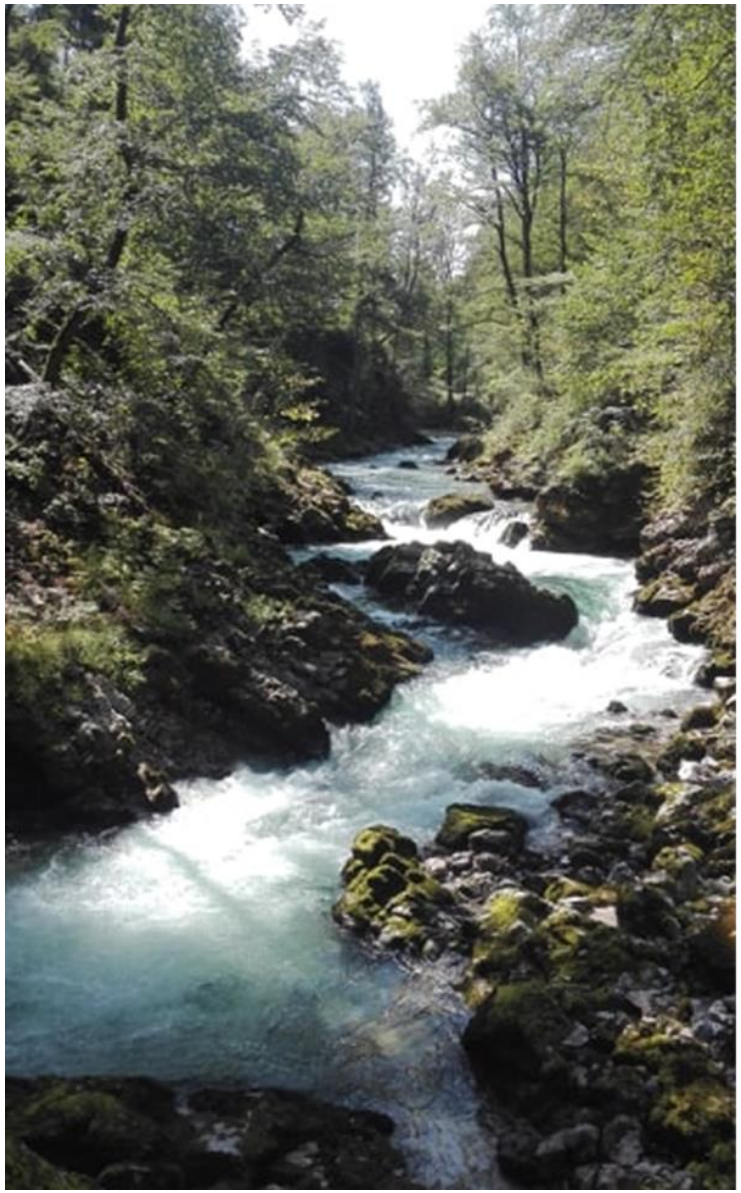
Responses of microbial communities exposed to combined stressors in hyporheic zone

Laura Kergoat, Aymeric Dabrin, Thibault Datry, Abdelkader Azougui, Bernadette Volat, Bernard Motte, Christophe Rosy, Chloé Bonnineau



ContaSed 2021

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Laura Kergoat[1], Aymeric Dabrin[1], Thibault Datry[1], Abdelkader Azougui[1], Bernadette Volat[1], Bernard Motte[1], Christophe Rosy[1], Chloé Bonnineau[1]

[1] INRAE, UR Riverly, Lyon-Villeurbanne, France

INRAE la science pour la vie, l'humain, la terre

RÉPUBLIQUE FRANÇAISE Liberté Égalité Fraternité

Lyon 1

FONDATION ROVALTAIN SCIENCE & ÉQUILIBRE

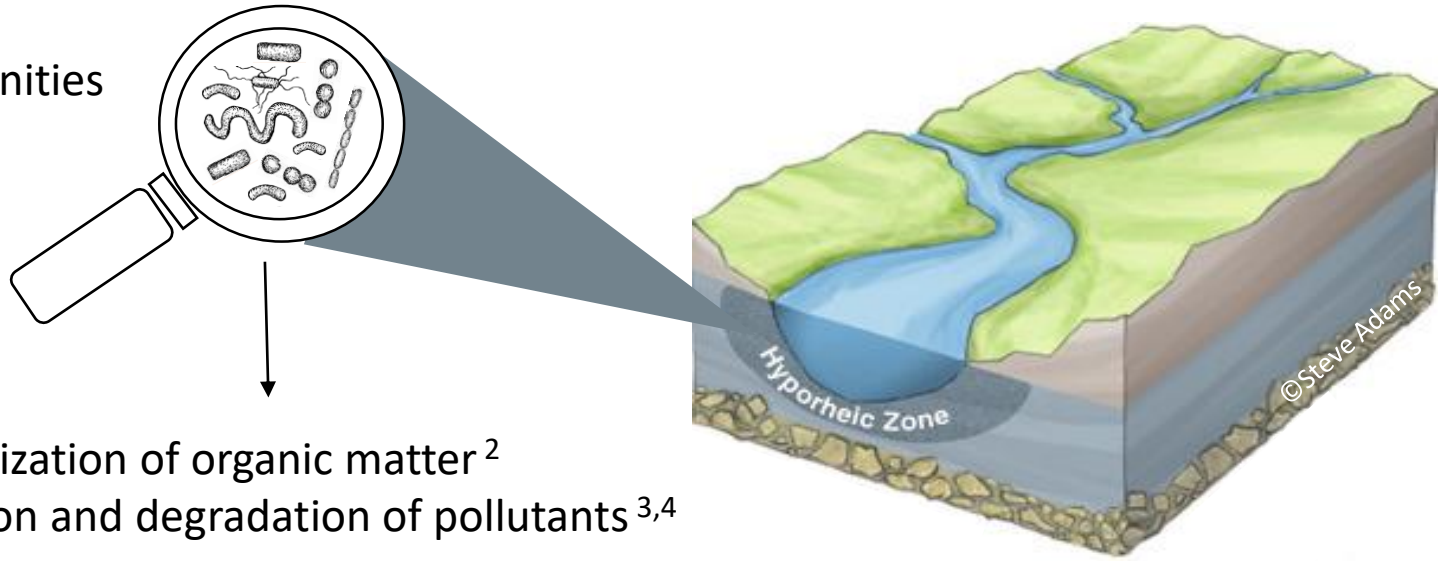
Context

Hyporheic zone : “the saturated interstitial areas beneath the stream bed and into the stream banks that contain some proportion of channel water” [1]

[1] White, D. S. (1993). Journal of the North American Benthological Society 12, 61–69.

Context

Microbial communities



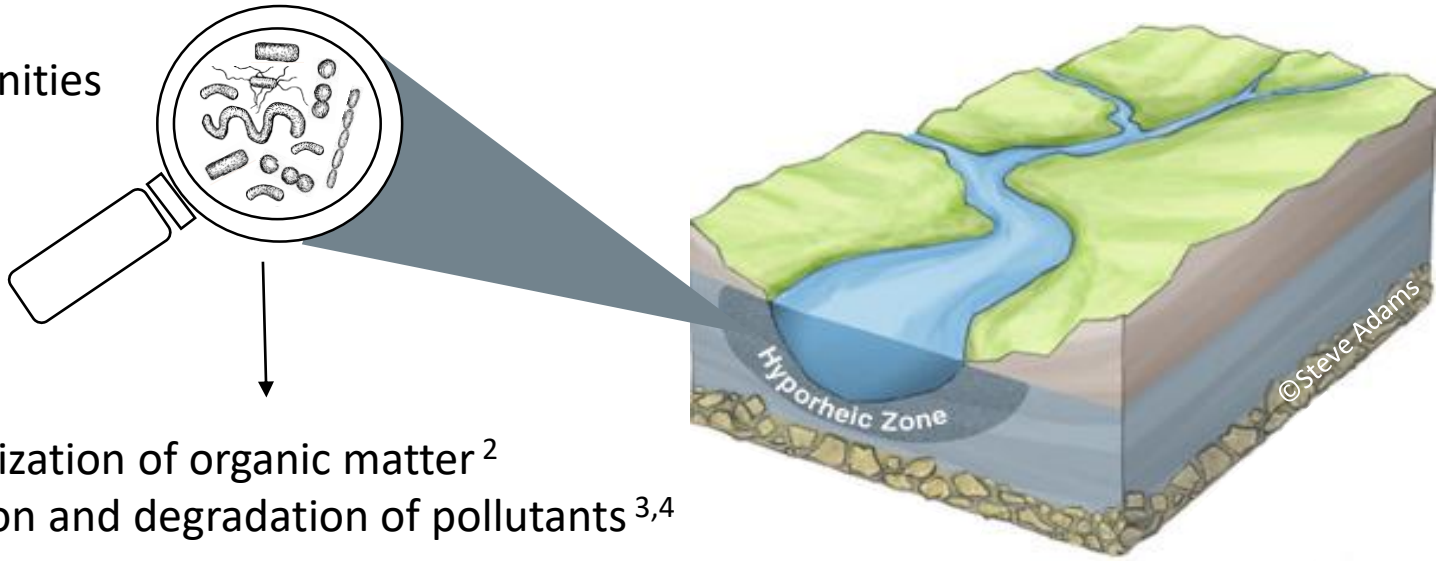
- Mineralization of organic matter [2]
- Retention and degradation of pollutants [3,4]

Filter for the river !

[2] Piscart, C. (2011). Science of The Total Environment 409, 4373–4380.
[3] Gandy, C. J. (2007). Science of The Total Environment 373, 435–446.
[4] Peralta-Maraver, I. (2018). Science of The Total Environment 610–611, 267–275.

