

Coupling geochemical and biological approaches to assess the availability of cadmium in a natural sediment

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Introduction

Context : Sediment

- Significant storage and releasing capacities of various contaminants
- Shelter numerous invertebrate species : important for the assesement of ecological integrity of aquatic ecosystems
- DIESE (french project) develops a toolbox for the hazard assessment of sediment

Aim :

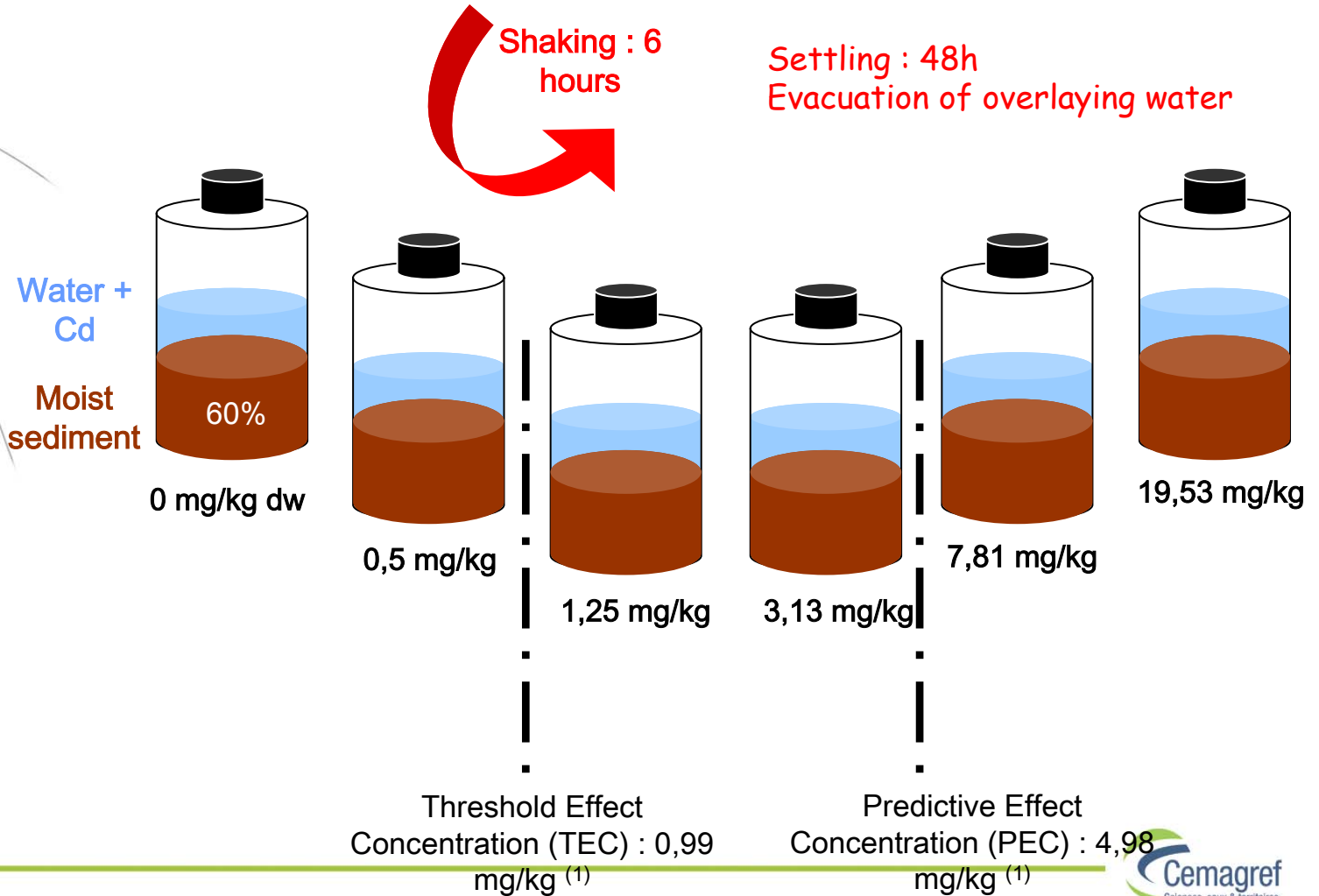
- To develop and assess the complementarity of the different tools for the evaluation of sediment toxicity : one exemple proposed here

Proceed :

- Coupling geochemical and biological approaches :
Exposition of Diffusive Gradient in Thin films (DGT) and 3 macroinvertebrates species simultaneously to a natural low contaminated sediment spiked with Cd

