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IMPLICATIONS OF TROPHIC TRANSFER STUDIES FOR DEVELOPING WATER AND SEDIMENT QUALITY CRITERIA

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Most water and sediment quality criteria are based on bioaccumulation and toxicity studies in which target organisms are exposed to dissolved toxicant concentrations. Further, established toxicity bioassay protocols approved by the Environmental Protection Agency in the US require that animals not be fed during the course of the tests. However, recent studies have demonstrated that bioaccumulation of metals from ingested food or sediment may dominate their uptake in diverse marine invertebrates, including crustacean zooplankton, bivalve molluscs, and deposit-feeding polychaetes. These studies used gamma-emitting radioisotopes to measure the assimilation efficiencies of ingested metals in these animals from food. These measurements, combined with the application of a bioenergetic-based kinetic model, have clearly demonstrated that the bioaccumulation of certain metals can be dominated by uptake from the food pathway. Environmental criteria which assume that this pathway is unimportant relative to uptake from the dissolved phase, or which apply a "safety factor" based on uptake parameters from the dissolved phase only, are inappropriate and need to be revised.

Recent radiotracer experiments involving Am, Ag, Cd, Co, Cr, Se, and Zn have quantified metal uptake rates from food (different algal species for bivalves and copepods, sediments for deposit-feeding worms) and water and efflux rate constants over a range of environmental conditions [1-4]. Table 1 presents ranges of these kinetic parameters and the %'s of total metal body burden in an animal accumulated from food for different species. The kinetic model we used describes uptake from food and solute pathways in an animal [5,6]. For metals, the steady state concentration in an animal (C_{ss}, µg g^{-1}) can be described as:

$$C_{ss} = \frac{(k_u \times C_w)}{(k_{ew} + g)} + \frac{(AE \times IR \times C_f)}{(k_{ef} + g)} \qquad (1)$$

$$C_{ss,w} = \frac{(k_u \times C_w)}{(k_{ew} + g)} \qquad (2)$$

$$C_{ss,f} = \frac{(AE \times IR \times C_f)}{(k_{ef} + g)} \qquad (3)$$

where k_u = metal uptake rate constant from the dissolved phase (L g^{-1} d^{-1}), C_w = metal concentration in the dissolved phase (µg L^{-1}), AE = assimilation efficiency from ingested food (%), IR = ingestion rate of the animal (g g^{-1} d^{-1}), C_f= metal concentration in ingested food (µg g^{-1}), k_{ew} = metal efflux rate constant following solute uptake (d^{-1}), k_{ef} = metal efflux following food uptake (d^{-1}), g = growth rate constant of the animal (d^{-1}), $C_{ss,w}$ = metal concentration in animal due to uptake from the dissolved phase, and $C_{ss,f}$ = metal concentration in animal due to uptake from food.

Overall, it is apparent that food uptake is a major pathway of metal accumulation in all animals examined. This is consistent with lab and field evidence and modeling sensitivity analyses for metal accumulation in marine mussels which showed that metal uptake is directly proportional to AE for all metals [6]. Even when AE values are low, the fraction of total body burden in an animal deriving from food ingestion can be well over 60% (e.g., Am, Cr). For all animals, Se is accumulated almost entirely from ingested food, because it has very high AE and low k_u values. Among the animals investigated, copepods display the lowest fraction of body burden obtained from food, although there is considerable variability which is dependent on AE and C_f values, and worms display the highest fraction obtained from food (sediment), due primarily to their high IR values. These results suggest that any water or sediment quality criteria must consider the trophic transfer of contaminants in aquatic food chains. By performing toxicity and bioaccumulation tests only with dissolved metals, the criteria generated would underestimate the likely impacts of the metals on resident aquatic biota.

Table 1. The relative importance of food as a source for metal accumulation in marine suspension feeders (mussels--*Mytilus edulis*, copepods--*Temora longicornis*) and deposit-feeding polychaetes (*Nereis succinea*). Ranges of assimilation efficiency (AE, %) from ingested food, uptake rate constants from the dissolved phase (k_u, L g^{-1} d^{-1}) and efflux rate constants following uptake from food (k_{ef}, d^{-1}) are also presented. R is the calculated percentage of total metal body burden that is accumulated from food. nd: not determined. Data obtained from refs. 1-4.

Animal		Ag	Am	Cd	Co	Cr	Se	Zn
M. edulis	AE	4-37	1-6	10-34	13-37	0.2-1	12-72	15-48
	k_u	1.794	0.398	0.365	0.124	0.034	0.035	1.044
	k_{ef}	0.034	0.020	0.014	0.010	0.010	0.022	0.015
	R	26-78	85-96	20-70	70-95	62-87	>96	50-94
T. longicornis	AE	8-19	nd	33-53	14-20	nd	50-58	52-64
	k_u	10.42	nd	0.694	0.606	nd	0.024	3.29
	k_{ef}	0.294	nd	0.297	0.281	nd	0.155	0.079
	R	10-55	nd	20-70	10-53	nd	>97	45-92
N. succinea	AE	10-30	nd	10-30	40-80	nd	30-50	20-50
	k_u	1.853	nd	0.010	0.016	nd	0.006	0.064
	R	65-95	nd	>98	100	nd	>98	>98

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