Context

Microbial communities



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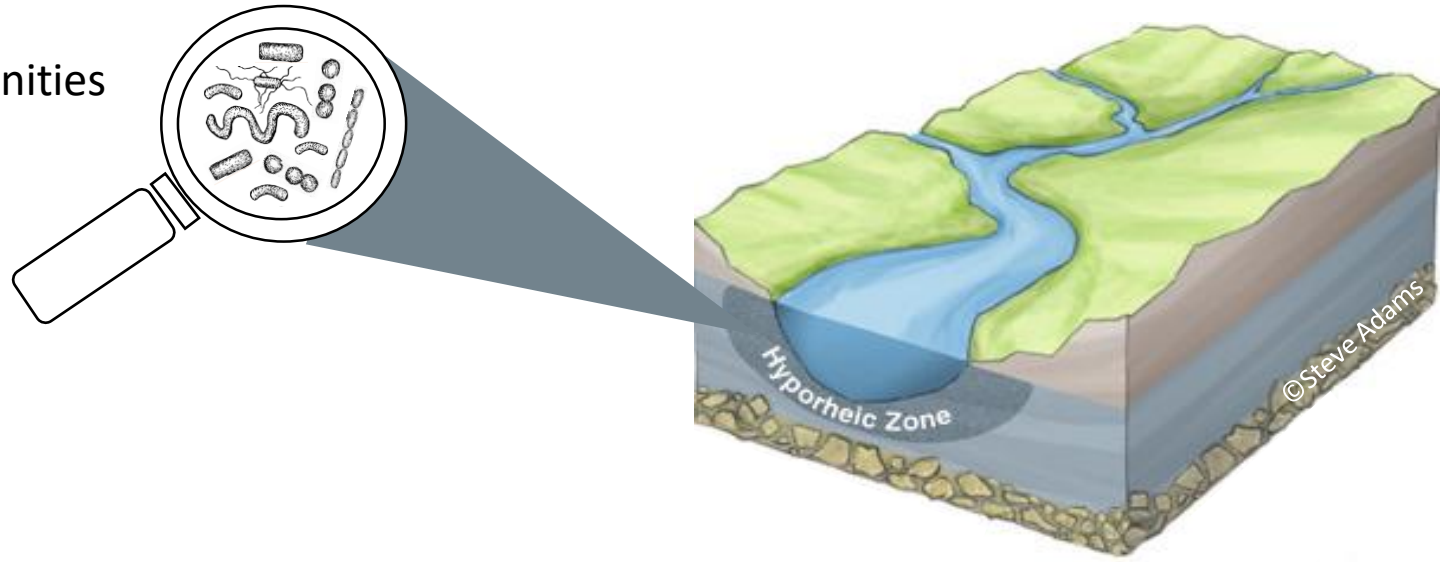
Context

Microbial communities



Clogging

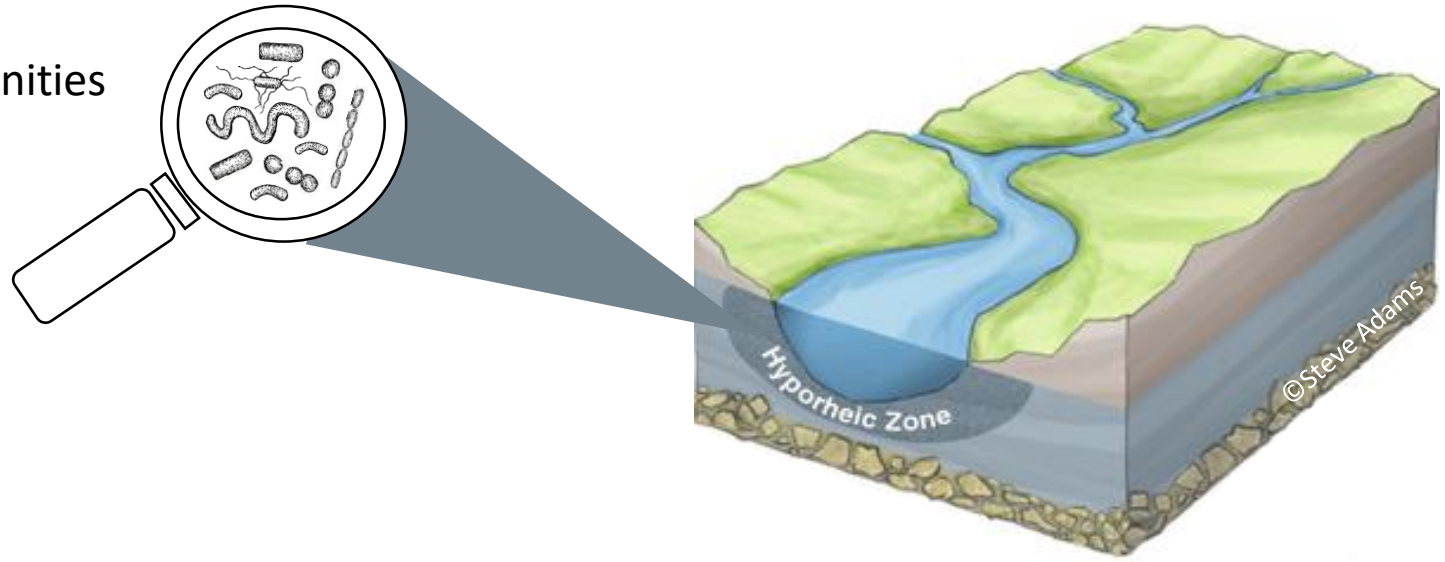
Clogging = fine sediment deposition onto the riverbed and their gradual infiltration into the hypoheic zone [5]

- Input of fine sediment and organic matter -> **stimulation of microbial activities** [6,7]
- Reduction of oxygen supply -> **anaerobic microbial communities** development [8]

[5] Wood, P. J. (1997). *Environmental Management* 21, 203–217.
[6] Hartwig, M. (2015) *Ecohydrol.* 8, 961–975.
[7] Nogaro, G. (2007). *Science of The Total Environment* 377, 334–348.
[8] Navel, S. (2011). *Microb Ecol* 61, 968–979.

Context

Microbial communities



Copper

- Used as a **fungicide** in agriculture
- Transferred to aquatic systems by **leaching**
- Frequently found in **sediment**

  [Cu] = 21,7 mg/kg (median concentration in France) [9]

- **Ecotoxicological effects**

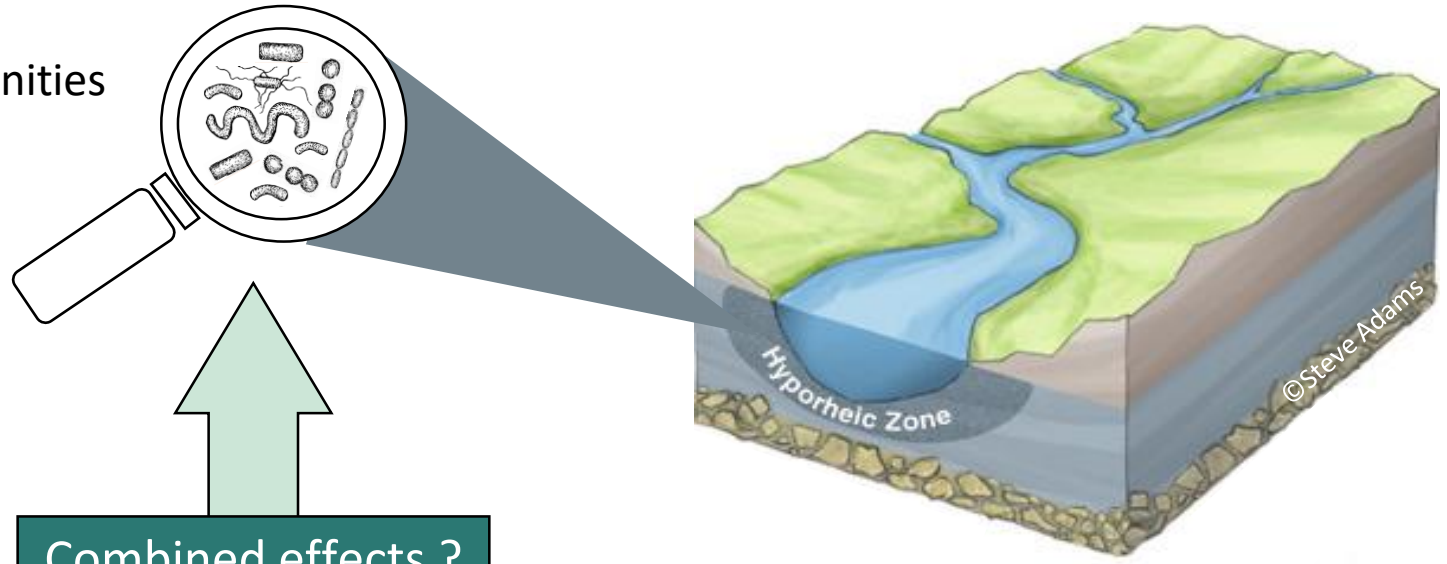
-> microbial functions (respiration, denitrification, mineralization of organic matter) [10, 11]

-> microbial structure [10, 11]

[9] INERIS 2010, Rapport d'étude
[10] Mahamoud Ahmed, A. (2018). *Front. Microbiol.* 9, 1852.
[11] Sutcliffe, B.(2019). *Environmental Pollution* 247, 1028–1038.