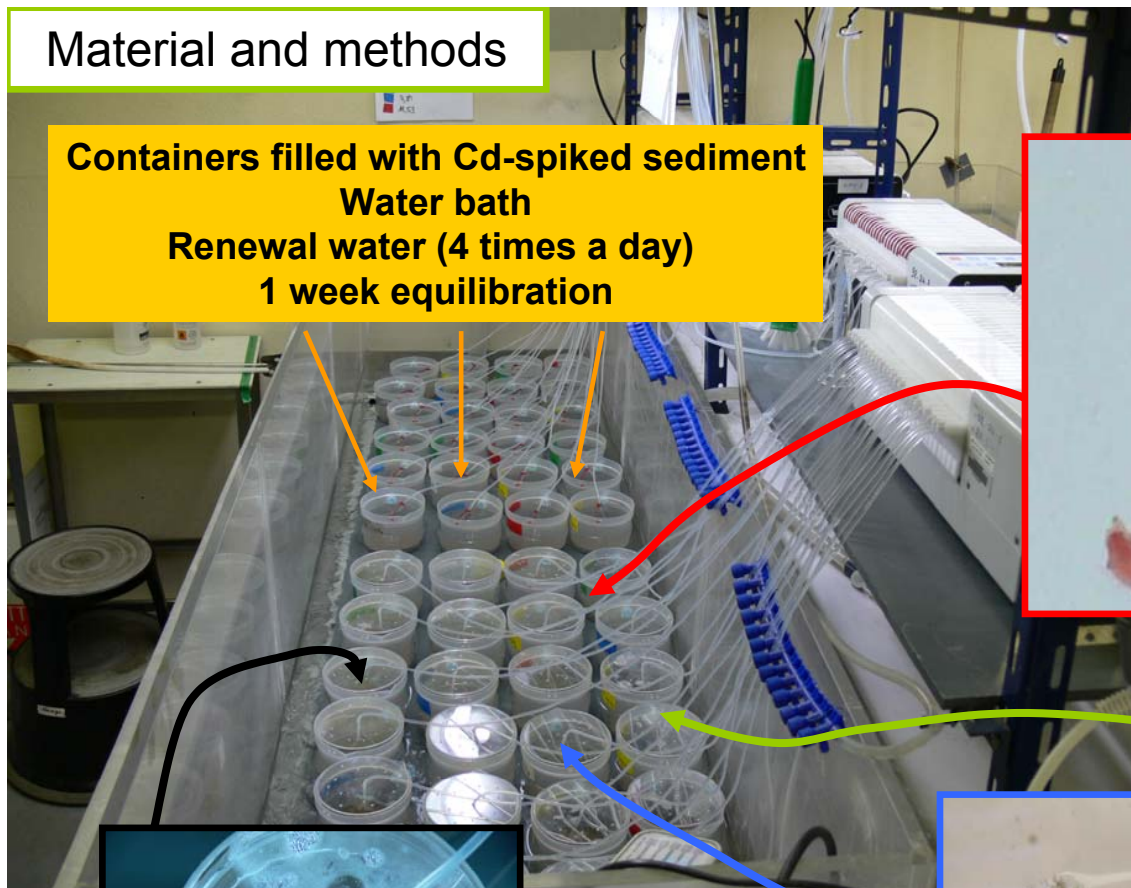
Material and methods

Natural sediment spiking with cadmium :



Material and methods

Containers filled with Cd-spiked sediment
Water bath
Renewal water (4 times a day)
1 week equilibration



Chironomus riparius



Potamopyrgus antipodarum



Gammarus fossarum



Passive sampler : DGT

3 benthic organisms

Material and methods

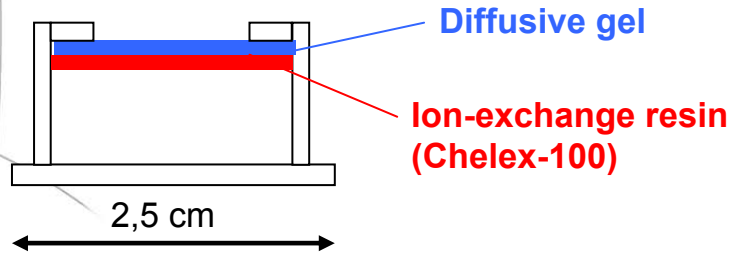
Geochemical approach :

- Kinetic of Cd accumulation in the DGT (2H to 6 days) : measurement of labile dissolved Cd concentration and evaluation of the sediment capacity to release Cd from particles to pore water
- Extraction of pore water : measurement of total dissolved Cd concentration
- Sequential extractions of the particulate phase : to determine metal carrier phases

Biological approach :

- Battery of organisms phylogenetically different, characterised by specific physiological and ecological traits (reproduction ; habitat ; growth ; nutrition...).
- Measurement of Cd bioaccumulation in 3 macroinvertebrate species : to estimate Cd bioavailability (7 days exposure)
- Measurement of Cd effects on life history traits related to population dynamics (e.g. reproduction or growth)

Material and methods

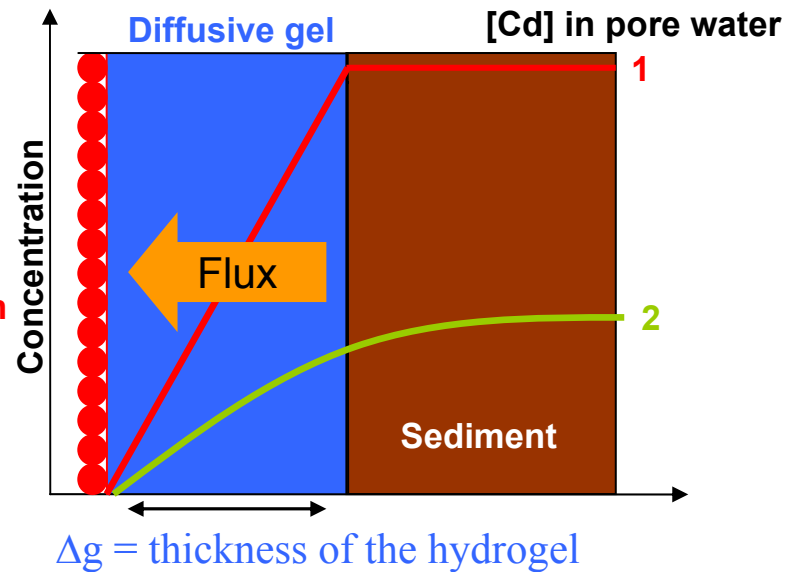


$$\text{Flux of Cd} = D \frac{dC}{\Delta g}$$

C_{DGT} = dissolved labile Cd concentration in pore water

The importance of the dissolved Cd concentration decrease in pore water is given by the R ratio :

$$R = C_{DGT} / C_{\text{pore water}}$$

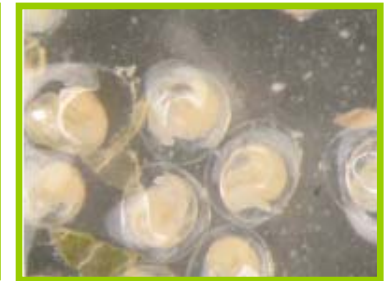


1 : particulate contribution
2 : no contribution from the particulate phase

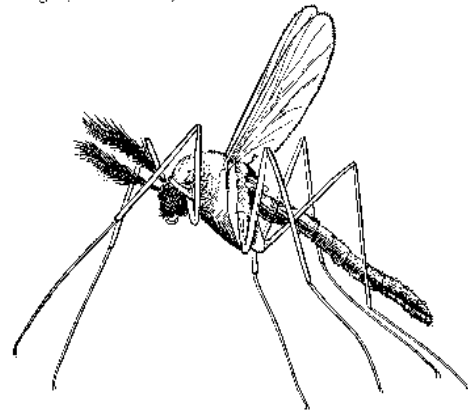
Material and methods

P. antipodarum

Growth – 6 weeks
Reproduction – 4 and 6 weeks
Survival



Chironomus midge (Packard #278)

