Modelling Pb and Cd bioaccumulation in *Gammarus pulex*: Application to realistic environmental conditions and consideration of water chemistry

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INTRODUCTION

Since lead (Pb) and cadmium (Cd) are both non-biodegradable and non–essential, they represent a serious threat for aquatic ecosystems. Metal determination in aquatic organisms such as gammarids offers encouraging perspective to monitor water quality. Indeed, bioaccumulation is considered as directly linked to active and bioavailable metals in water, fraction expected to be toxic for biota. However, metal uptake in organisms may be influenced by water cationic composition because of competition processes on biological binding sites. The development of bioaccumulation models constitute promising tools to quantify metal bioavailability and predict metal impact on aquatic ecosystems. In order to arise such models, it is necessary to formalize the abilities of organisms to regulate metals and water chemistry effects in controlled conditions. However, what is the environmental relevance of experimentally derived models to predict bioaccumulation in field conditions?

OBJECTIVES

1. Determine kinetic constants to describe Pb and Cd bioaccumulation in *G. pulex* under controlled conditions.

2. Assess the influence of calcium on Pb and Cd uptake under controlled conditions.

3. Assess the suitability of experimentally derived models to describe bioaccumulation under environmental conditions.

RESULTS & DISCUSSION

1. Bioaccumulation model

- *G. pulex* significantly accumulated Pb and Cd over time (see example of Pb, ***Fig.1***).
- Kinetics constants k_u and k_e required to describe bioaccumulation were successfully determined by fitting model on uptake and elimination dataset.