Context

Microbial communities



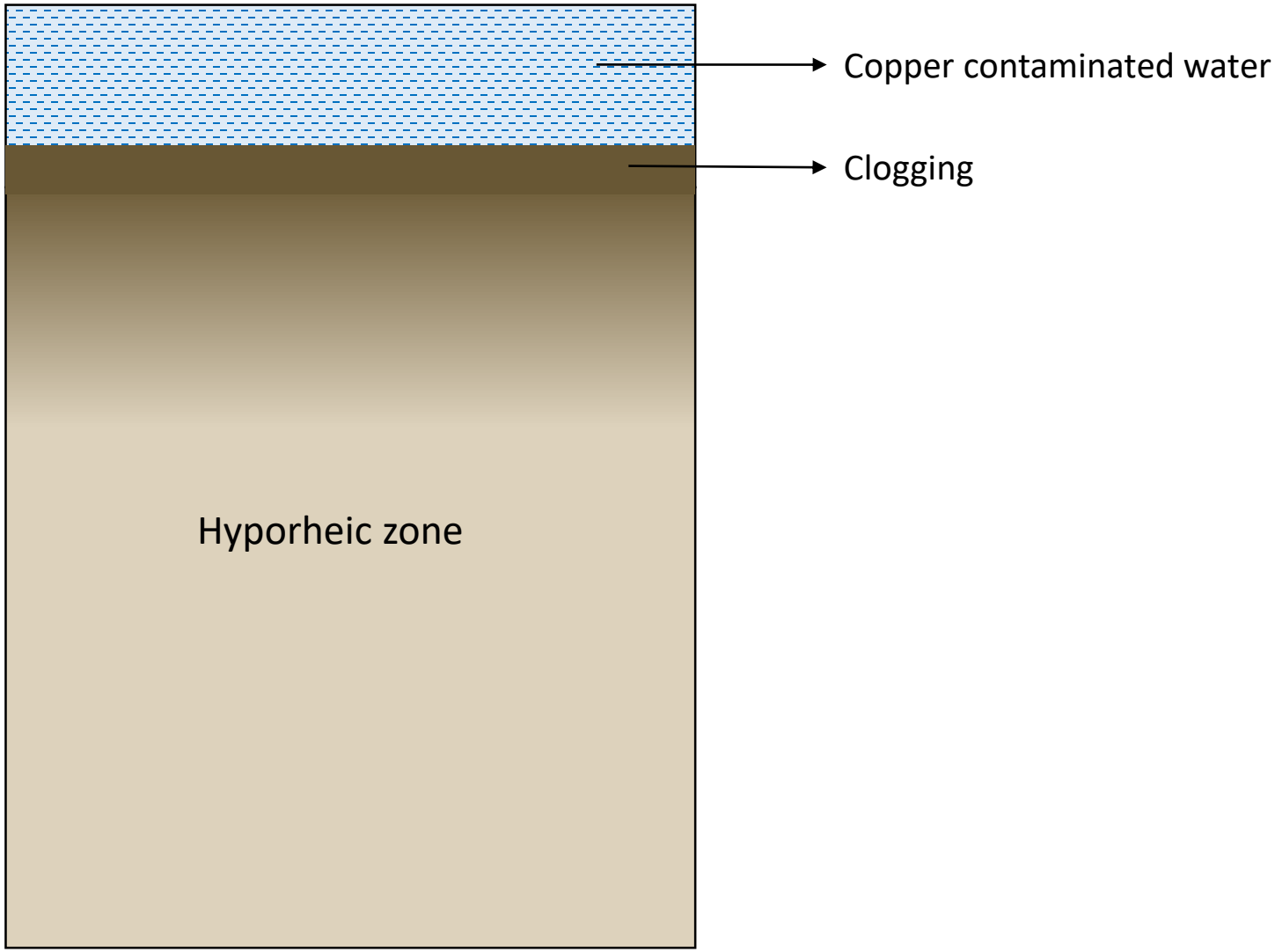
Combined effects ?

Clogging

Copper

Hypotheses

What are the combined effects of copper contamination and clogging on microbial communities in the hyporheic zone?



Hypotheses

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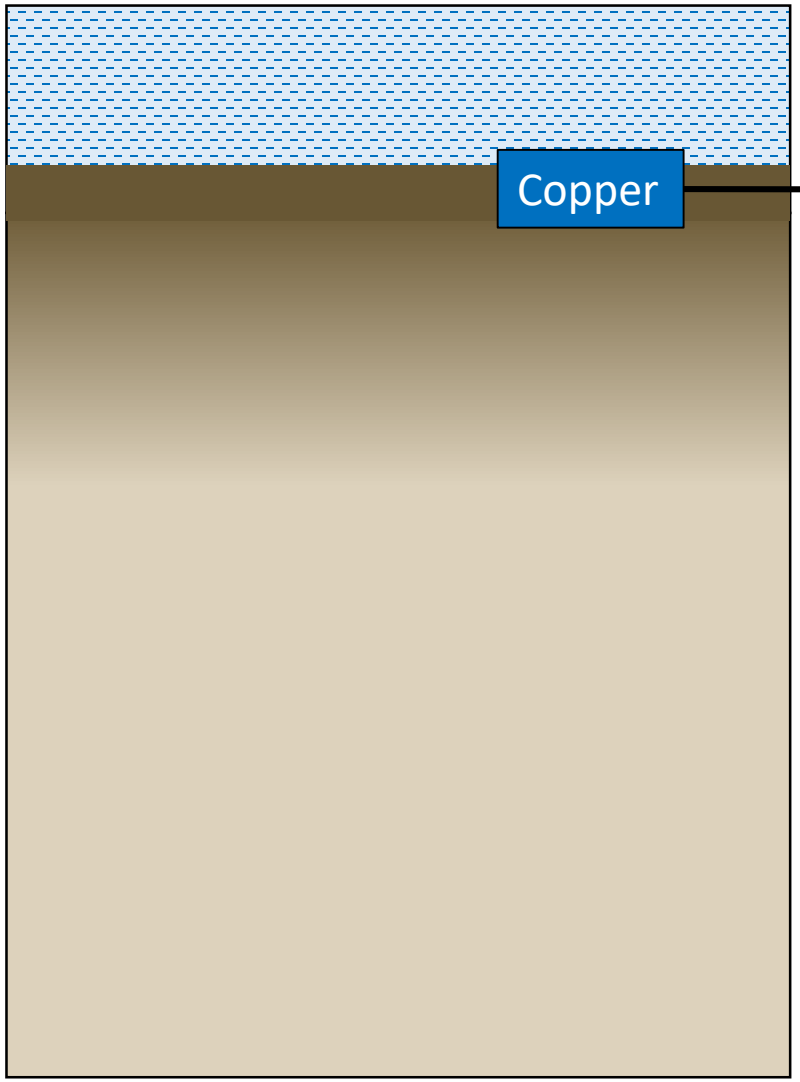
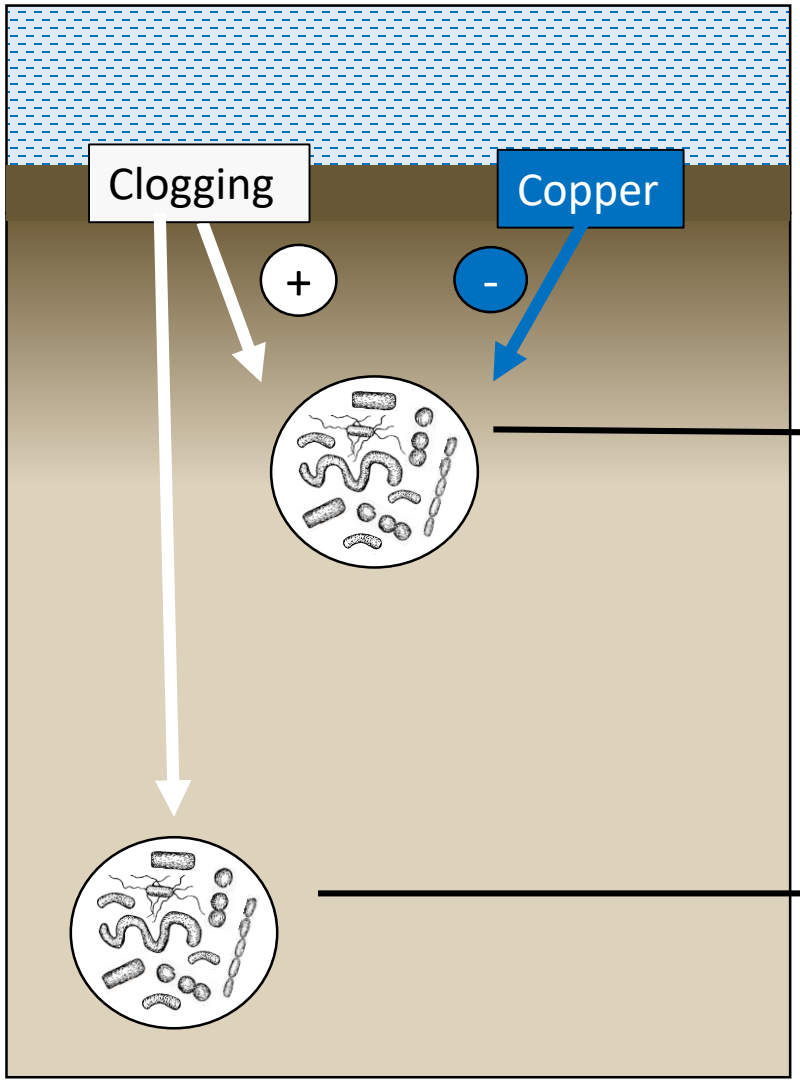


Hypothesis 1

Copper fixation in the first centimeters

What are the combined effects of copper contamination and clogging on microbial communities in the hyporheic zone?

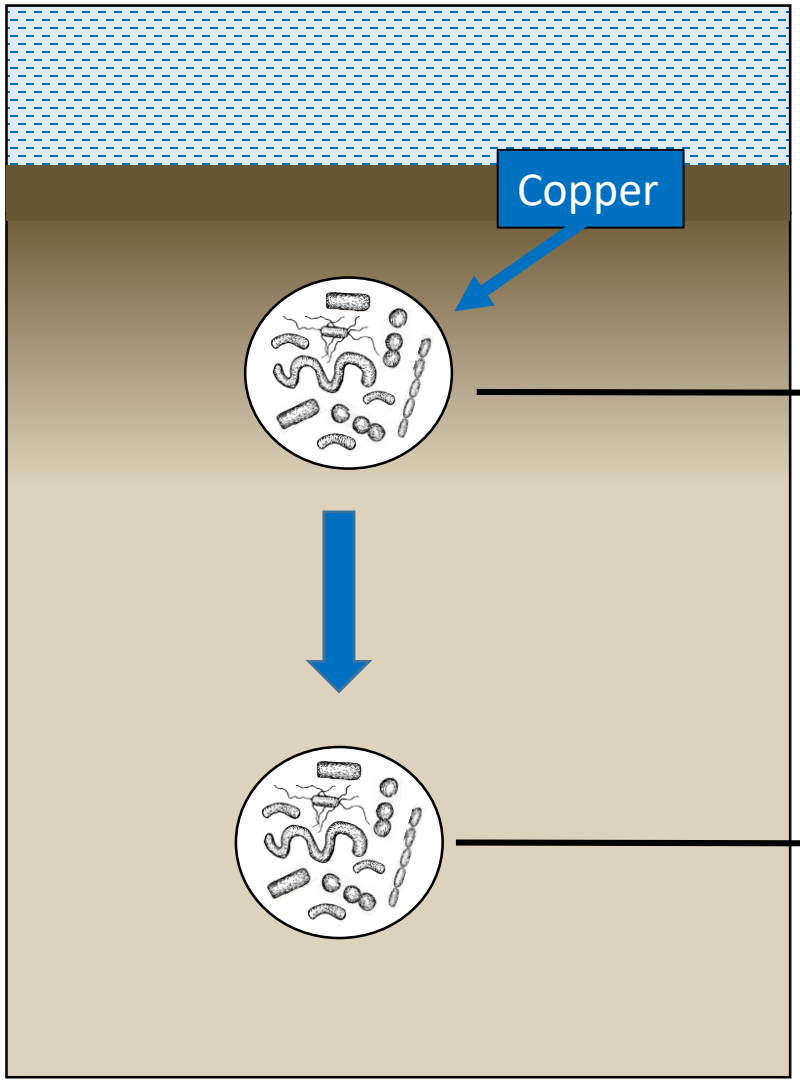


Hypothesis 2

- Antagonistic effects of copper and clogging on microbial functions
- Modification of microbial structure

- Only the effects of clogging on microbial functions and structure (development of anaerobic microbial communities)

What are the combined effects of copper contamination and clogging on microbial communities in the hyporheic zone?