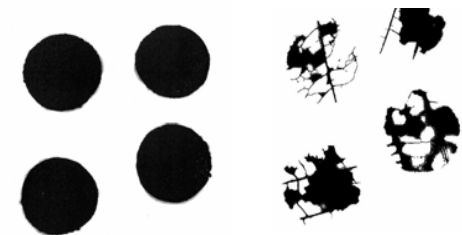


C. riparius

Emergence – 28 days
Growth – 7 days
Survival

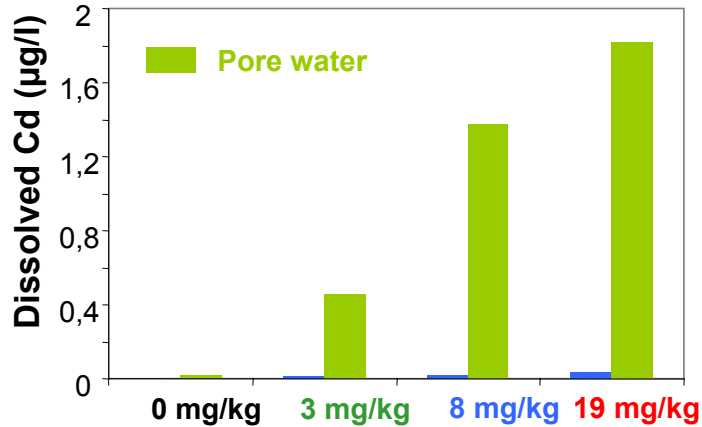
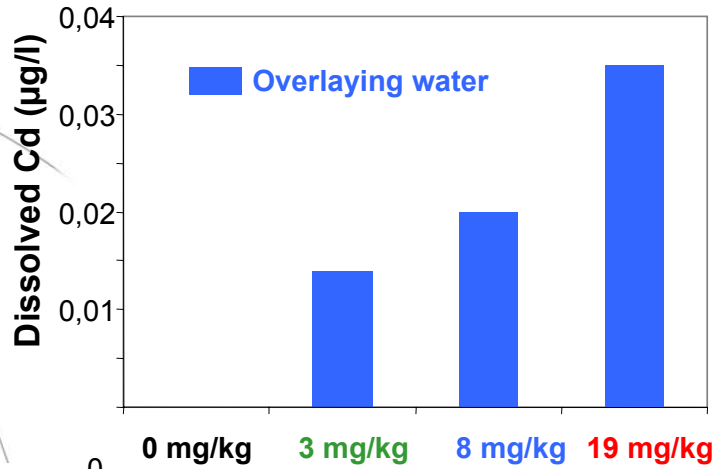
G. fossarum

