ETH zürich

Evaluation of the Environmental Impacts of Bioaccumulating Chemicals

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An Eco-factor for POPs

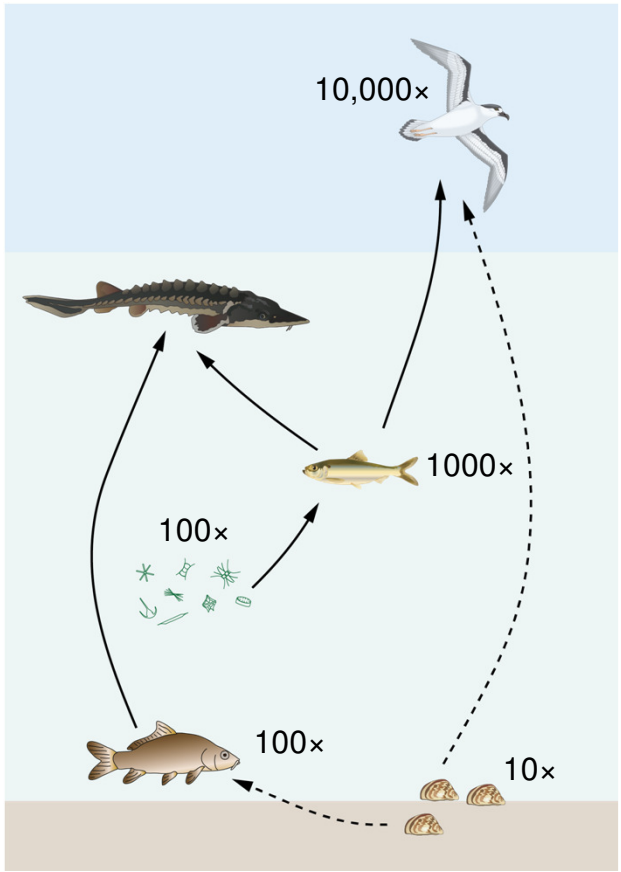
- As a first step towards incorporating persistent organic pollutants into the Ecological Scarcity method, we developed a new Eco-factor for bioaccumulating chemicals.

- Two main pieces of work:

  - Development of the Eco-factor.

  - Compilation of emissions estimates for Switzerland and application of method to 225 chemicals.

Why Bioaccumulation?



- Bioaccumulation can increase chemical concentration in organisms far above environmental levels.
- Bioconcentration Factor (BCF) is a standard hazard metric:

$$BCF = \frac{C_{\text{organism}}}{C_{\text{water}}}$$

- Robust, linked to physicochemical properties.
- Regulatory relevance (e.g. REACH):
  - PBT and vPvB (2000 and 5000)

link to T

Fits Eco-factor format: evaluate ecological relevance according to policy targets.

Incorporating the BCF

- We utilize the Impact-oriented Eco-factor:

$$\text{Eco-factor} = K \cdot \frac{1EP}{F} \cdot \left(\frac{F}{F_k} \right)^2 \cdot c$$

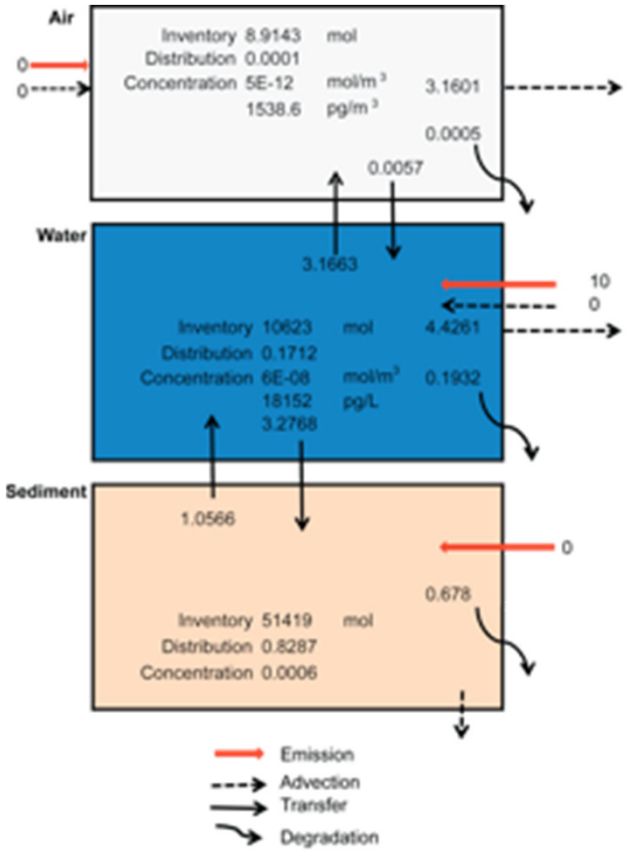
- Characterization factor captures the harm from a specific environmental impact (e.g. global warming).
  - Often relative to reference substance (e.g. CO_2 and the GWP).
- Critical flows describe the maximum permissible level in context of policy goals.