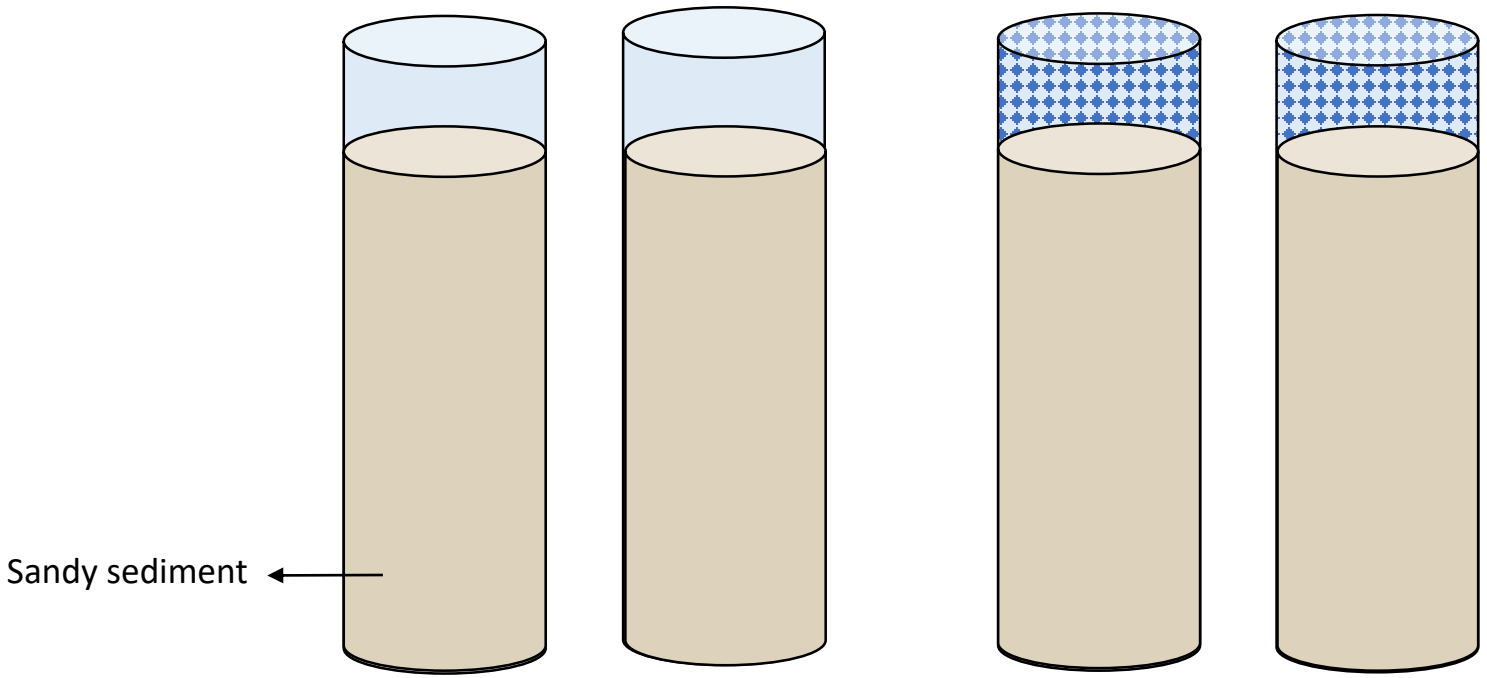


Hypothesis 3

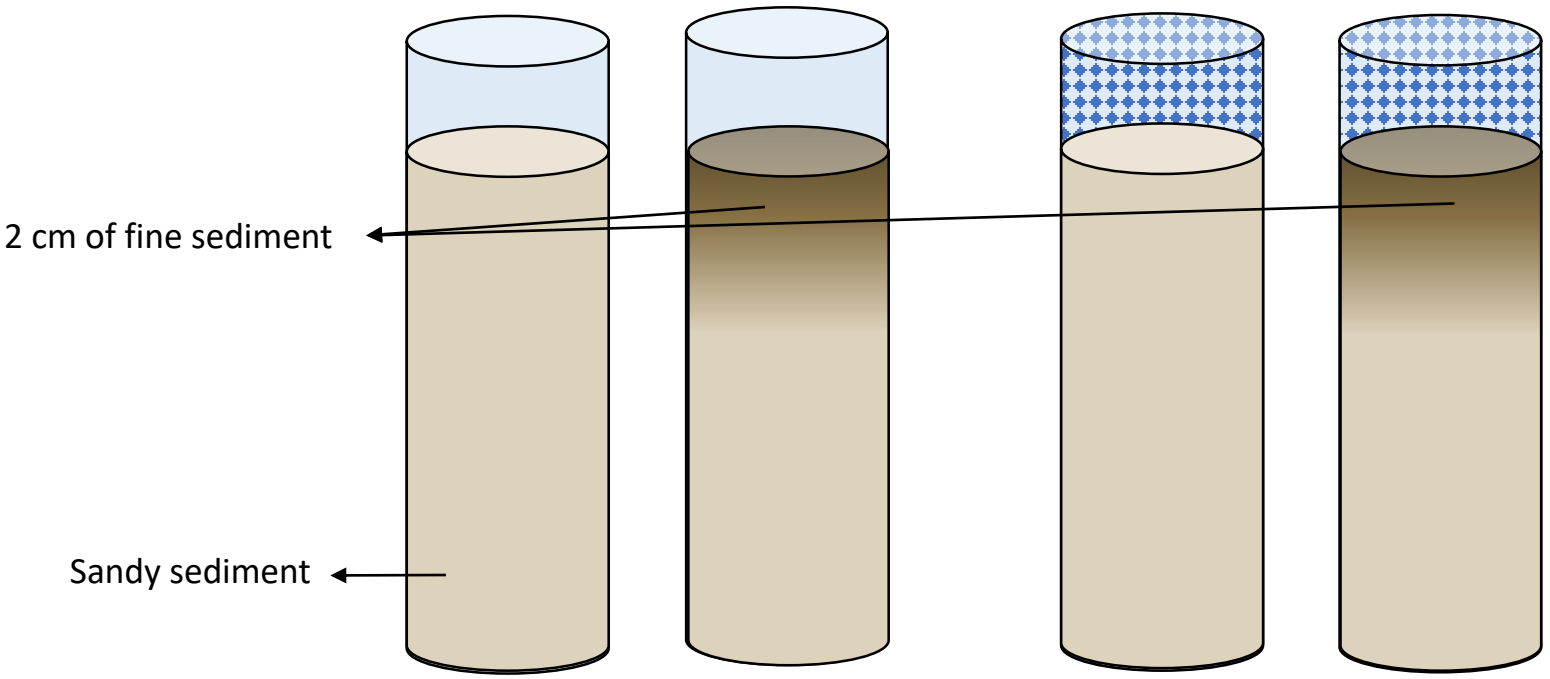
Copper tolerance acquisition in the first centimeters

Diffusion of copper tolerance in deep zone

Experimental design



Experimental design



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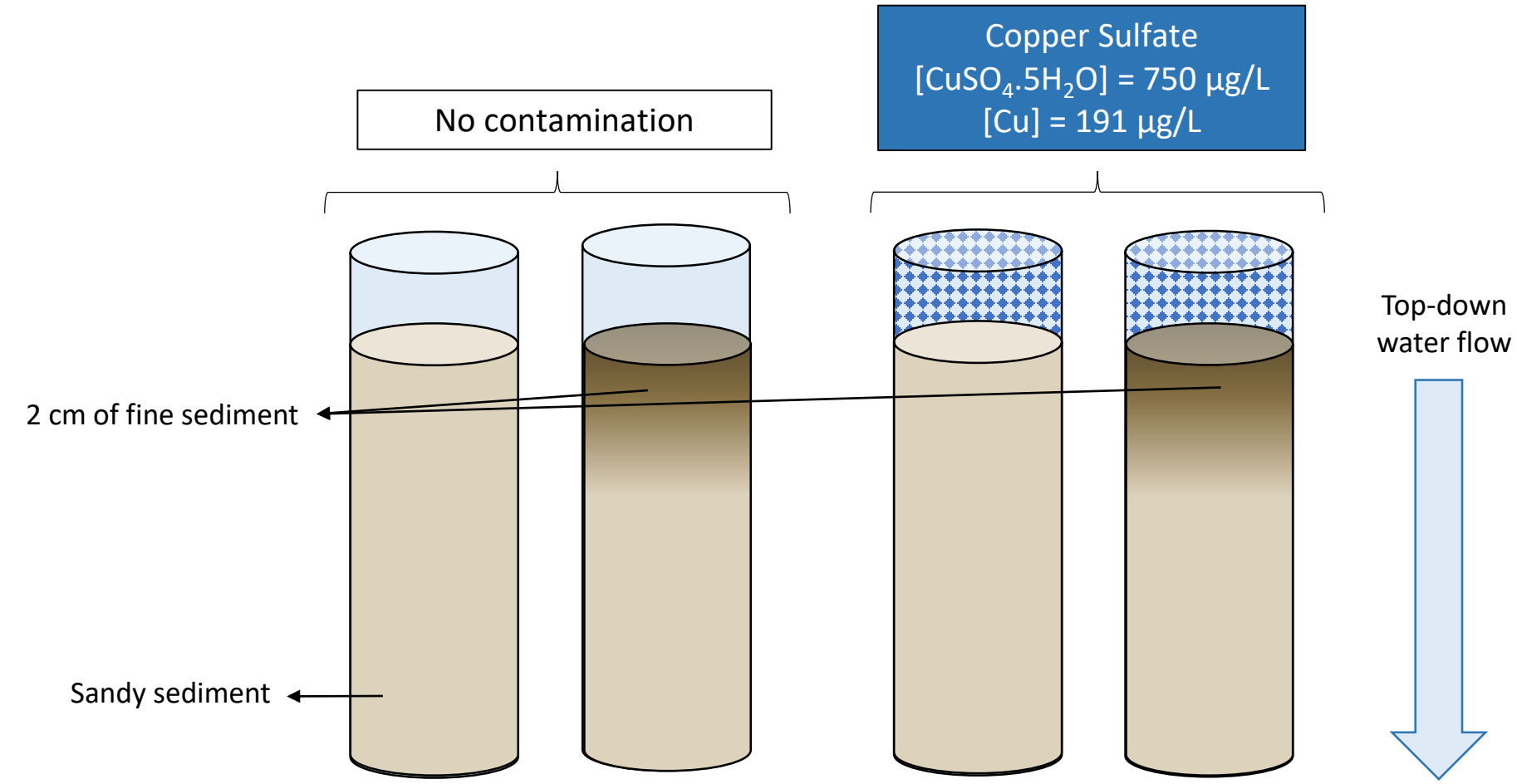