Feeding rate – 1 week
Growth – 3 weeks
Reproduction – 3 weeks
Survival



Results

Efficiency of Cd spiking : between 90 and 140% of nominal concentrations



Gradient of Cd pools

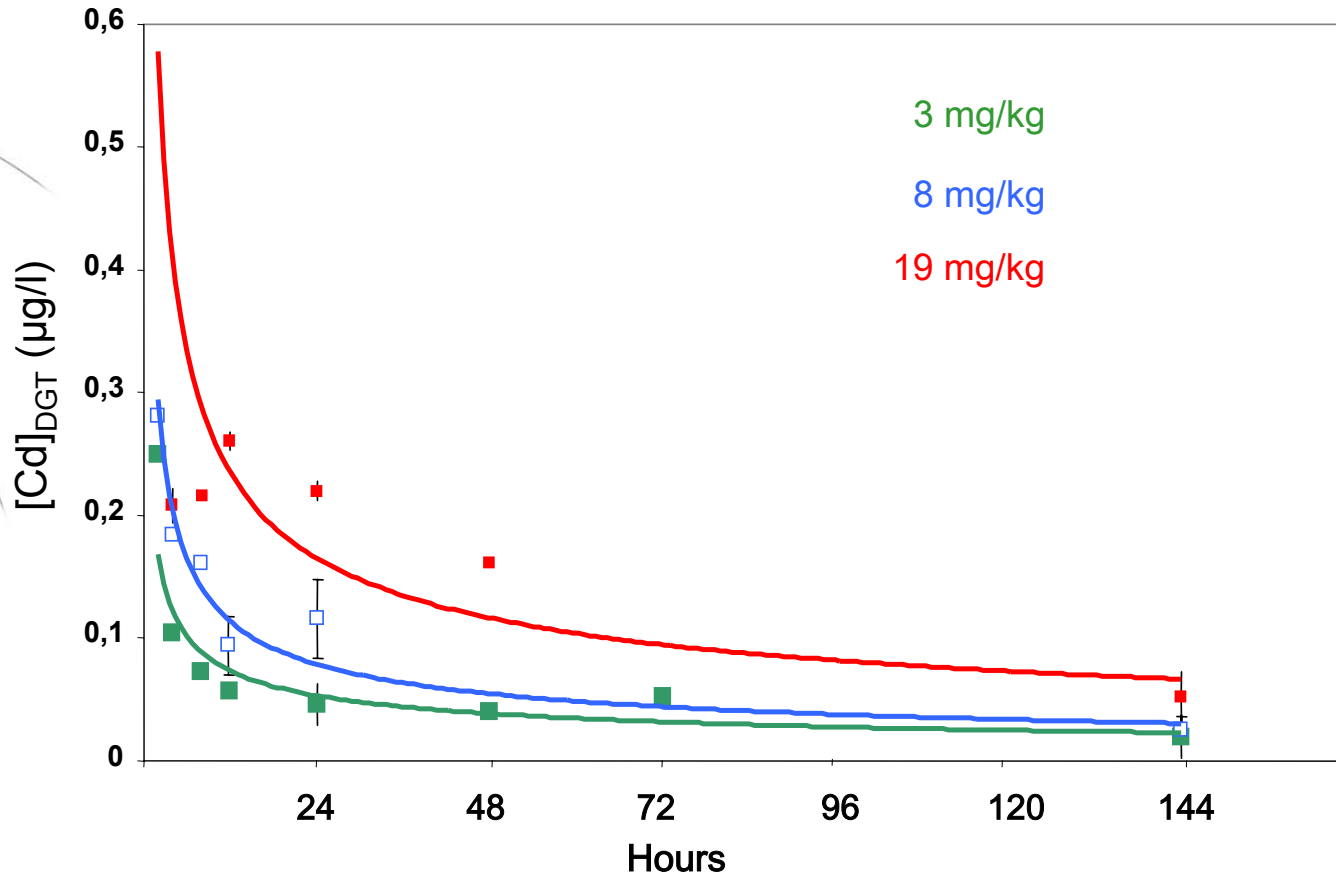
Particulate pool

Pore water

Overlaying water

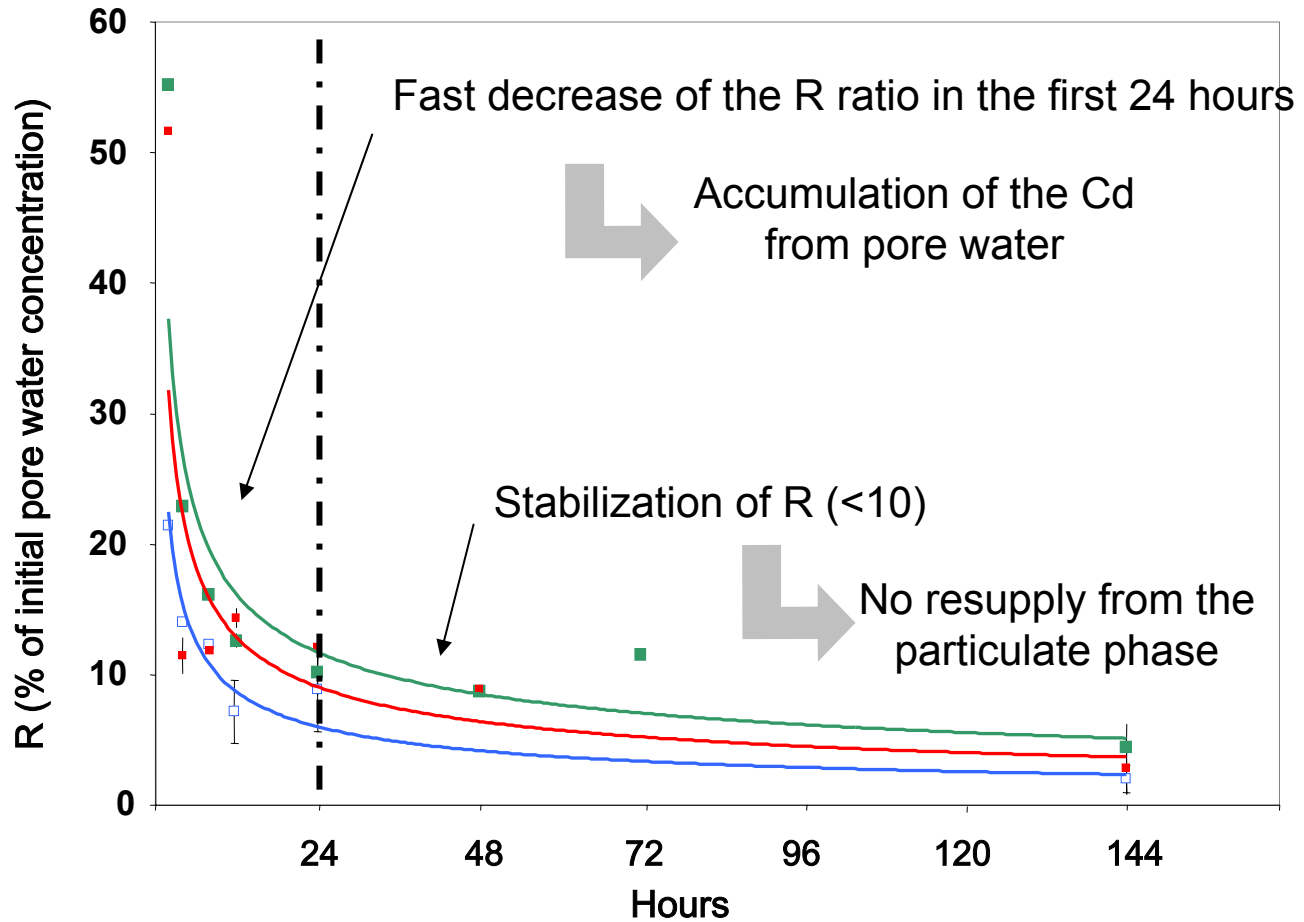
Results

Dissolved Cd concentration = C_{DGT}



Results

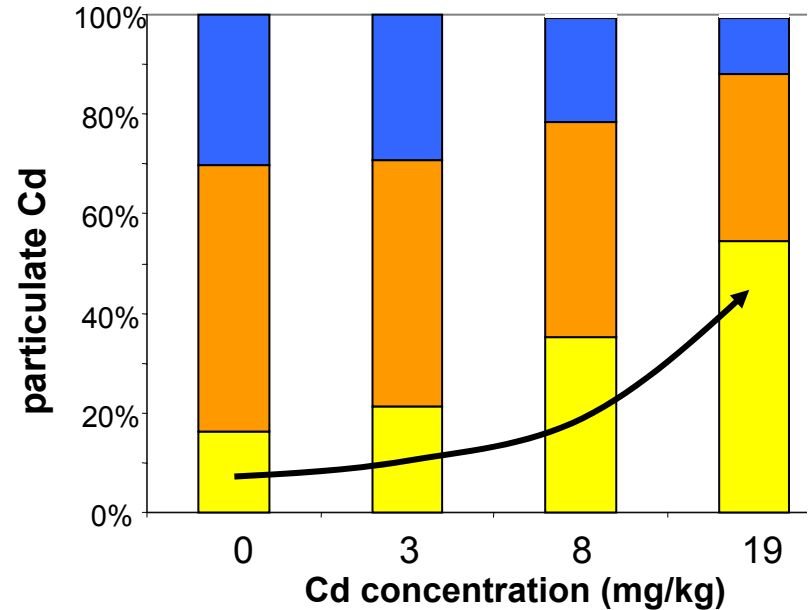
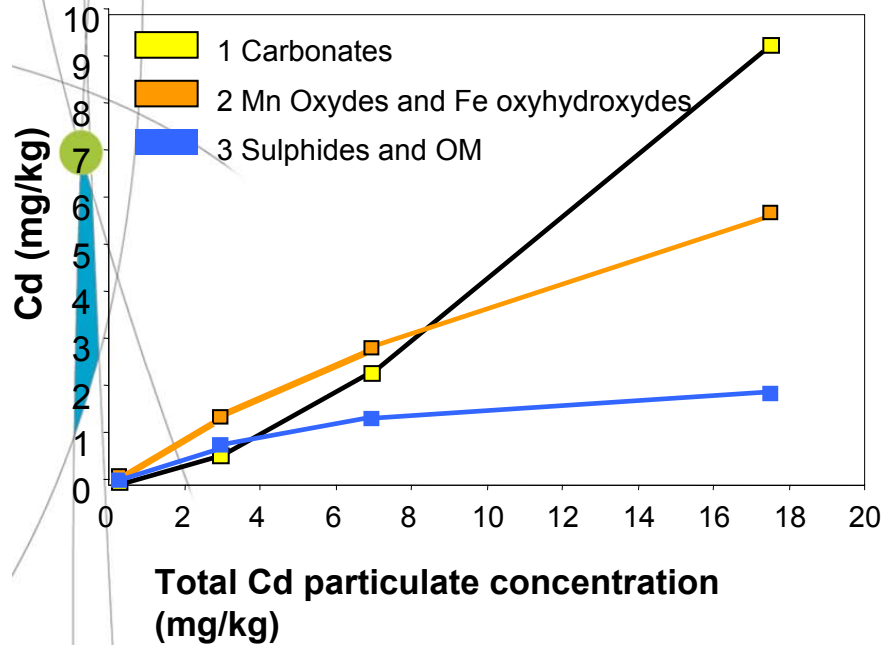
$$R = [\text{Cd}]_{\text{DGT}} / [\text{Cd}]_{\text{EI}}$$