Incorporating the BCF

- How to define K and F_K for bioaccumulating chemicals?
- K:
  - What should be used as a reference substance?

- F_k:
  - No specific BCF policy in Switzerland, how to describe environmental impact?
  - Can baseline toxicity provide a pathway?
  - What do B-based regulations imply?

A toxicity-based approach to F_k?



$$PNEC_{water} = \frac{2 \times 10^{-4}}{K_{OW}}$$

- Back-calculating critical flows based on baseline toxicity:
  - Make a model of Swiss environment.
  - Emit chemical to water compartment.
  - Determine amount needed to reach PNEC.
- Nice idea, but problematic to implement.
  - "Double counts" BCF.
  - More suited to impact methods.
  - Fate modeling complications (see e.g. Schulze et al. 2001).

"Regulatory" BCF Eco-Factor

- What is the alternative using policy targets?
- Swiss law:
  - Swiss Chemical Ordinance on Risk Reduction (ORRChem) – prohibits specific chemicals.
- REACH:
  - Classifies a chemical as 'B' if BCF>2000, 'vB' if BCF>5000

- Set critical flows of banned chemicals to zero.
- Set critical flows of B chemicals to zero.

Features of the BCF Eco-factor

$$\text{BCF-Eco-factor}_i = \frac{BCF_i}{BCF_{ref}} \cdot \frac{1EP}{\sum_i \frac{BCF_i}{BCF_{ref}} \cdot F_i} \cdot \left(\frac{\sum_i BCF_i \cdot F_i}{\sum_i BCF_i \cdot F_{k,i}} \right)^2 \cdot c$$

- Characterization: BCF
- Normalization: current flow of bioaccumulative substances.
- Weighting: current flows relative to critical flows.

- Normalization flow is key.

BCF Eco-factor in analogy to GWP

Global warming	Bioaccumulation
Chemicals Included	
CO_2, CH_4, N_2O, SF_6, fluorinated hydrocarbons	Plastic additives, PCBs, PFCs, PBDEs, PFASs, PAHs, HFCs
Characterization Factor	
GWP	BCF
Reference Substance	
CO_2 (GWP=1)	2,4,6-tribromophenol (log BCF_{ref}=2.39)
Normalization	
Overall flow greenhouse gases.	Overall flow bioaccumulating chemicals.
Weighting	
Based on Kyoto Protocol and CO_2 Act targets.	Based on ORRChem and REACH.
Emissions to air	Emissions to water