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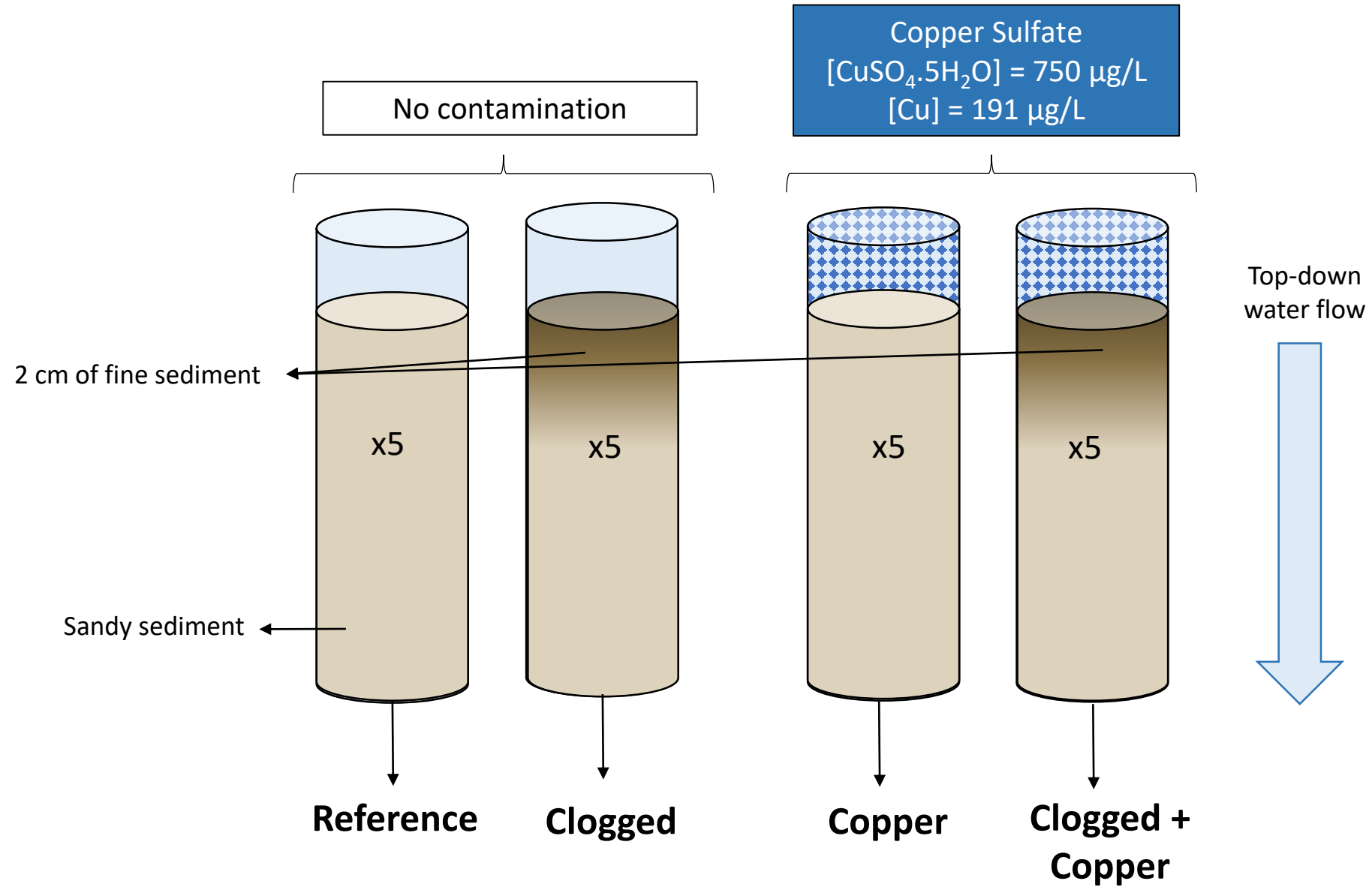
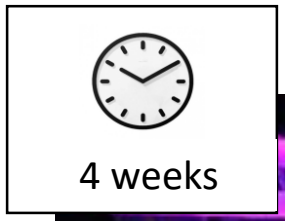
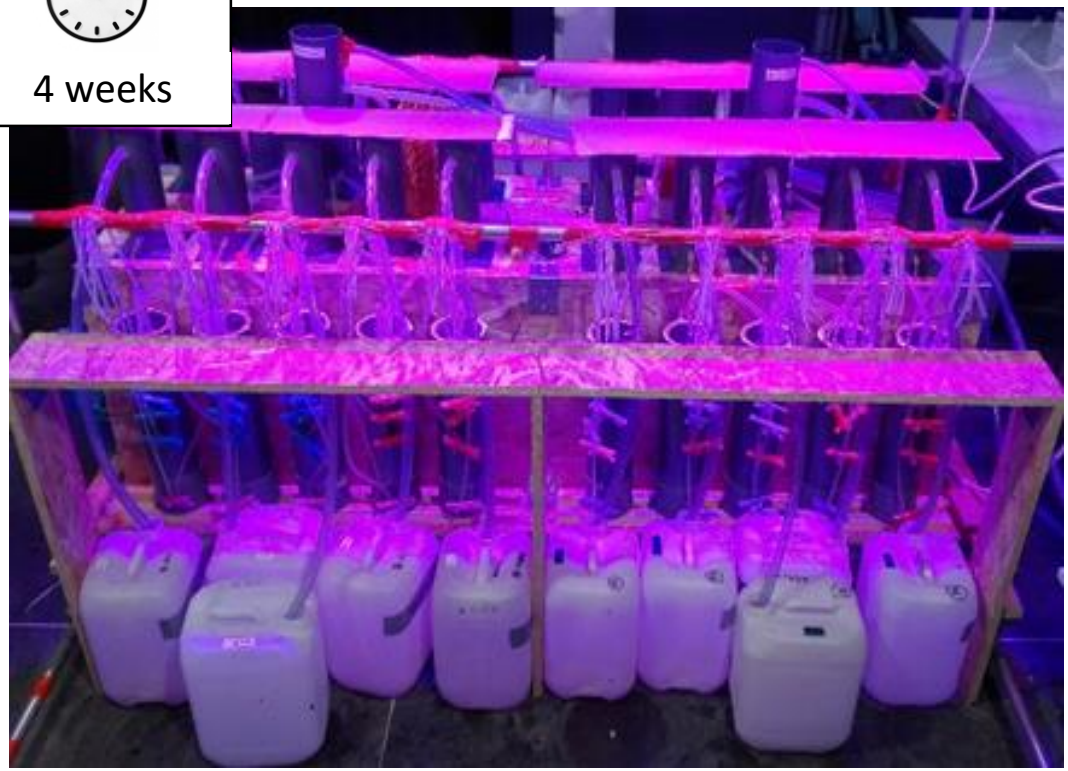
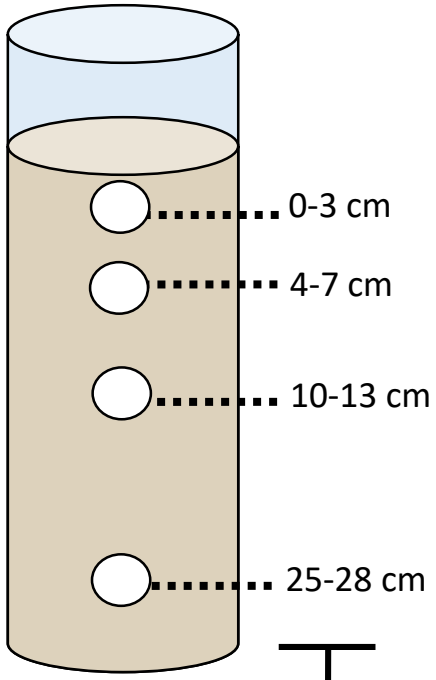


