National Institute for Public Health and the Environment
Ministry of Health, Welfare and Sport

Derivation of environmental quality standards for biota

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INVESTMENTS IN EDUCATION DEVELOPMENT

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National Institute for Public Health and the Environment
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1 Protection goals

Protection goals of biota standards

- Avian and mammalian wildlife species
  - › predators (freshwater and marine food chain)
  - › top predators (especially marine food chain)
  - – Population level
  - – Direct link with aquatic ecosystem
  - – Fully dependent on water body
- Humans exposed through fishery products (fish, shellfish, molluscs)
  - – Individual level
    - › 10^{-6} lifetime cancer risk
    - › NOAEL with high assessment factor
  - – No direct link with individual ecosystem
    - › Consumed fish is not from single spot
    - › Contribution of exposure from other sources as well

Higher trophic level marine predator

Lower trophic level predator

$QS_{biota, sec pois}$

BMF2

Large fish

$QS_{biota, sec pois}$

Human fish consumption

$QS_{biota, hh}$

BMF1

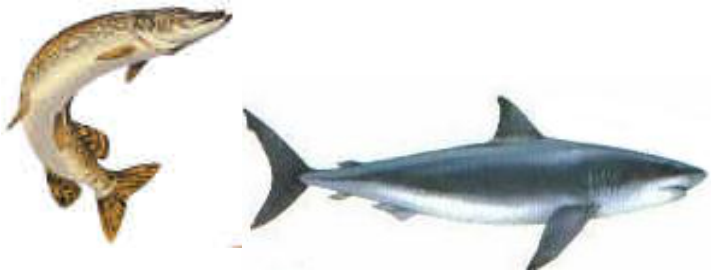
Aquatic organisms

BCF

Water

Not included in default scenarios

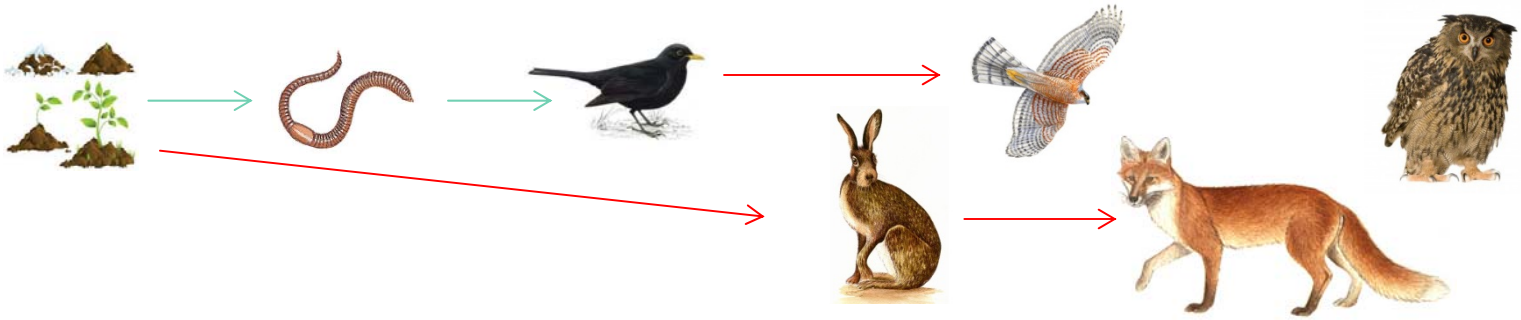
- Freshwater predatory fish
- Marine water predatory fish



- Amphibians

- Reptiles

- Terrestrial food chain is limited



2 Derivation of biota EQS

Human fish consumption: $QS_{biota, hh\ food}$

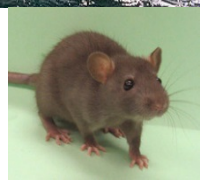
- $EQS_{hh, food} = (0.1*TL*70)/0.115$

  - 0.1 contribution of fish consumption to total intake (fraction)
  - TL threshold level: TDI, ADI, RfD or similar [mg/kg_{bw}/day]
  - 70 average body weight [kg]
  - 0.115 daily fish consumption of fishery products [kg/d]