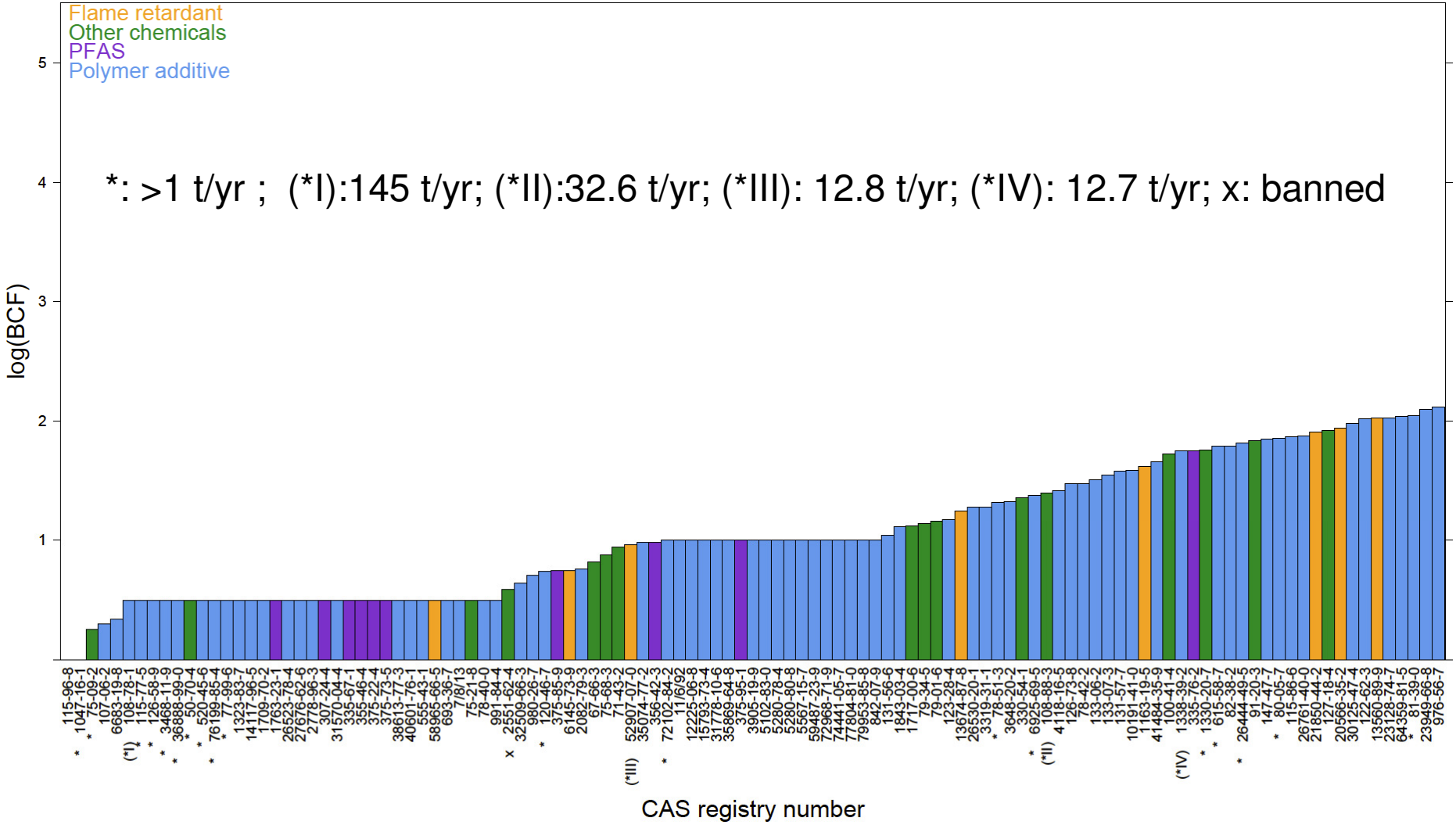
Application to Chemicals in Swiss Water

- 'Direct' emissions to Swiss waters found for 17 chemicals (30 databases searched).

