The Biodynamic Model (BM)

A means to improve sediment bioaccumulation protocols and a potentially regulatory tool

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Contaminant accumulation from sediment is important

Deposit-feeders

- Live by extracting organic matter from sediment
- Particle ingestion: main route of contaminant uptake*
- Bioturbate: mix and irrigate sediment

*E.g., Selck et al. 1998; 2003a,b

=> Important role in remobilization of sediment-associated contaminants to higher trophic levels

Widely used bioaccumulation (B) models, e.g., FIAM (Free Ion Activity Model) and BLM (Biological-Ligand Model) predict B based on dissolved metal concentration

Challenges

- Other potential uptake routes exists
- Excluding dietary uptake will for some contaminants severely underestimate accumulation and thus internal exposure.

Aim

To discuss the biodynamic model as a means to measure and predict bioaccumulation from various exposure routes

Biodynamic (kinetic) Model (BM)

Experimentally derived unidirectional rate constants

$$C_{ss} = \frac{\overbrace{(ku \times Cw)}^{\text{Water}} + \overbrace{(AE \times IR \times Cf)}^{\text{Food}}}{\underbrace{(ke + k_g)}_{\text{Loss}}}$$

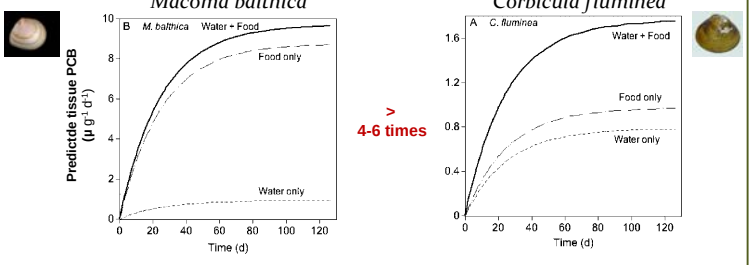
Takes into account all uptake routes and allows capturing the biologically driven processes that govern bioaccumulation among species both for metals and organic compounds

C_{ss}: steady state; k_u: uptake rate constant (µg/g_{tissue}/d); k_e: loss rate constant (d^{-1}); C_w: conc in water (µg/L); IR: ingestion rate (g_{food}/g_{tissue}/d); AE: assimilation efficiency (%); C_f: conc in food (µg/g_{food}); k_g: growth rate constant (d^{-1})

Example 1: Organics (PCB)

BM model used to explain why the body burden of *M balthica* was 4-6 times higher than for *C fluminea* despite that total sediment PCB was similar between field sites

PCB Accumulation



McLeod et al 2007 (ET&C 26); 2008 (ES&T 42)

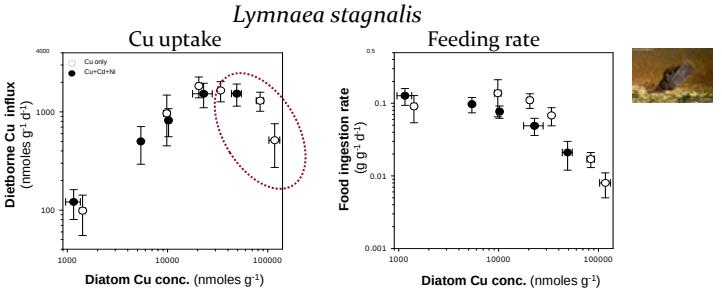
Explanation based on BM

Based on BM, McLeod et al. (2008) demonstrated that the lower uptake in *Corbicula* compared to *Macoma* was related to feeding mode: for *Corbicula* (predominantly filter-feeding) the aqueous uptake is almost equally important to dietary uptake; whereas for *Macoma* (facultative deposit-feder) 90% of the body burden came from sediment ingestion.

Example 2: Metals (Cu)

BM model used to examine the link between diet-borne Cu uptake and toxicity: i.e., why uptake influx levels off at the very high concentrations.

Lymnaea stagnalis



Croteau & Luoma 2009 (ES&T 43)

Explanation based on BM

Using the biodynamic model (uptake from food depends on IR and AE; AE was similar for all concentrations), Croteau and Luoma (2009) were able to ascribe the decline in diet-borne Cu uptake rates in the freshwater snails *L. stagnalis* to feeding inhibition, showing that metal accumulation is not simply a function of exposure, but also of biology, i.e., animal behavior.

Compared to OECD 315

BM as a means to improve sediment bioaccumulation protocols

- Experimentally require similar effort (labor, money) to conduct
- Employed for all systems, organisms and chemicals
- Not restricted to one uptake route
- Examining unidirectional uptake and efflux rates from water and diet, will provide information on a number of parameters (influx/efflux, AE, IR, FR etc)
- Experimental data are directly implementable in the BM model

BM allows capturing biologically driven processes governing B among species both for metals and organic compounds

Potential as a regulatory tool

Applicability of BM

- Capacity to include site-specific & species specific characteristics:
  - Relative importance of dietary and aqueous uptake routes for organisms differing regarding habitat, feeding strategy etc.
  - Distinguish between differences in uptake related to physico-chemical properties and e.g., behavioral differences
- Predict steady state and thus calculate BAF/BSAF in a quantitative manner which undoubtedly has advantages regarding the role of B metrics in evaluation of risk criteria
- Modelled B can be validated by field samples

BM will be an improvement of sediment B protocols and has potential as a regulatory tool