Secondary poisoning: $QS_{biota, sec pois}$

- Concentration based approach
  - Concentration of toxicant in **diet** of bird or mammal
  - Diet concentration measure for prey species in the field
  - Bias due to different food intake rates
    - › Extra factor 3
      - caloric content: constant factor not justified
      - different metabolism
- Dose based approach
  - daily toxicant **intake (rate)** per mass of body weight
  - key species has highest food intake rate
    - › daily energy expenditure
    - › small species have higher food intake rates
      - Does not lead automatically to highest body residue for chronic exposure to slowly depurating toxicants

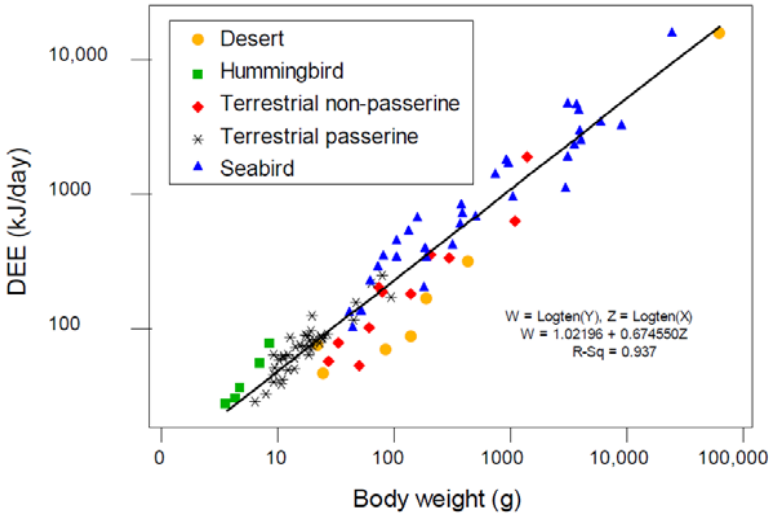


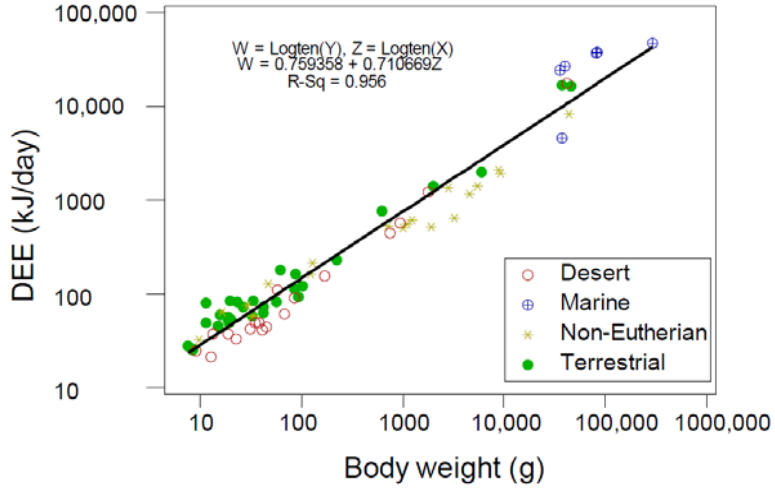



Alternative method

- Differences in caloric content
  - Prey items
  - Diet in toxicity studies
    - › Factor 3 realistic for standard laboratory food to fish
    - › Not for earthworms, mussels, etc.
    - › Not for other diets

- Normalisation of to caloric content?
  - Daily energy expenditure is function of body weight
  - Daily energy expenditure under field conditions could be estimated





D Crocker et al. 2002. Project pn0908: Methods for estimating daily food intake of wild birds and mammals

Analysis of the assessment factor

- Acute/subchronic to chronic extrapolation
  - 100 for 5-d bird study
  - 10 for 28-d mammal study
  - 3 for 90-d mammal study
  - 1 for true chronic study (preferred)

- Interspecies variation and laboratory data to field impact extrapolation
  - 10 (standard for birds and mammals)
    - No differentiation for the number and type of data, as for aquatic species (only 10 for algae, daphnids and fish

- Extra factor for caloric content only for diet based approach
  - 3 because wildlife species often have a higher food intake ratio than laboratory animals