Great similarity of the R ratio distribution for the 3 spiked level concentrations

Results

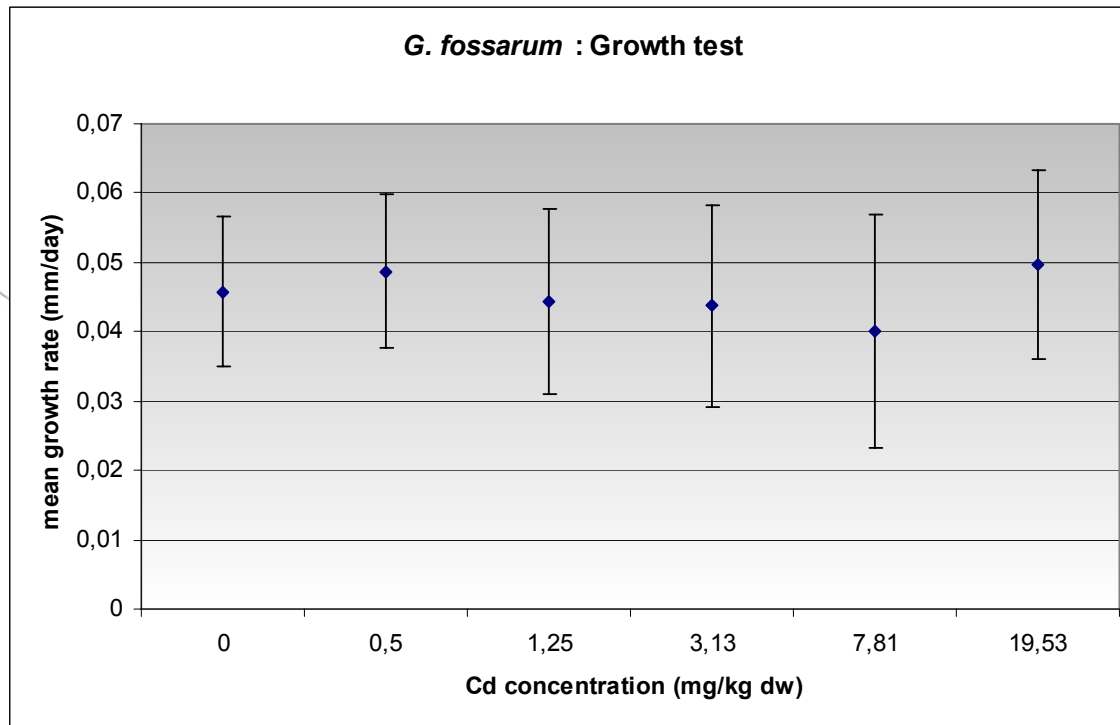
Sequential extractions : carrier phases ? What are their relative contributions?



Cd is preferentially fixed by carbonate phase
This is in relation with the high CaCO_3 content of the sediment (54%) which represents an unlimited pool of binding sites