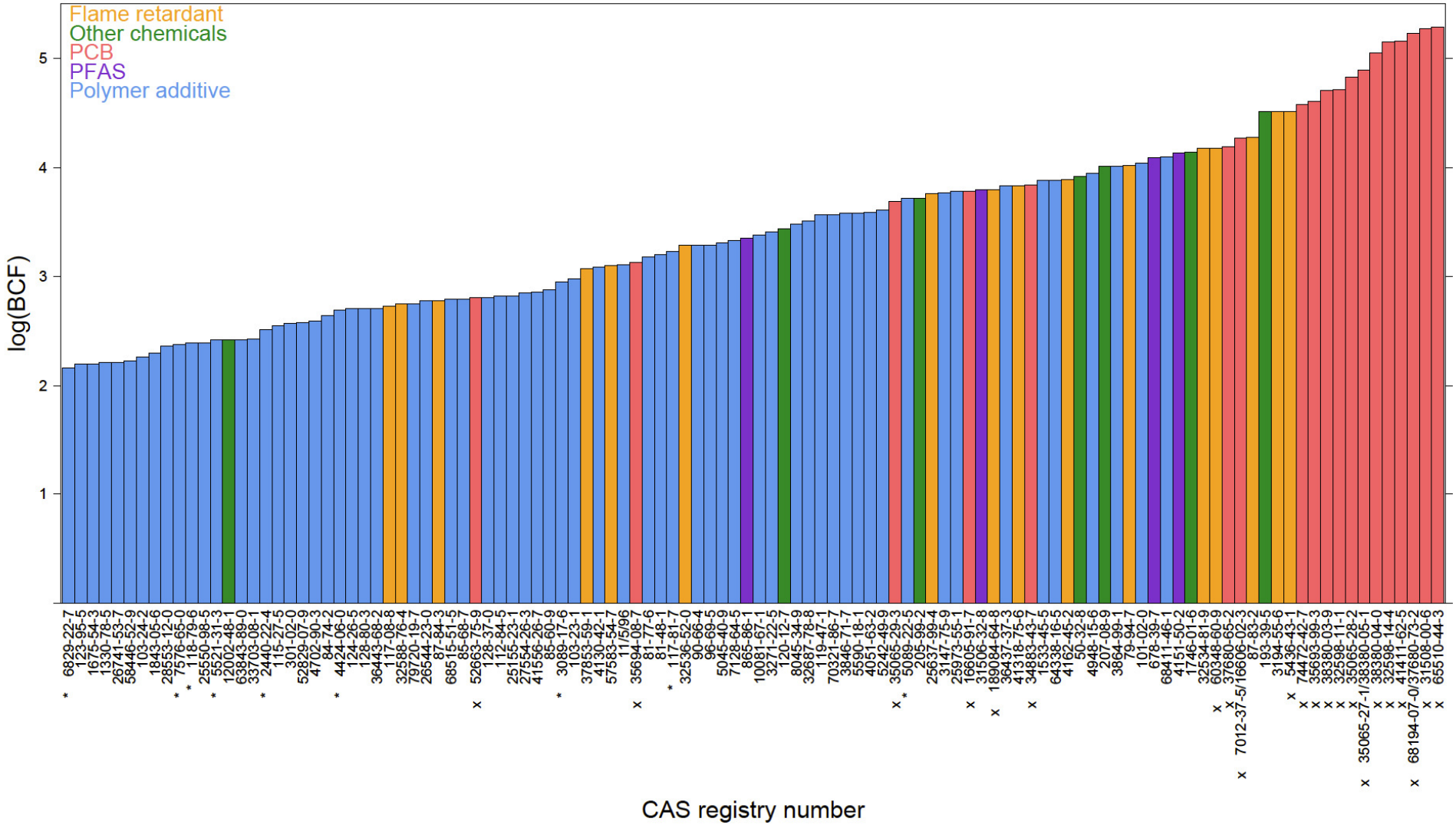
- Emissions estimates for a group of BFRs, PCBs, and PFASs to Zurich air and/or water available from the literature.
- Emissions estimates for Germany and Sweden for plastic additives.
- Conversion: by population and from air to water.

- Summary: 225 substances with log BCF from <1 to >5.