- Not very conservative

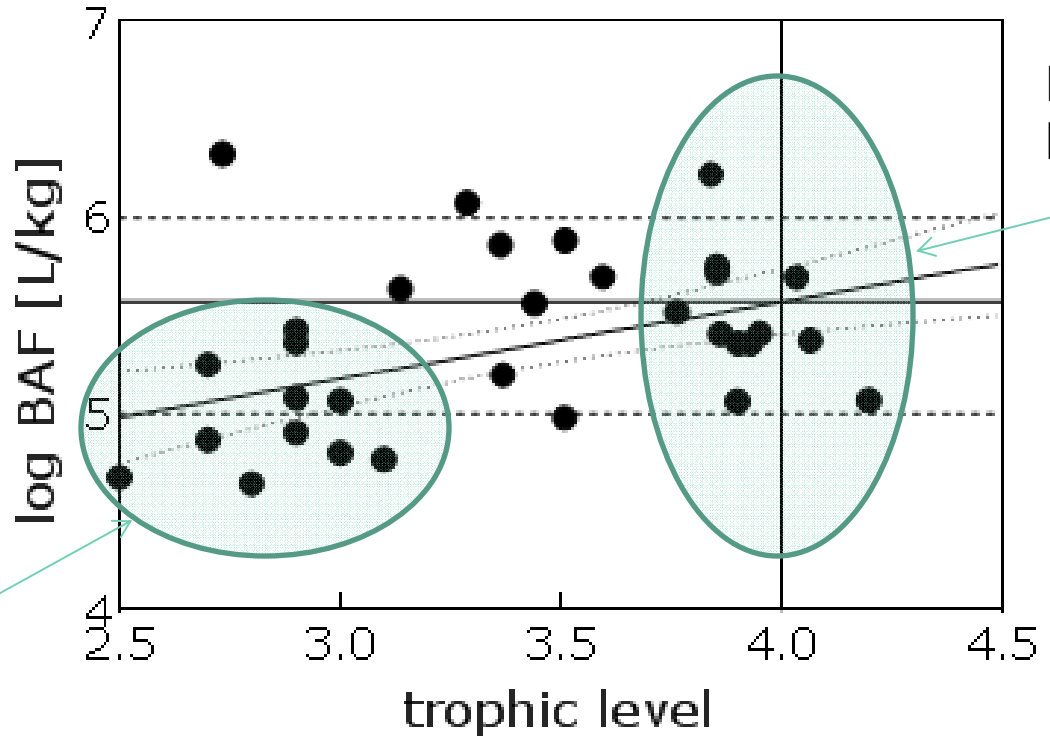
3 Options for implementing biota EQS

Biota standards most reliable?

- Biota
  - Advantages
    - Direct measure of exposure
    - Analytically more feasible
  - Disadvantages
    - More heterogeneous
    - Difficult to obtain
      - Less frequent sampling

- Uncertainty in biota EQS in compliance checking (monitoring)
  - Which trophic level (species, age, size)
    - Trophic level 4 for humans and predators, 5 for top predators
  - Large difference between individual organisms
    - Migrating biota
    - Different behaviour

Variability of biota (hexachlorobenzene in fish)



Large fish, highly variable

Small fish,probably underestimated

CTA Moermond & EMJ Verbruggen. 2013. Integrated Environmental Assessment and Management Volume 9, Issue 1, pages 87–97.