Results

G. fossarum

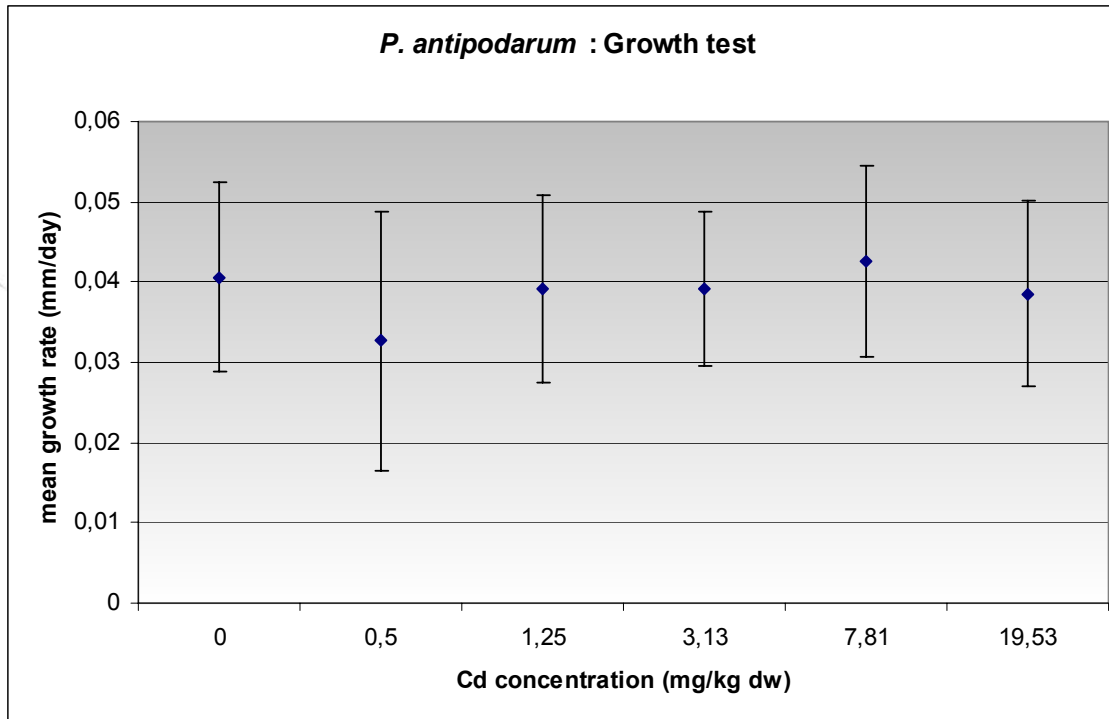


Statistics : no difference between [0] and higher concentrations

Reproduction and feeding rate : no differences

Results

P. antipodarum

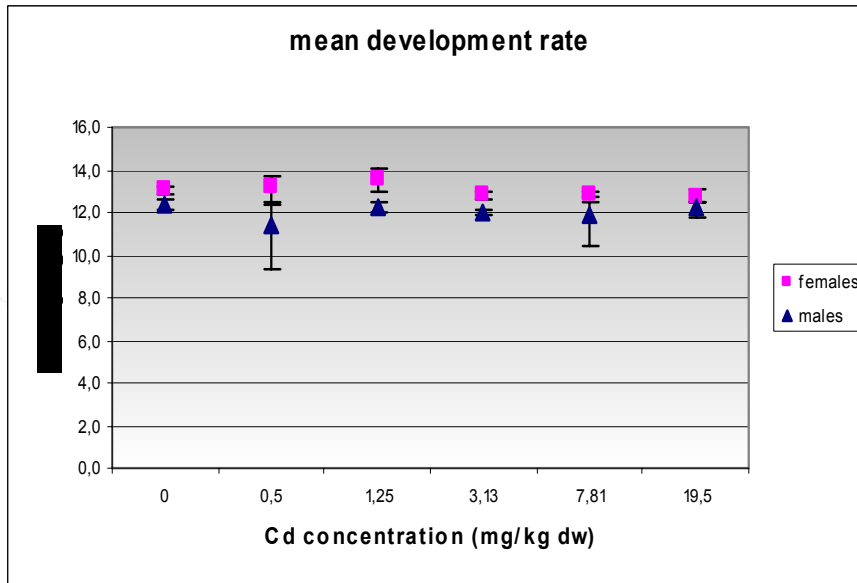


Statistics : no difference between [0] and higher concentrations

Reproduction : no differences

Results

C. riparius



Statistics : no difference between [0] and higher concentrations

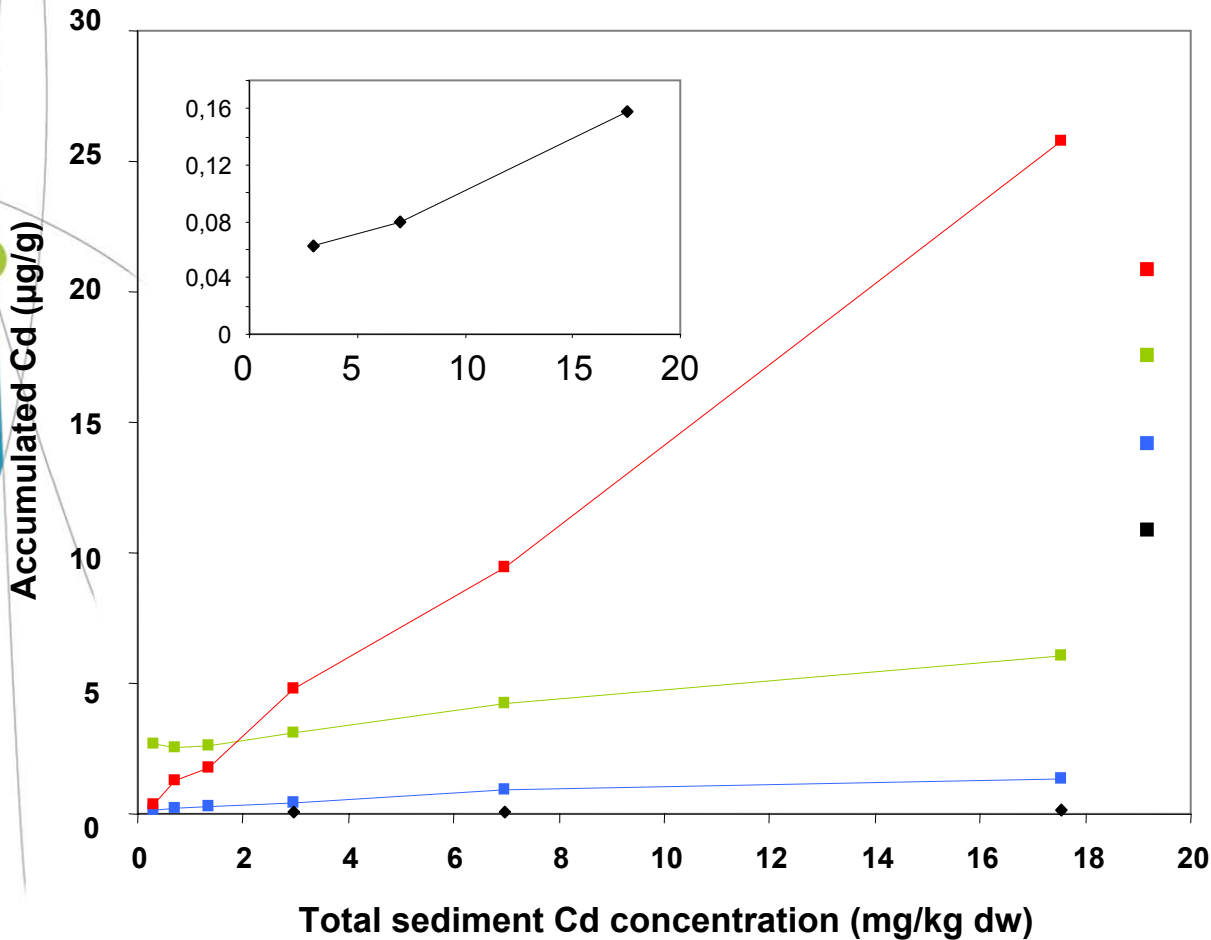
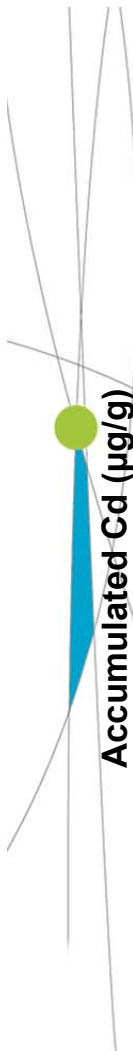
Sex ratio and growth : no differences

concentration en Cd (mg/kg dw)	emergence rate	écart type
0	0,90	0,10
0,5	0,73	0,25
1,25	1,00	0,35
3,13	0,87	0,12
7,81	0,77	0,25
19,53	0,47	0,21

χ^2 19.5 vs 0 mg/kg p=0.020

Results

Bioaccumulation



- C. riparius
- P. antipodarum
- G. fossarum
- DGT

Conclusions and perspectives

Informations provided by both methods are complementary

- DGT : Cd strongly bound to carbonate (confirmed by sequential extraction)
- biotests : only effect on emergence of Chironomids
- Bioaccumulation related to feeding habits and behaviour

What to do next?