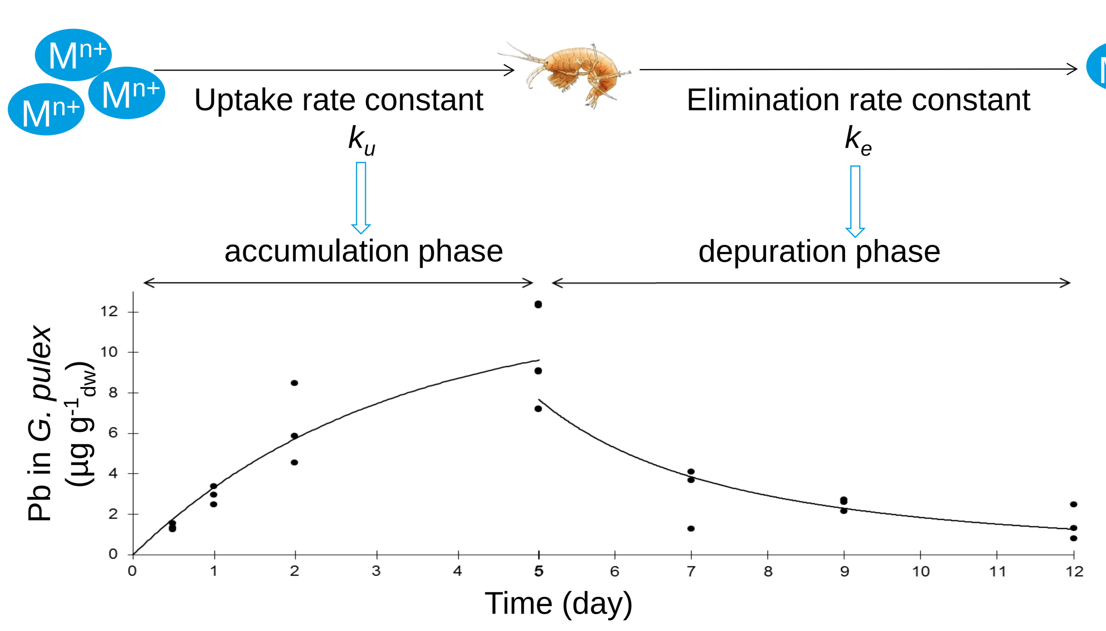
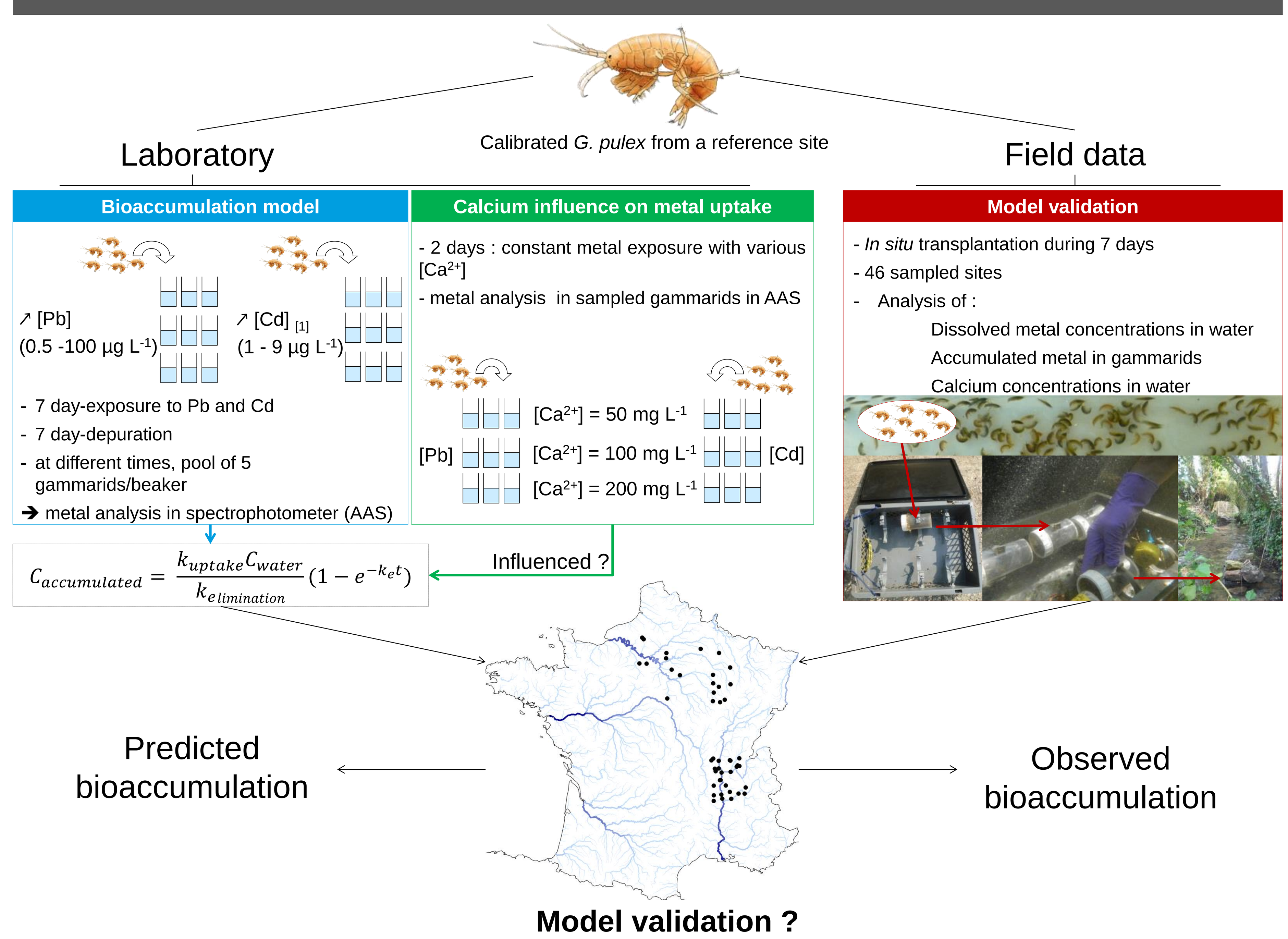


Fig. 1. Accumulation and elimination kinetics of Pb in G. pulex exposed to 5 µg L-1. Points represents a pool of 5 individuals.

Pb	Cd [1]	
0,78 ± 0,03	0,46 ± 0,02	k_u (L-1 g-1 d-1)
0,24 ± 0,08	0.032 ± 0,010	k_e (d-1)

Table 1. Experimentally derived kinetic constants of Pb and Cd in G. pulex (mean ± S.E).