Experimental design

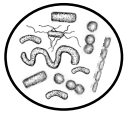




Sediment sampling

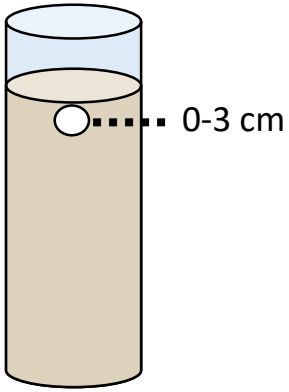


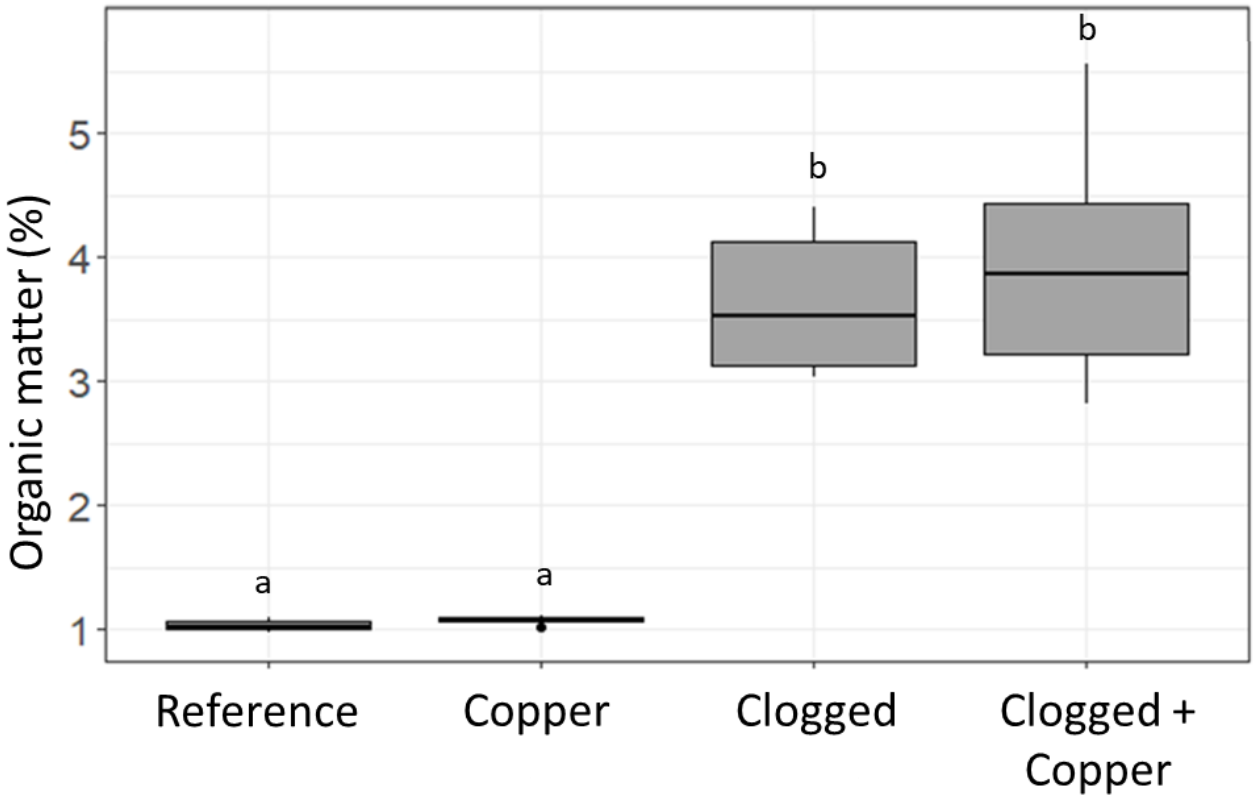
Physical and chemical parameters



Function/structure of microbial communities

❖ Organic matter in sediment

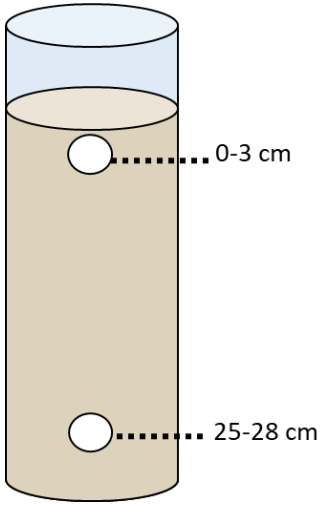


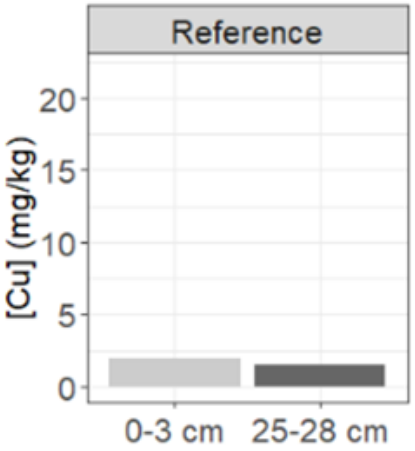


The first centimeters of the clogged columns are rich in organic matter

(Different letters indicate significant differences between two treatments after a Tukey post hoc test)

❖ Copper distribution in sediment





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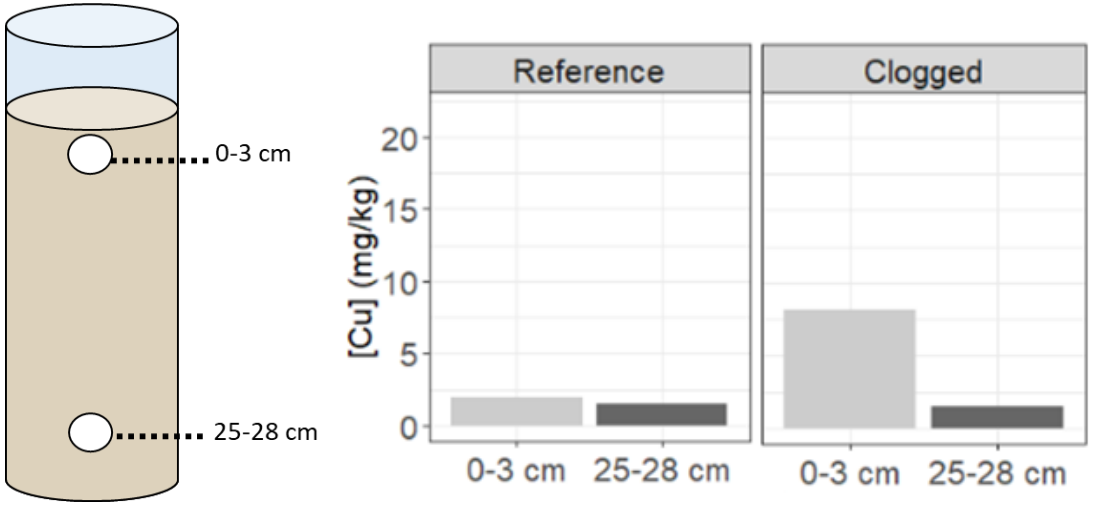

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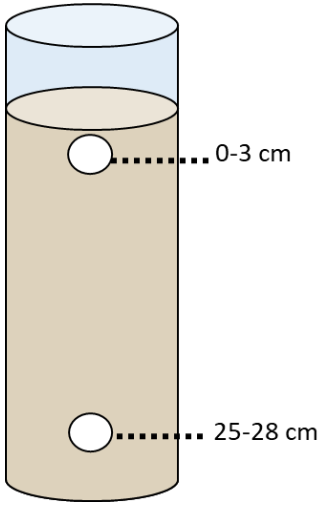
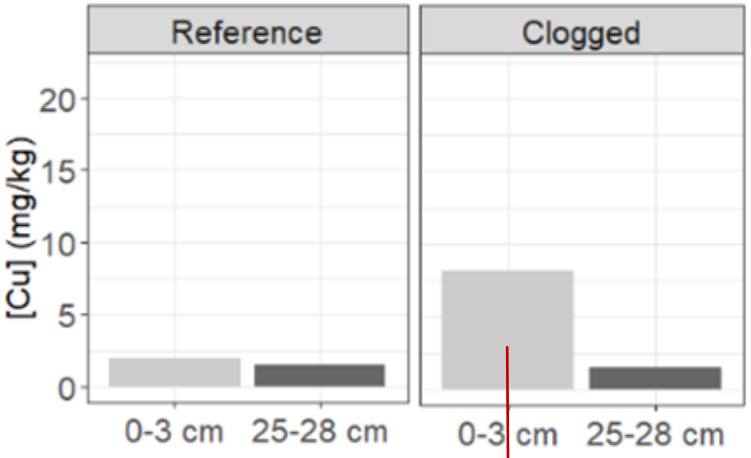
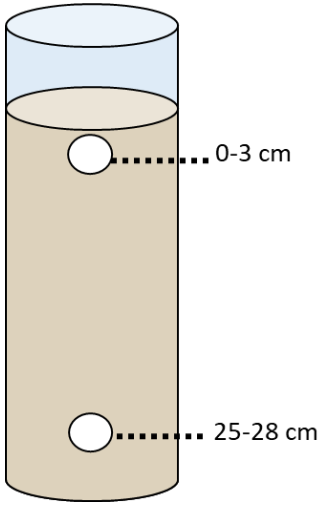
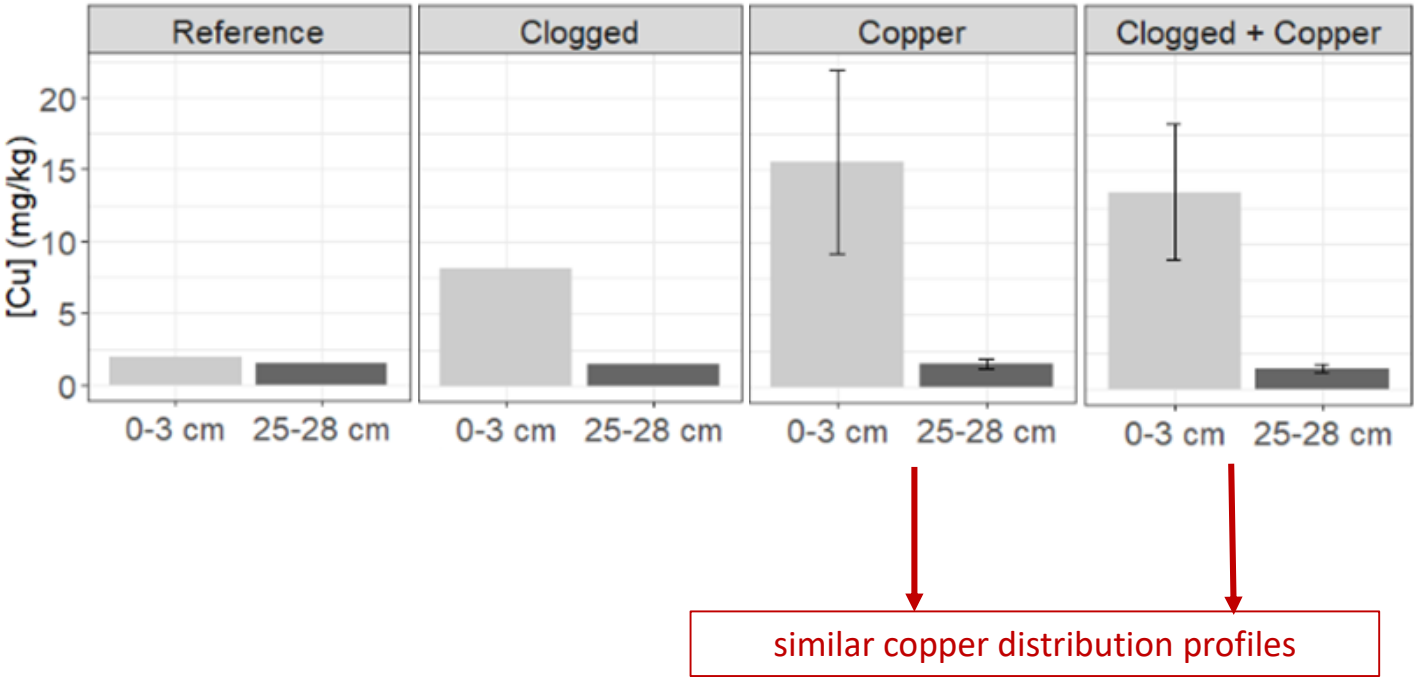