- To make CaCO_3 varied
- To test sediments naturally rich in Cd
- Tangential Ultrafiltration (UFT)
- Organisms fractionation : measurement of cytosolic concentrations

To verify both methods complementarity with other conditions

To measure which dissolved fraction of Cd is trapped by the DGT (free ions or colloids)

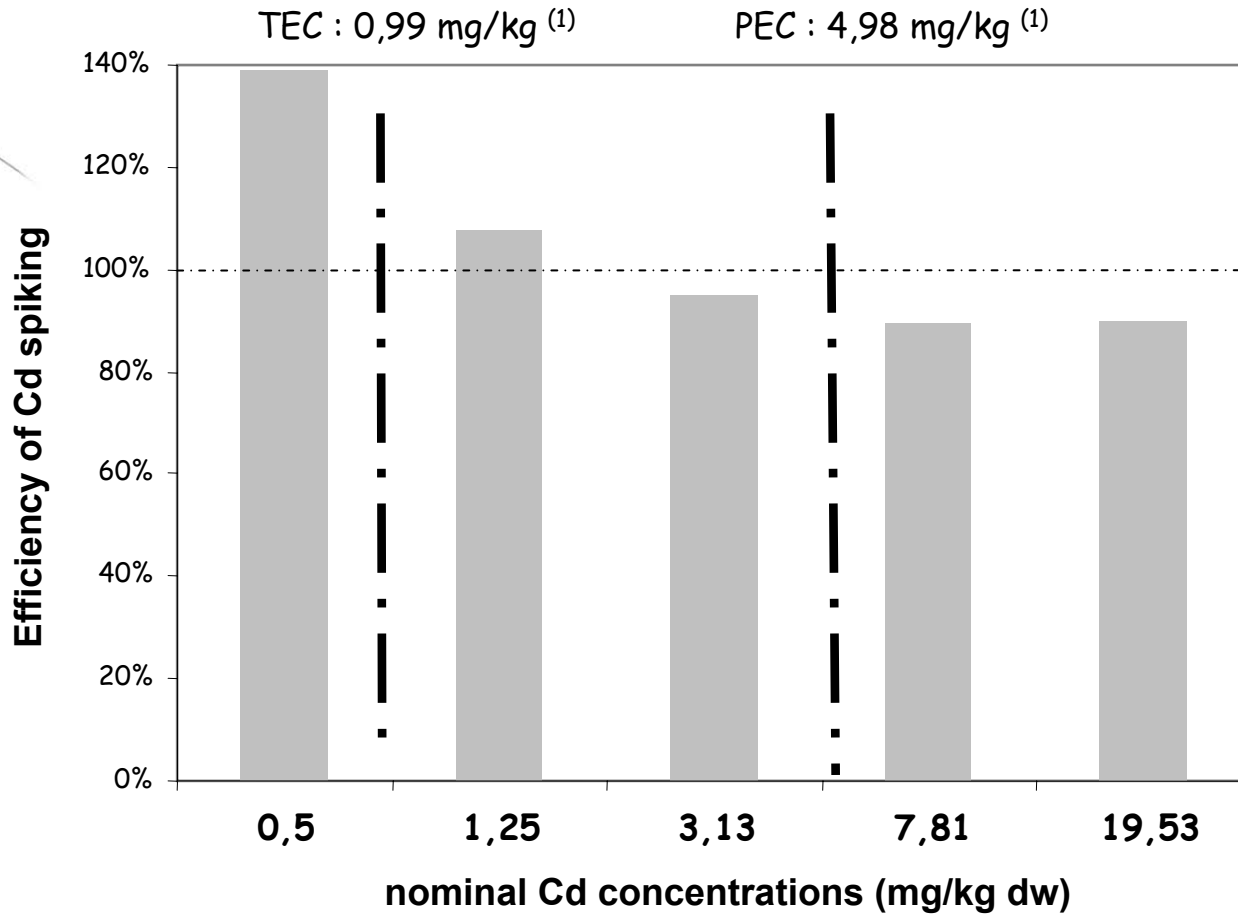
To estimate precisely the Cd toxicologically bioavailable



Thank you !

