DIETARY SOURCES DOMINATE METAL UPTAKE IN MARINE FISH

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Abstract

The bioaccumulation of 10 metals in five fish species was experimentally evaluated following exposure to dietary or aqueous metal at environmentally realistic metal concentrations. A biokinetic model showed that, with few exceptions, >90% of a fish's metal body burden was obtained from diet. Regulatory bodies need to consider these findings in setting appropriate water quality criteria. Metal uptake from the aqueous phase was influenced by dissolved organic carbon and salinity, but no consistent patterns were evident for all metals.

Keywords: Bio-Accumulation, Fishes, Models, Metals

Like other aquatic animals, fish can acquire contaminants, including potentially toxic metals, from their diet and from the surrounding water [1]. Most water quality criteria for regulatory purposes are based on aqueous concentrations, as are most standard toxicity tests. However, because metals are concentrated in the food that fish eat by hundreds to thousands of times over levels in the ambient water [2], the dietary sources commonly represent especially enriched sources of metals. Here we present results of experimental studies in which diverse fish from coastal and estuarine environments were exposed to metals from both water and from their diet to assess the relative importance of these sources. We quantified uptake rate constants from the dissolved phase for diverse metals and assimilation efficiencies from ingested food, and determined the release rates of metals following different exposure pathways. We then used these kinetic parameters in a metal bioaccumulation model to compare the relative importance of diet and aqueous exposures as sources of metals for fish.

We used gamma-emitting radioisotopes to determine the uptake, retention, and tissue distribution of Am, As, Cd, Co, Cs, Hg, monomethylmercury (MeHg), Mn, Se, and Zn in four teleosts (*Fundulus heteroclitus, Sparus auratus, Menidia menidia, Psetta maxima*) and one elasmobranch (*Scyliorhinus canicula*) exposed to these metals either from their food or the dissolved phase. The diets consisted of either worms, amphipods, brine shrimp nauplii, or juvenile fish. We also evaluated the influence of dissolved organic carbon (DOC) and salinity on the uptake of metals from the aqueous phase in the euryhaline *F. heteroclitus*, which is used as a bioindicator organism of coastal contamination. Assimilation efficiencies (AEs) from diet were determined using pulse-chase methodology [3]. A biokinetic model [4] to assess metal bioaccumulation describes metal concentrations in fish, at steady state (C_{ss}), as: $C_{ss} = [(k_u \times C_w)/(k_{ew} + g)] + [(AE \times IR \times C_f)/(k_{ef} + g)]$, where k_u = uptake rate constant from the aqueous phase, C_w = dissolved metal concentration, AE = assimilation efficiency of ingested metal, IR = weight-specific ingestion rate, C_f = metal concentration in food, k_{ew} and k_{ef} = efflux rate constants of metals following aqueous and dietary uptake, respectively, and g = growth rate constant (Wang et al. 1996). This model evaluated the relative importance of diet and aqueous phases as sources of metal for these fish. For modeling, values for AE, k_u, k_{ew}, and kef were determined experimentally, whereas C_w, C_f, IR and g were taken from the literature [5,6]. Metal uptake was predominantly from dietary sources for most metals and fish species (Table 1). DOC concentrations were generally inversely related to Cr, Hg, and MeHg uptake and positively related to As uptake from the aqueous phase [8]. Salinity, over a range of 0 -20 psu, was inversely related to uptake of Cd and positively related to uptake of As, Hg, and MeHg [8]. Although uptake of metals from the aqueous phase is not negligible in marine fish, clearly dietary sources predominate (Table 1), and must be considered in setting appropriate water quality criteria for coastal regions.

Tab. 1. Model-estimated per cent of metal body burden calculated for diverse metals in 5 fish species feeding on crustaceans using measured kinetic parameters [3, 6-8]. Model predictions assumed that g was negligible compared to k_e values and assumed a mean IR value = 0.05 g g^{-1} d^{-1}. nd = not determined.

Metal	*S. canicula*	*P. maxima*	*S. auratus*	*M. menidia*	*F. heteroclitus*
Am	<1	43	91	nd	nd
As	nd	nd	nd	nd	12
Cd	>99	>99	>99	>99	35
Co	98	99	>99	nd	nd
Cs	97	86	78	nd	nd
Hg	nd	nd	nd	>99	69
MeHg	nd	nd	nd	98	>99
Mn	>99	99	>99	nd	nd
Se	nd	nd	>99	>99	nd
Zn	>99	>99	>99	>99	nd

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