Sediment used for clogging was copper contaminated (30.19 mg Cu/kg in dry sediment)

❖ Copper distribution in sediment

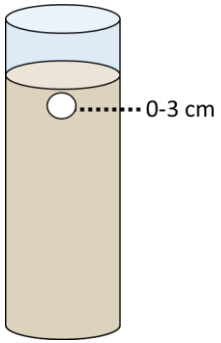


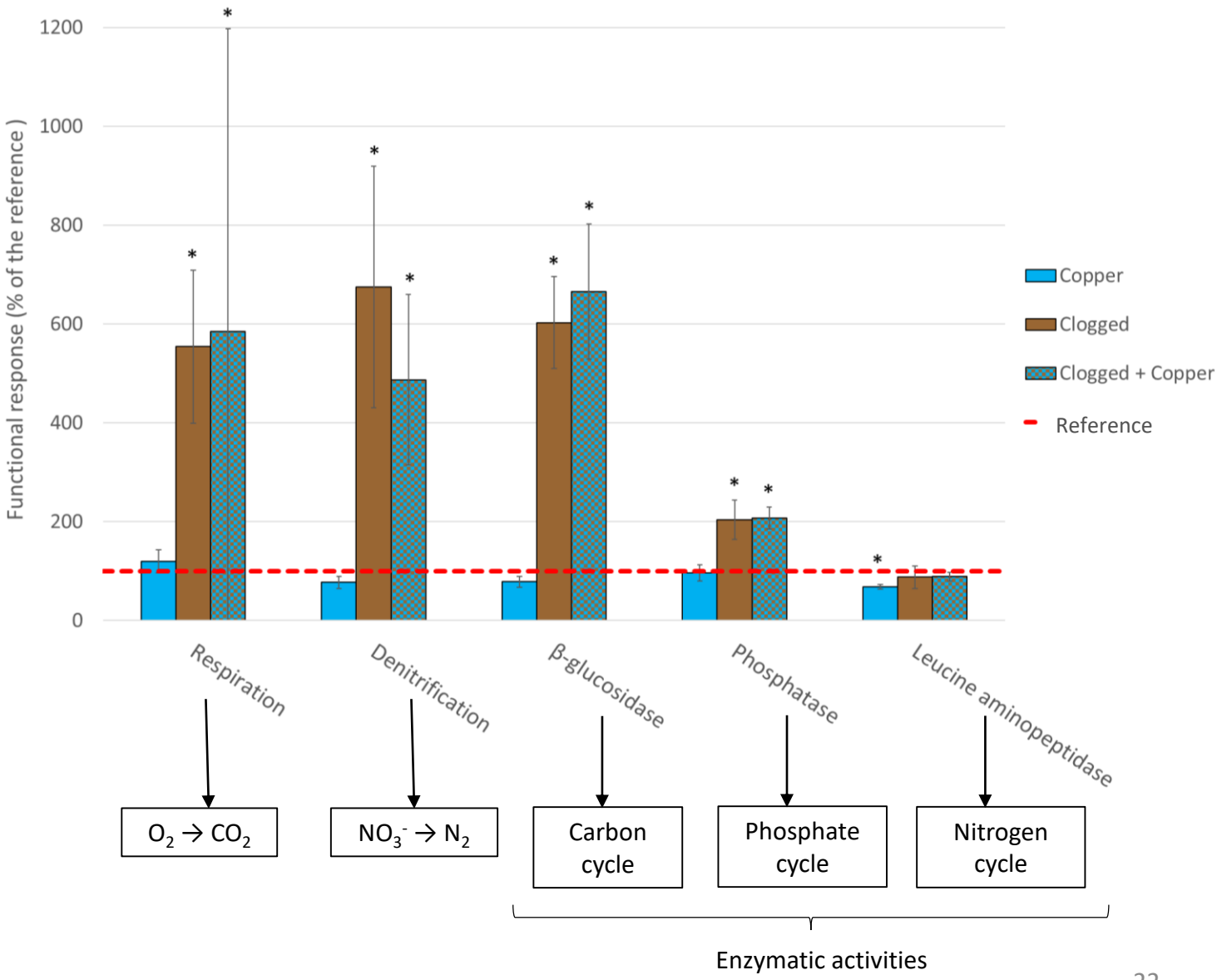


similar copper distribution profiles

- Clogging did not change the distribution of copper in the column
- No diffusion of copper in depth in the presence or not of clogging sediment

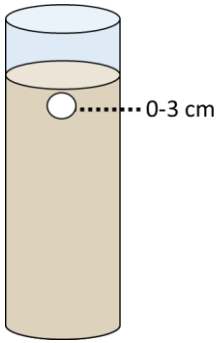
Results – Functional responses of microbial communities

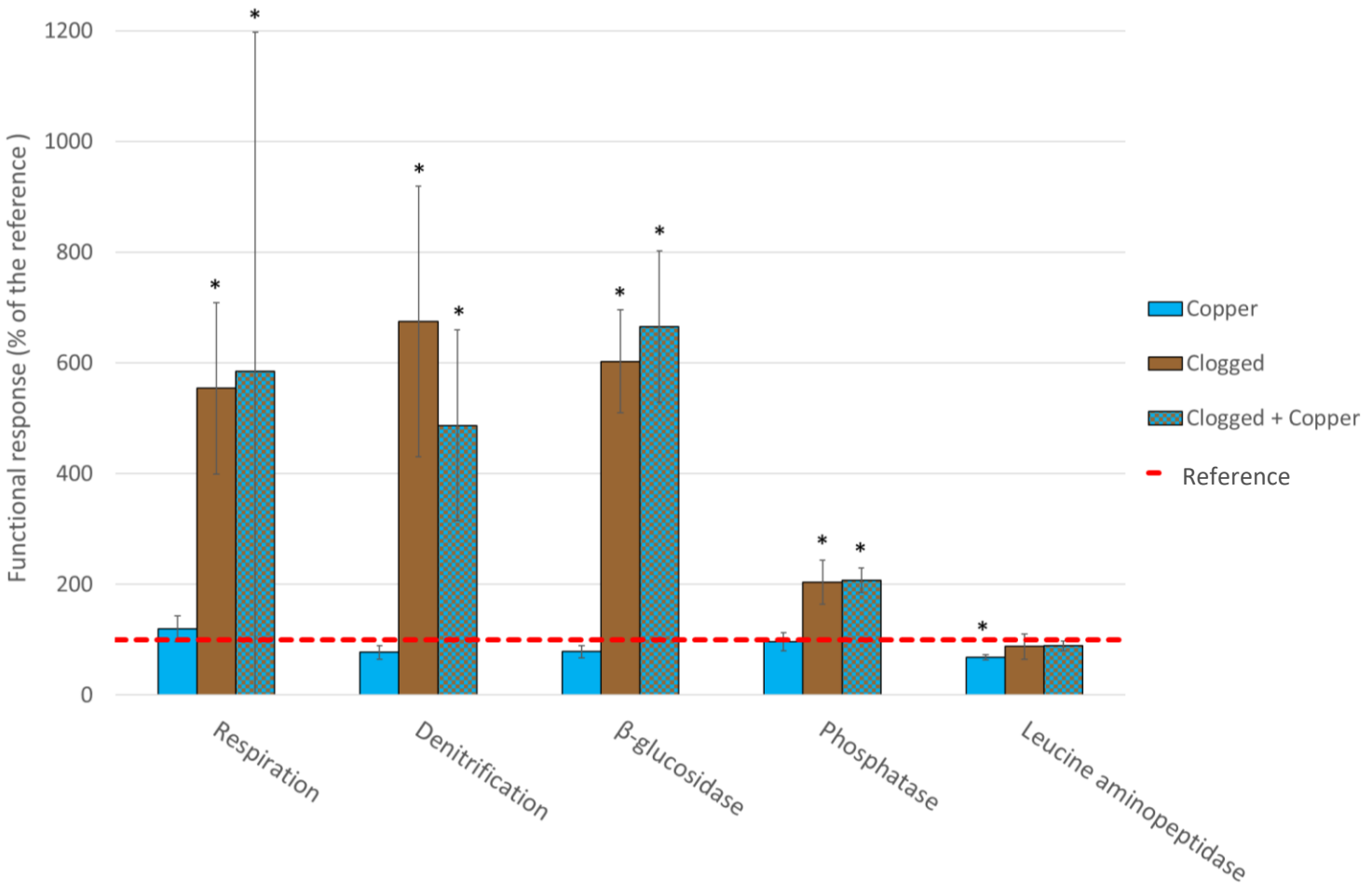




(Stars indicate significant differences from Reference for a given depth after a Tukey post hoc test)

Results – Functional responses of microbial communities





No effect of copper except for leucine aminopeptidase
Stimulation of microbial activities in the presence of clogging except for leucine aminopeptidase