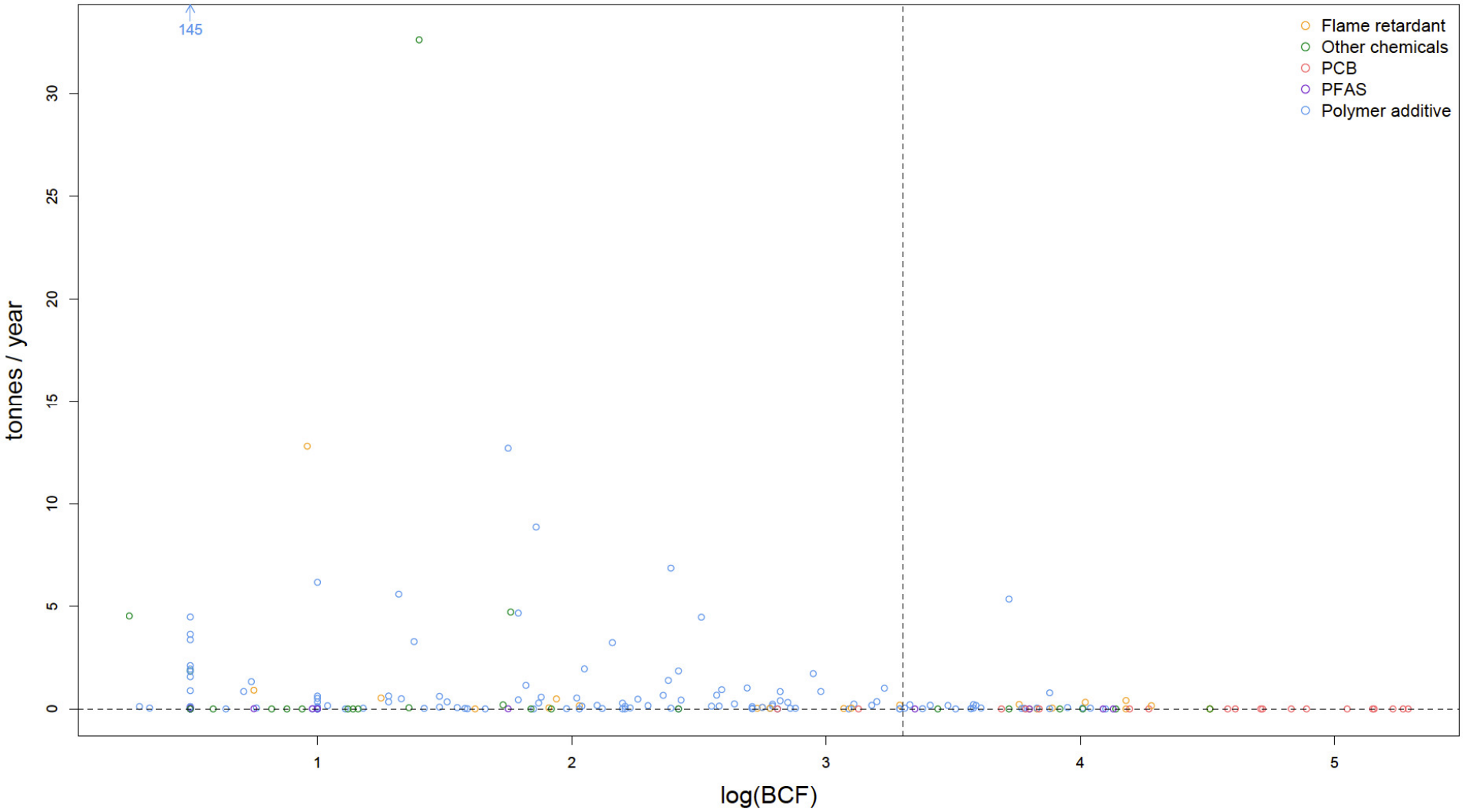
Results: BCF (low)