Derivation of an equivalent QS_{water}

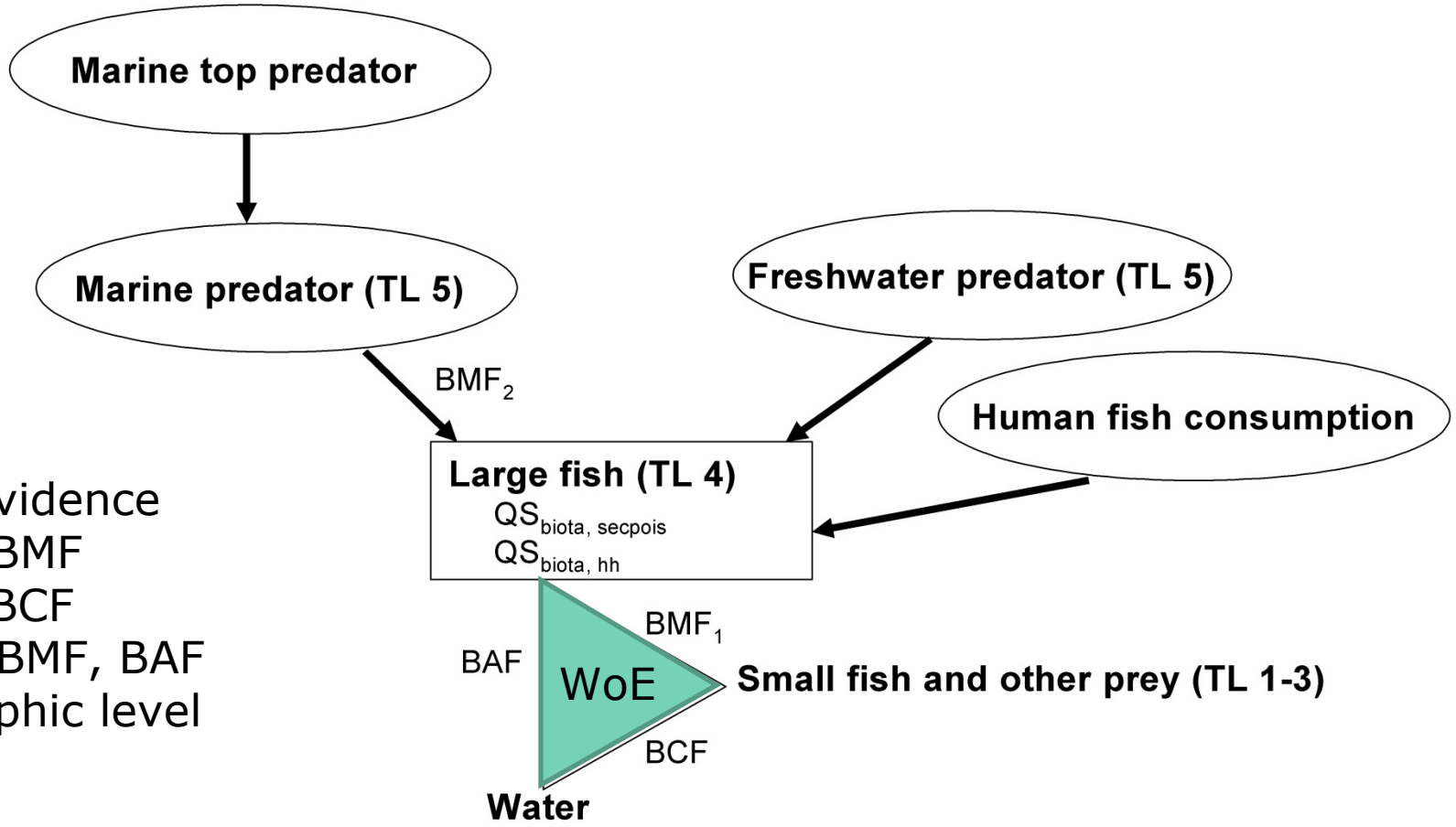
- $QS_{fw/sw,\ sec\ pois} = QS_{biota,\ sec\ pois,\ fw/sw} / (BMF1 * BCF \text{ or } BAF)$
- $QS_{fw/sw,\ hh\ food} = QS_{biota,\ hh\ food} / (BMF1 * BCF \text{ or } BAF)$
- $QS_{sw,\ sec\ pois} = QS_{fw,\ sec\ pois} / BMF2$

- BCF: bioconcentration factor (laboratory based)
- BAF: bioaccumulation factor (field derived, exposure food & water)
- BMF1: biomagnification factor in poikilotherms (food chain up to fish)
- BMF2: biomagnification factor in homeotherms (food chain aquatic organisms to birds and mammals)

Pitfalls in this method

- BCF is not the right metric
  - BAF data from the field may represent BMF*BCF rather than BCF
- BMF values derived from monitoring data may not adequately cover the change in trophic level that should be addressed
- Variability especially with regard to metabolic capacity between species may lead to erroneous BMF values
- Uncertainty in equivalent water EQS in derivation of EQS
  - Uncertainty surrounding BCF, BAF, and BMF
  - Requires evaluation and validation of bioaccumulation data