EXPERIMENTAL DESIGN



2. Calcium influence on metal uptake

- For both Pb and Cd, k_u decreased with increasing [Ca^{2+}]
- k_u expressed as a function of [Ca2+] in media :

$$k_u' = \frac{k_u}{1 + \frac{[Ca^{2+}]}{K_{iCa^{2+}}}}$$

$K_{iCa^{2+}}$, the affinity constant of calcium for its ligands determined by fitting a competition model on k_u dataset obtained by varying calcium concentrations in waters. (see example of Pb, *Fig. 2*)

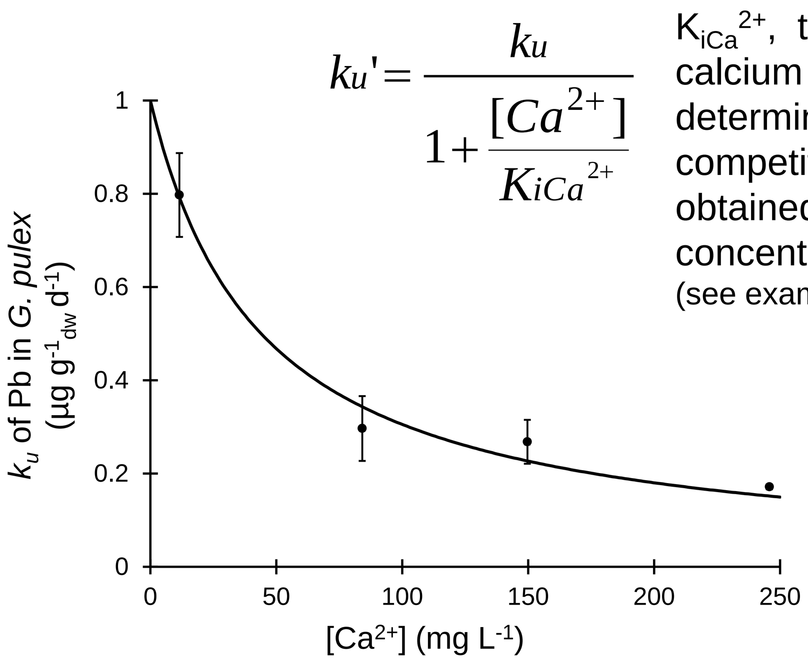


Fig. 2. Effects of calcium on Pb uptake rate constant in G. pulex exposed to 10 µgPb L-1. Points are means of triplicates of 5 individuals.

K_{iCa}^{2+} (L g-1)	Pb	Cd [1]
	44.0 ± 10.3	66.4 ± 21.1

Table 2. Experimentally derived affinity constants of Pb and Cd in G. pulex (mean ± S.E).

3. Model validation

46 sampled sites:

- Contrasted [Ca^{2+}] 4 to 200 mg L-1
- Few sites where bioaccumulation goes over the threshold value = bioavailable contamination in gammarids, above which measured concentrations are expected to reveal a contamination at the sampling site [2].

7 retained sites for Pb
8 retained sites for Cd

For both Pb and Cd :

- Good agreement between predictions and observations
- Using the calcium-dependent model leads to a tightening of the plots around the theoretical fit

