and numerical dominance in organically enriched areas. Both dissolved and particulate sources contribute to metal accumulation in *Capitella* sp. I; however, accumulation from sediment is the most important source of metals to the deposit-feeding polychaetes (Selck et al., 1999; Wang et al., 1999). *C. capitata* can be easily collected from the field, kept alive and cultured in the laboratory throughout the year. Morever, *C. capitata* was chosen because it takes up metals bound to sediment and occurs in organically enriched sediments.

Muddy surface oxic sediments were collected from a clean site Sai Kung, Hong Kong for this study (sediment Cd and Zn concentrations of 0.1 and 55 μg g^{-1}, respectively). The sediments were sieved through 250 μm mesh for the laboratory culture of *C. capitata* and through 63 μm mesh for the radioactive feeding experiments described below. Briefly, the sediments were sieved through a 63 μm mesh and collected by centrifugation at 11 750*g* for 6 min. All sediments used in this study were prepared at the same time and stored at 4 °C to ensure a homogeneous sample. Laboratory cultures of *C. capitata* on the sediments were maintained in flow-through seawater and gently aerated at room temperature, with 29–31 psu filtered seawater. The polychaetes were fed weekly with ground fish food (TertraMarin™) added as a supplementary food source.