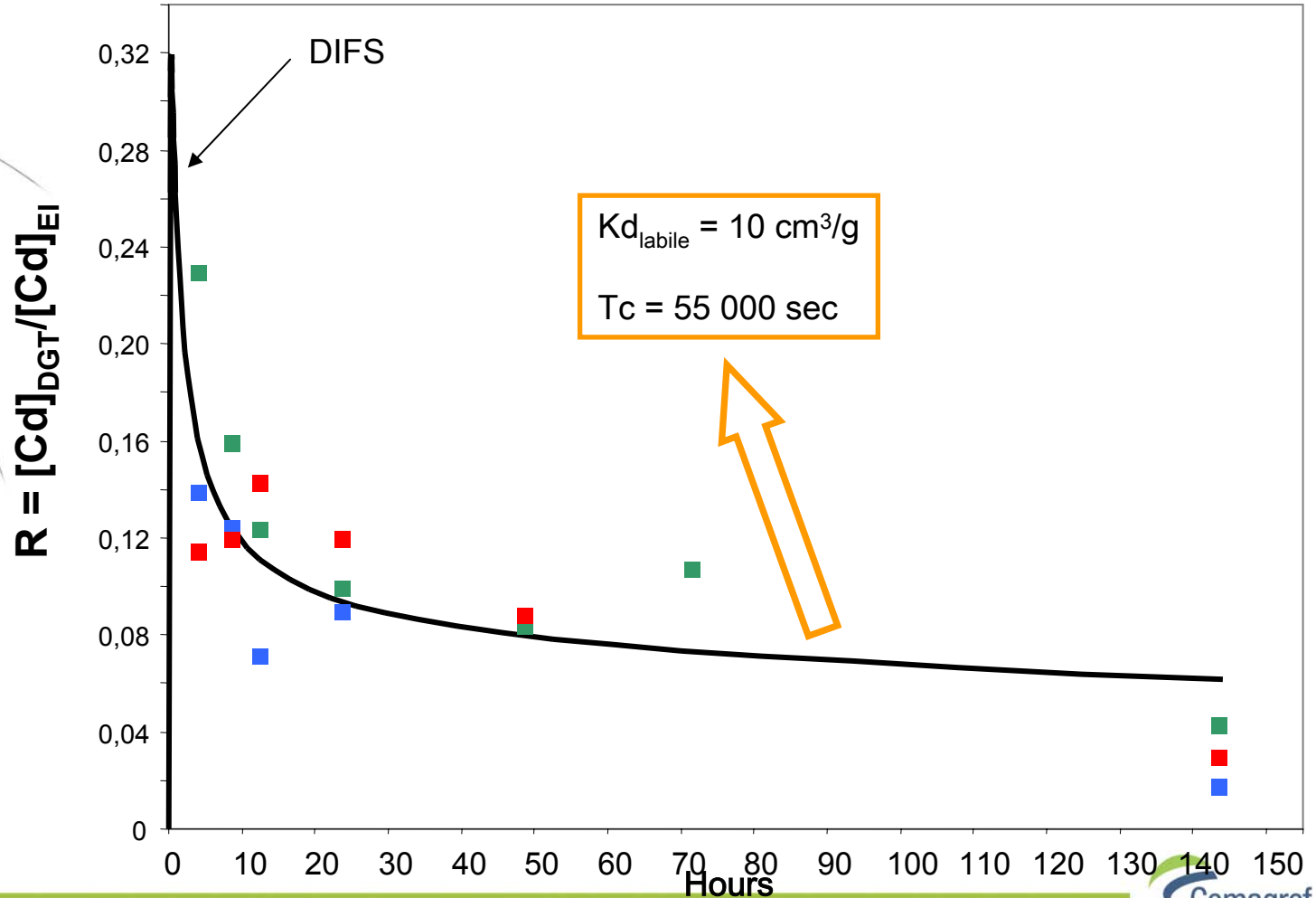
Complementary information

Efficiency of Cd spiking

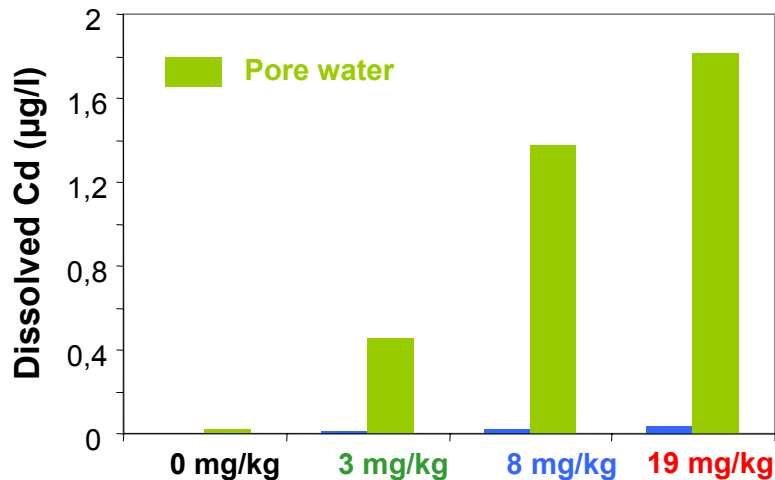
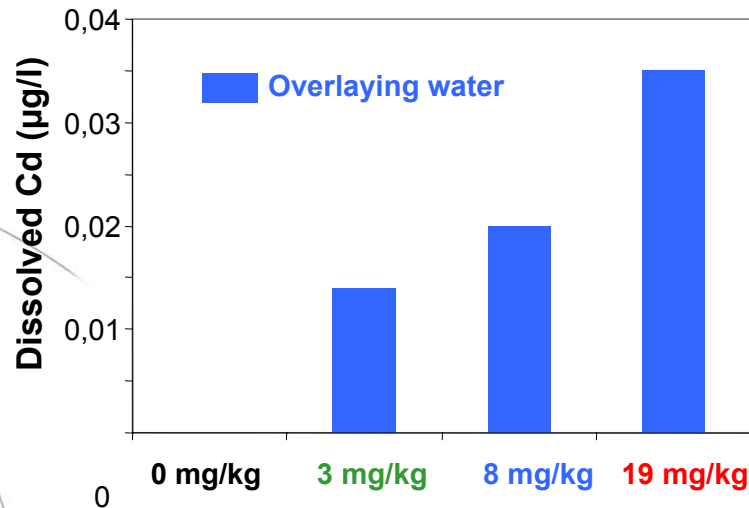


Complementary information

R ratio modelling by DIFS model : estimation of reactivity parameters of the sediment ($K_{d_{lab}}$ et T_c)



Complementary information



Cd LC50 :

0.07 mg/L (96h) *G. fossarum*

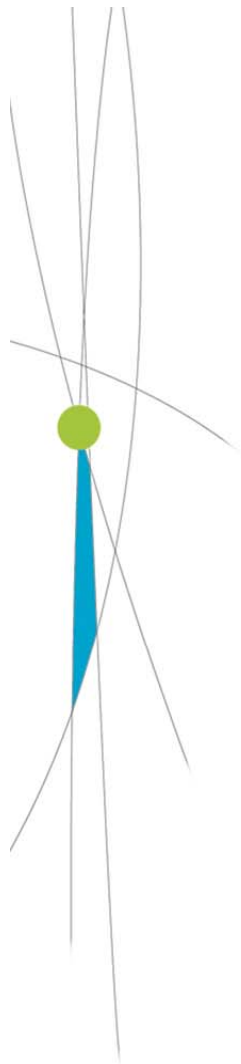
0.3 mg/L (7d) *P. antipodarum*

Chronic exposition : observed effects :

Survival rate affected at 3µg/L and feeding rate at 3 µg/L (21d) *G. fossarum*






Reproduction rate affected at 20 µg/L (8w) *P. antipodarum*

Complementary information



Mobility
Reactivity



-  exchangeable Cd (MgCl_2)
-  Cd bound to carbonates (pH 5, buffer solution acetic acid /Sodium Acetate)
-  Cd bound to Mn oxydes and Fe oxyhydroxydes (pH2, hydroxylamine)
-  Cd bound to sulphides and OM (pH2, H_2O_2)
-  Cd bound to residual fraction (Aqua regia)