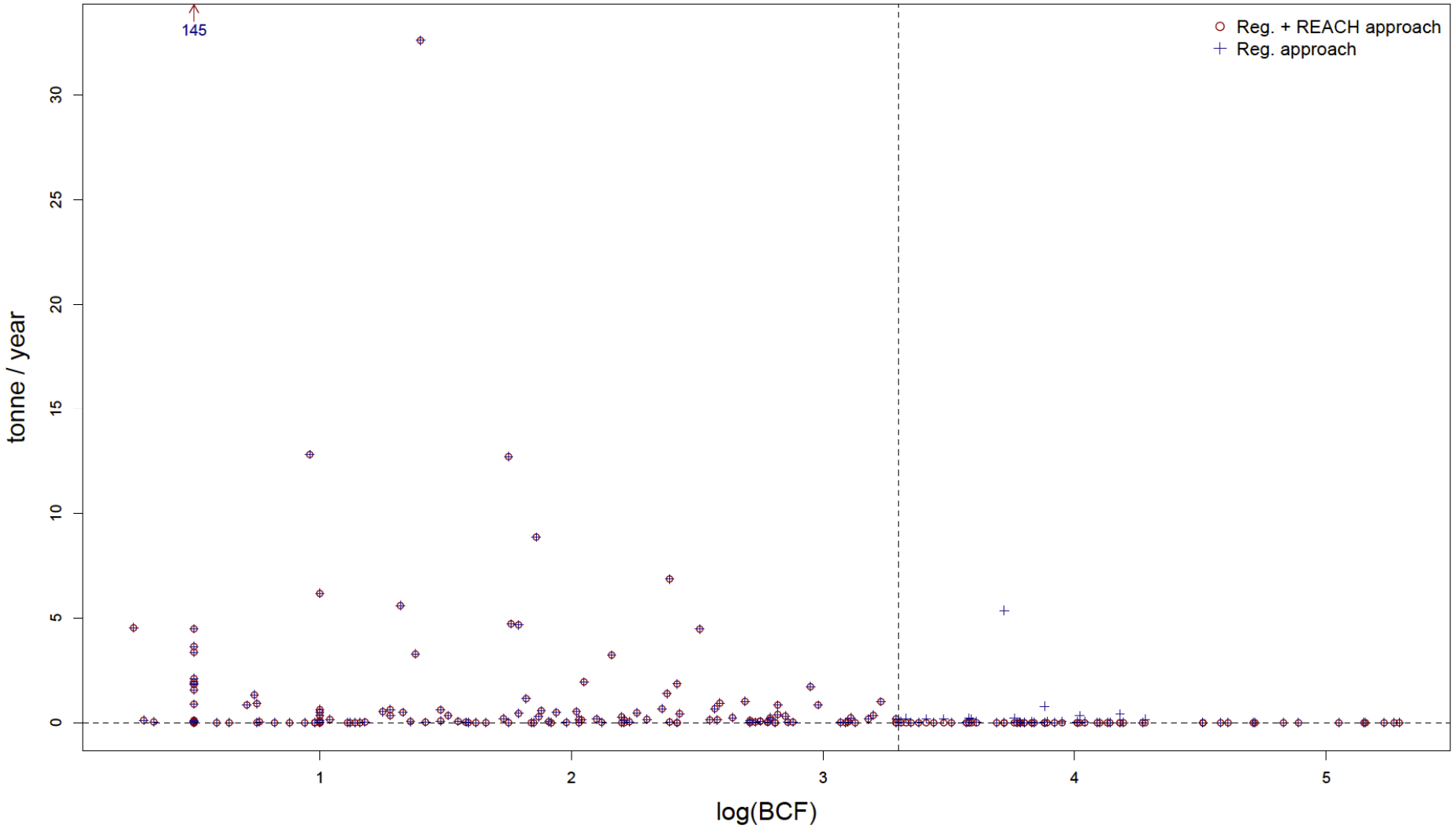
Results: BCF (high)