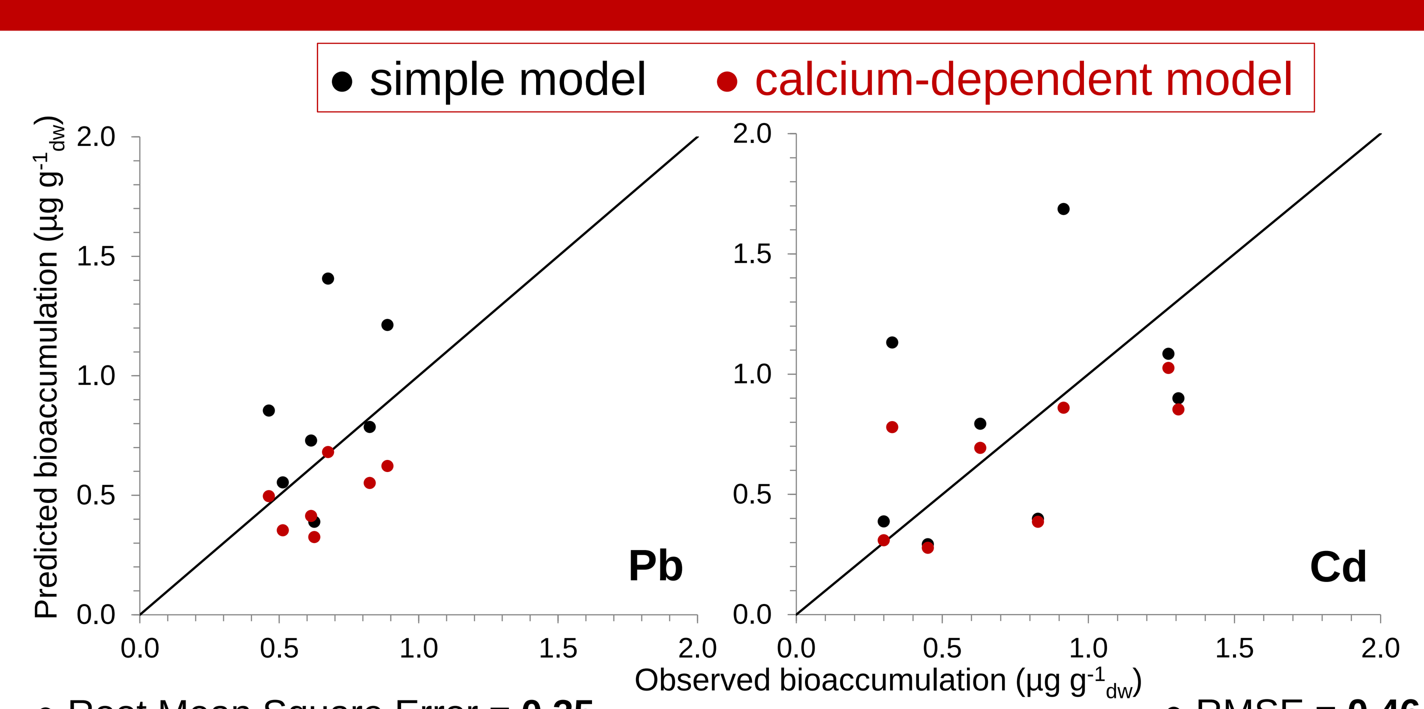


Fig. 3. Observed versus predicted bioaccumulation with a model using k_u (black points) and k_u' (red points) integrating the effect of calcium. The solid line represents a theoretical model fit (1:1) (points are mean values of triplicates of 5 individuals).

The consideration of [Ca^{2+}] increased model predictions of :
40 % for Pb
35 % for Cd

REFERENCES

[1] Pellet B, Geffard O, Lacour C, Kermoal T, Gourlay-Francé C, Tusseau-Vuillemin M-H. 2009. A model predicting waterborne cadmium bioaccumulation in Gammarus pulex: the effects of dissolved organic ligands, calcium, and temperature. Environ Toxicol Chem 28:2434–2442

[2] Besse, J.-P., Coquery, M., Lopes, C., Chaumot, A., Budzinski, H., Labadie, P., Geffard, O. 2013. Caged Gammarus fossarum (Crustacea) as a robust tool for the characterization of bioavailable contamination levels in continental waters: Towards the determination of threshold values. Water Res. 47, 650–660

CONCLUSION

This study confirms the environmental relevance of using experimentally derived bioaccumulation model to monitor metal bioavailability in freshwaters and the importance of considering water chemistry in interpretation of field dataset. Nevertheless, the sampling of a larger number of sites with contrasted contamination could be opportune to emphasise our results in order to improve the robustness of predictions. In that sense, further studies with a very high *n* are suggested to increase the power of observed data.

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