Conversion to equivalent water standards



Weight of evidence
- BAF=BCF*BMF
- BMF=BAF/BCF
- Valid BCF, BMF, BAF
- Correct trophic level

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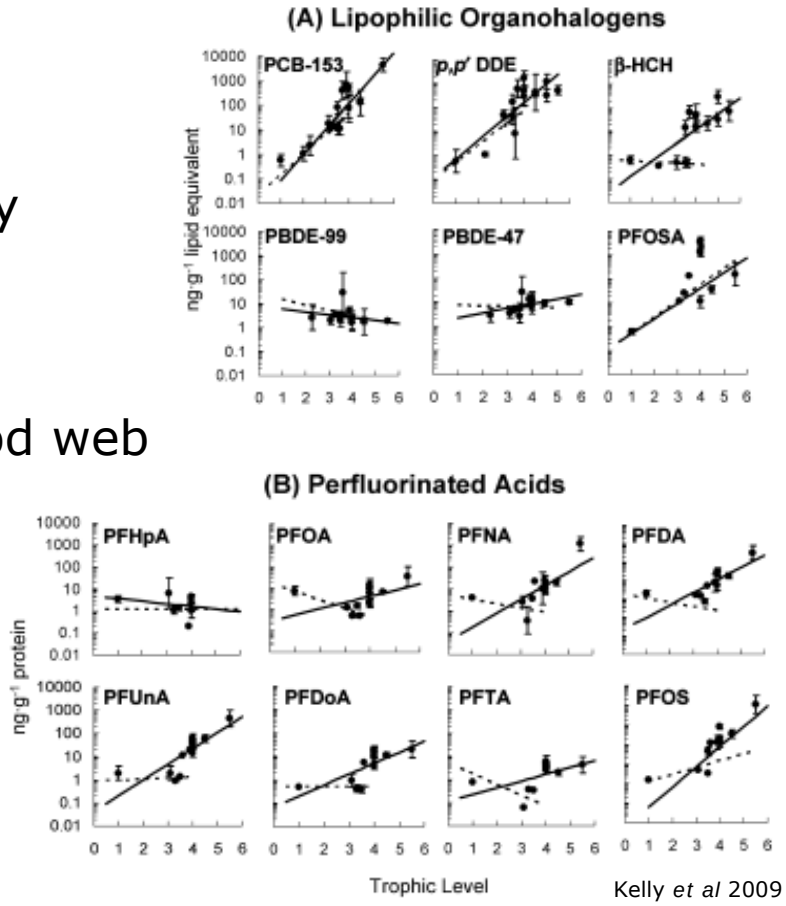
BAF from field studies

- Field derived studies
- No established protocol
- Exposure through aqueous phase and food
- Water concentrations are critical
  - dissolved?
  - bioavailability (DOC/POM)?
- Space/time considerations
  - Biota linked to the sampled water sample?
    - not migrating?
  - Biota and water sampled at the same time?
  - Biota and water sampled at the same location?

BMF from field studies

- Field derived studies
- No established protocol
- Space/time considerations
- Biomagnification from predator and prey
  - BMF = $C_{predator}/C_{prey}$
  - or corrected for trophic level
    BMF = $e\{(\ln C_{predator} - \ln C_{prey})/(TL_{predator}\text{-}TL_{prey})\}$
- Most reliable: regression over whole food web
  - Trophic magnification factor
    TMF = e^{slope}
    - ln C = slope * TL + b
    - trophic level derived from stable isotopes
- BMF ≥ 1
- How many trophic levels for BMF1?



Kelly *et al* 2009

Default BMF for organic substances

log K_{ow} of substance	BCF (fish)	BMF_1	BMF_2
<4.5	<2000	1	1
4.5–<5	2000–5000	2	2
5–8	>5000	10	10
>8–9	2000–5000	3	3
>9	<2000	1	1

Passive samplers to mimick uptake in biota

Some quotes from previous work:

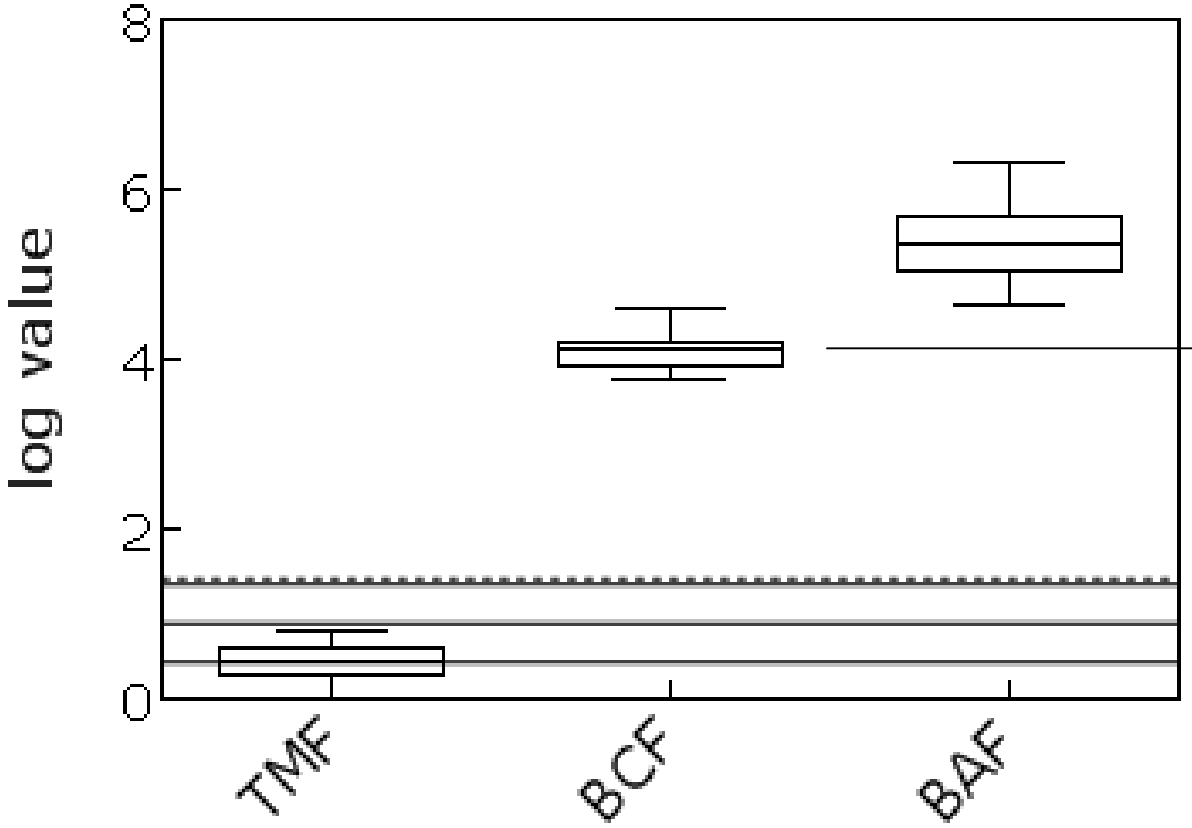
- Since the biomimetic extraction process is a simple physical partitioning, it cannot take into account effects such as bioaccumulation, which includes food chain uptake, and metabolism. The procedure thus mimics the bioconcentration process (passive diffusion) in organisms that do not metabolize.

Verbruggen EMJ, Vaes WHJ, Parkerton TF, Hermens JLM. 1999. Polyacrylate SPME fibers as a tool to simulate total internal concentrations of complex organic mixtures for estimation of baseline toxicity. Environ Sci Technol 34 (2): 324-331.

- The uptake to the disk is only physical partitioning, and therefore body residues are overestimated for species in which the compounds are metabolized. Nonetheless, it should be noted that the biomimetic extraction procedure represents a worst case for species that are not able to metabolize these compounds.

Verbruggen EMJ, van Loon WMGM, Tonkes M, van Duijn P, Seinen W, Hermens JLM. 1999. Biomimetic extraction as a tool to identify chemicals with high bioconcentration potential: An illustration by two fragrances in sewage treatment plant effluents and surface waters. Environ Sci Technol 33 (5): 801-806.