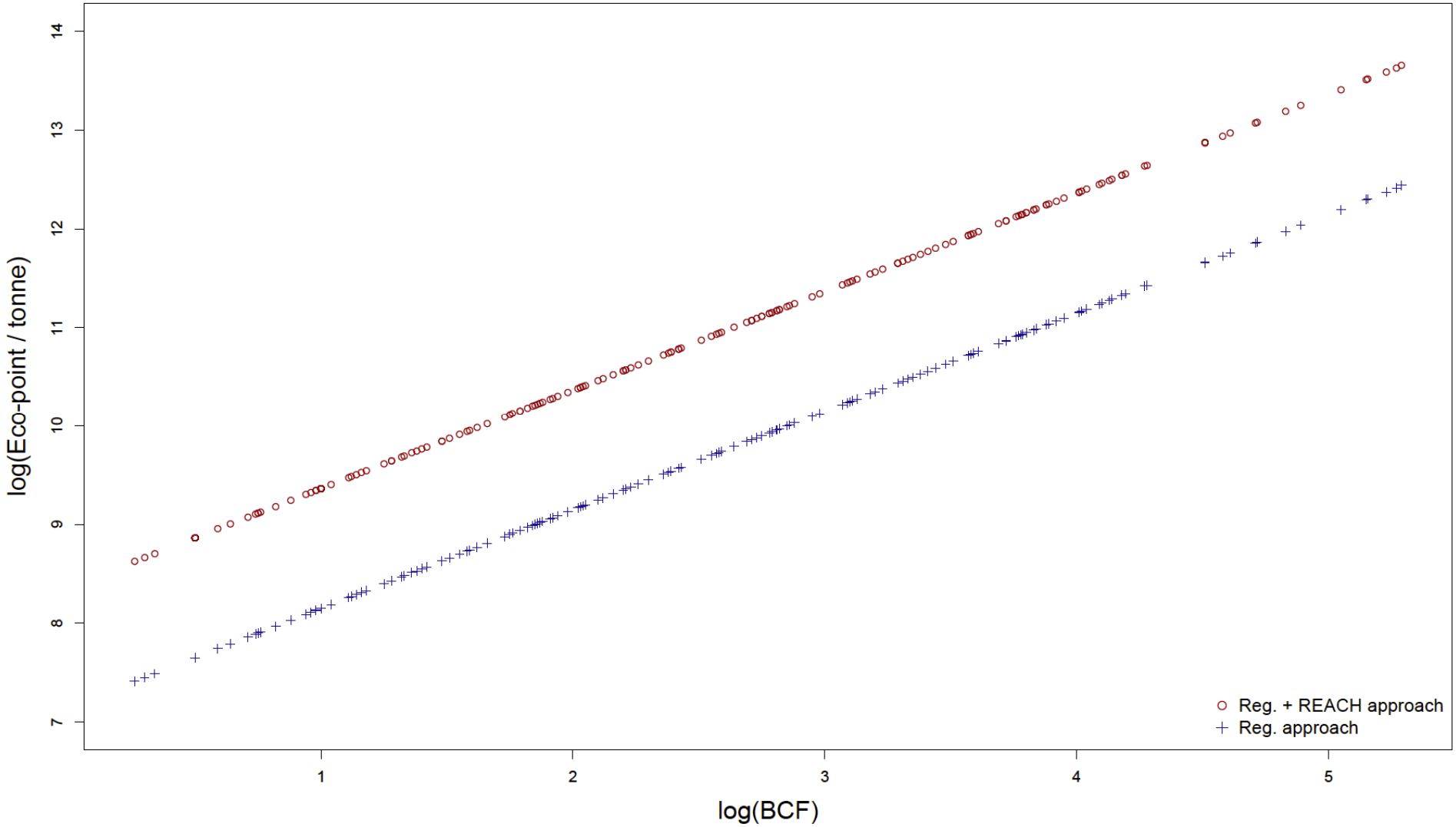
Results: Current Flows



Results: Critical Flows



Results: BCF Eco-factors



Summary and Implications

- The BCF-based Eco-factor described the relative flow of bioaccumulative chemicals in the Swiss environment.
- Robustness needs comprehensive normalization flow.
- A stringent setting of critical flows was explored.
- 39 chemicals were identified which would be ‘B’ under REACH but were not included in ORRChem.
- Can be directly compared to other impact-oriented methods (e.g. global warming).

Open questions

- What is the 'right' policy target for BCF (and how much does it matter?)
- How can we cover other environments (air, soil)?
- Is there a need for separate impact categories for different hazard dimensions? (P, B, T)
- Should legacy emissions be included? What is 'fair' accounting for normalization flows?

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- Questions?
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