Equilibrium or not? Biomagnification of HCB



Thermodynamic equilibrium

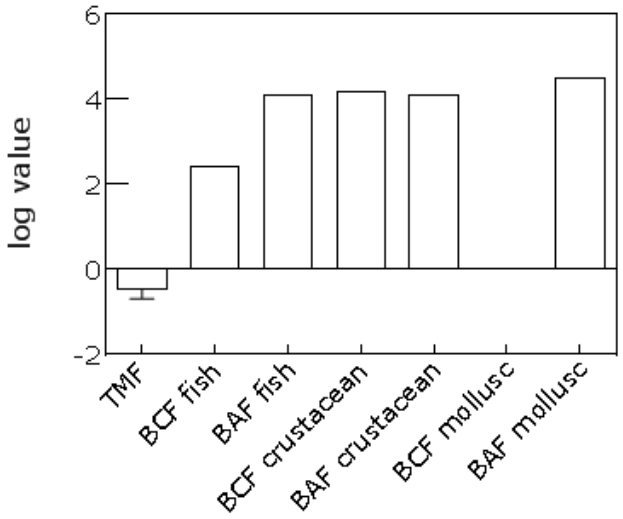
Difference between BAF at trophic level 4 and BCF = TMF^3

TMF^2

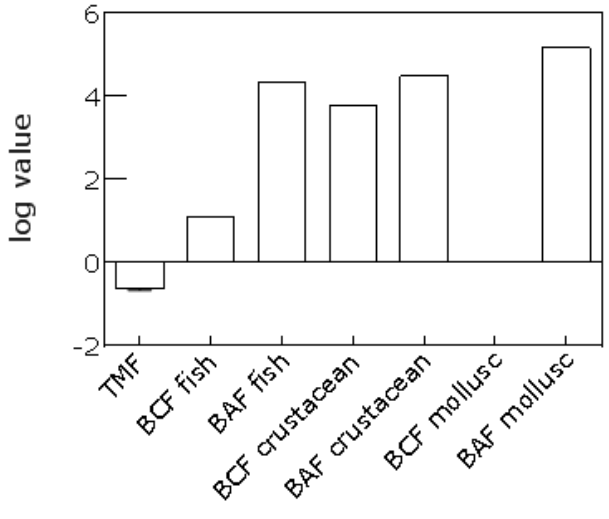
TMF

CTA Moermond & EMJ Verbruggen. 2013. Integrated Environmental Assessment and Management Volume 9, Issue 1, pages 87–97.

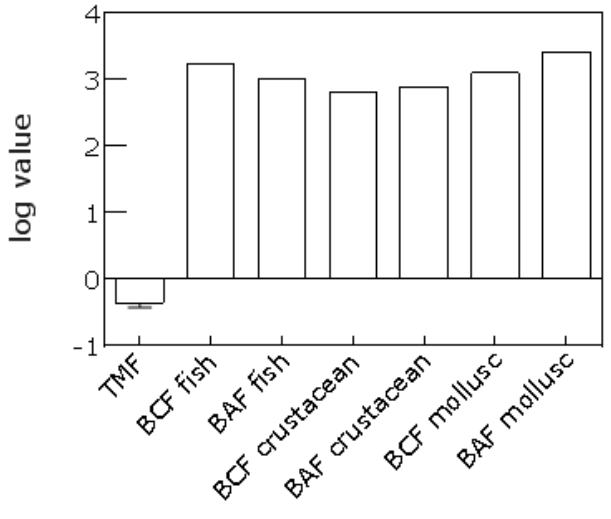
Equilibrium or not? Metabolism of PAHs



Benz[*a*]anthracene



Chrysene



Phenanthrene

Passive samplers and biota

- Biota and passive samplers are not connected but both exposed to water phase
- Use passive samplers to reliably determine freely dissolved concentrations
- Derive water based quality standards based on freely dissolved concentration
  - Make use of
    - Bioaccumulation factors
    - Bioconcentrations factors
    - Biomagnification factors, including trophic magnification factors

4. Conclusions

Conclusions

- Biota standards for human fish consumption are rather stringent
- Biota standards for secondary poisoning are realistic
  - directly linked to the ecosystem
  - low assessment factors

- Biota concentrations are highly variable and therefore less useful for quality standard setting
- Water concentration are difficult to measure, especially freely dissolved concentrations instead of total concentrations
- Passive samplers might be more sensitive but are only an approximation of accumulation in biota
- Passive samples used to measure freely dissolved concentrations correspond with BAFs and BCFs used in the EQS derivation