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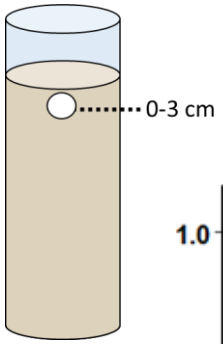
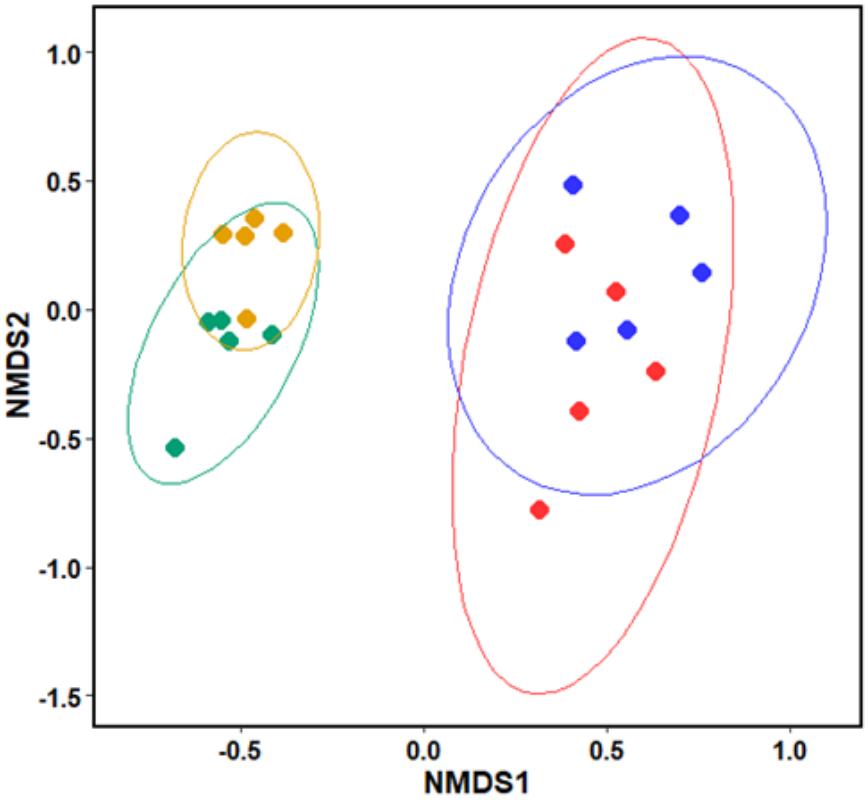
Results – Structural responses of microbial communities



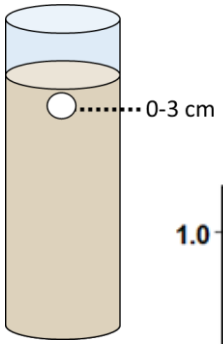


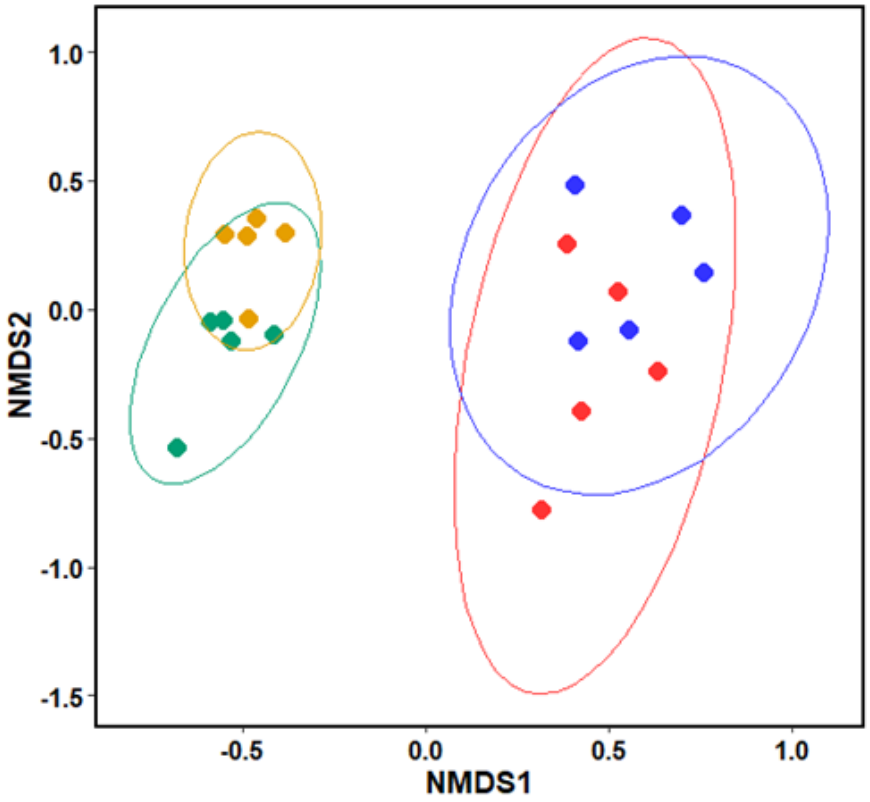
Clogging
Clogging + Copper
Copper
Reference

Stress value : 0.08657793

Separation in two groups : exposed or not exposed to clogging
Small effect of copper at the tested concentration

Results – Structural responses of microbial communities





- Clogging
- Clogging + Copper
- Copper
- Reference

Stress value : 0.08657793

Adonis2 test results (999 permutations)

Factor	Pr (>F)
Clogging	0,001 ***
Copper	0,040 *
Copper*Clogging	0,018 *

Separation in two groups : exposed or not exposed to clogging
Small effect of copper at the tested concentration

Results - Acquisition of copper tolerance in microbial communities

EC50 = Concentration causing 50% reduction in microbial activity measured in an acute toxicity test (PICT method)

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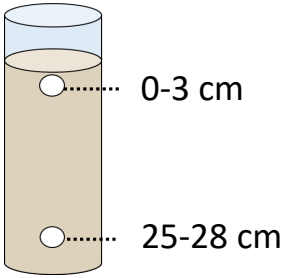
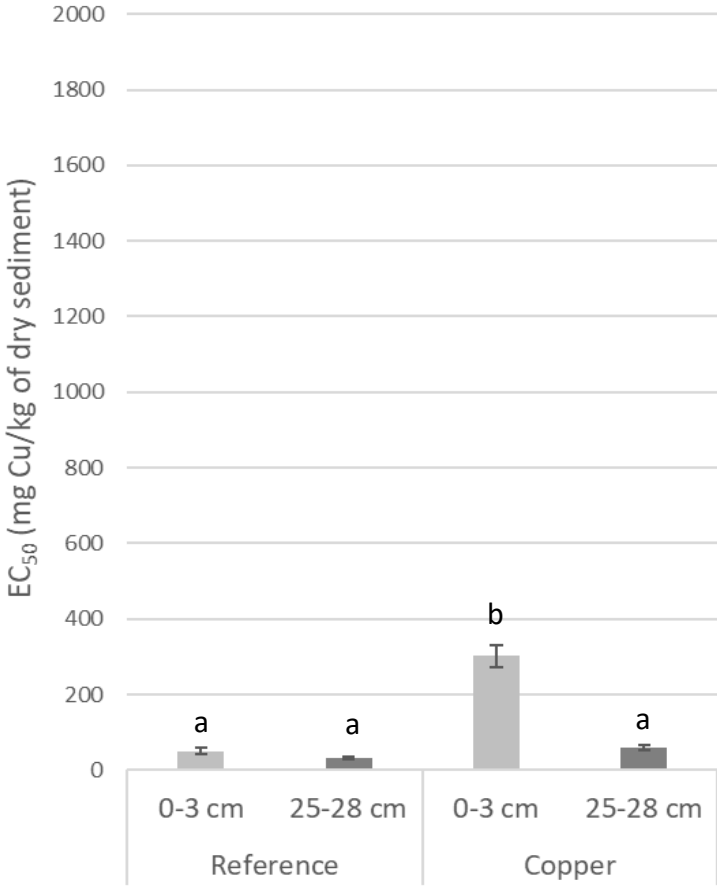
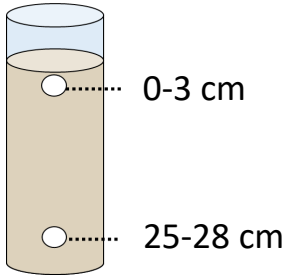
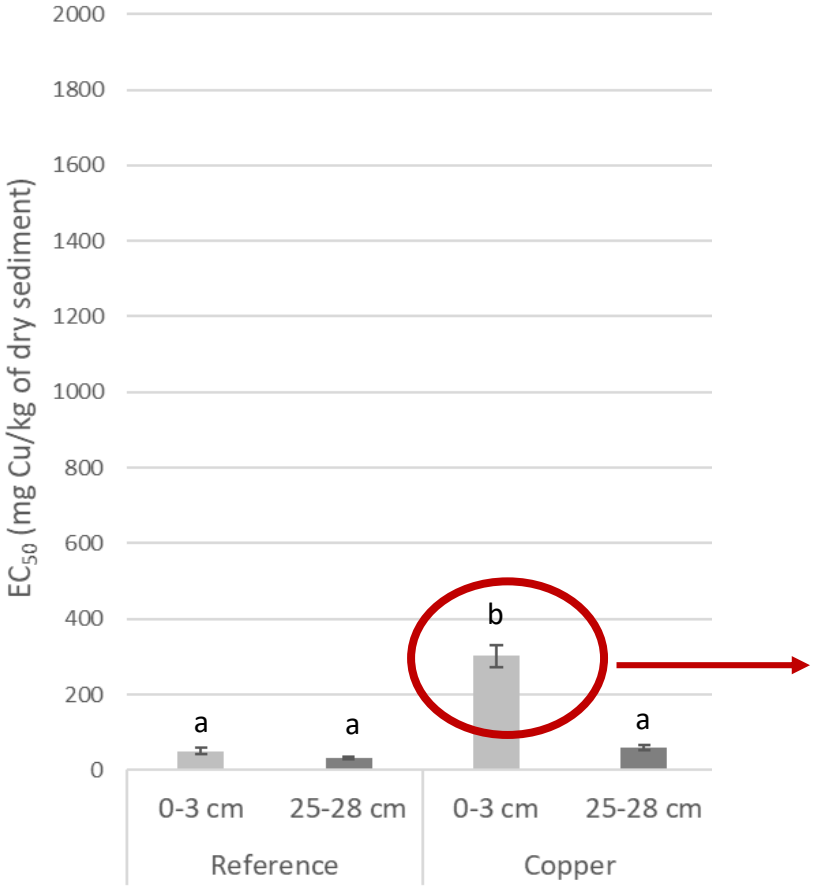


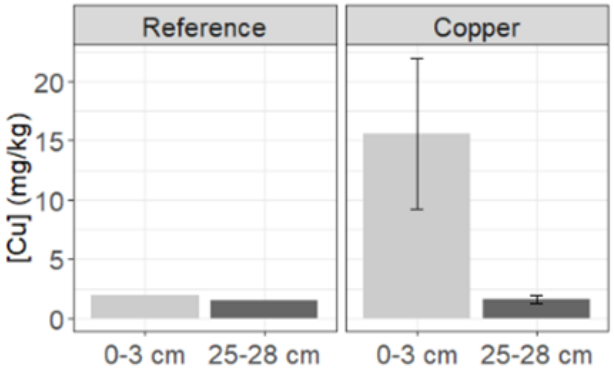


(Different letters indicate significant differences between two treatments)

Results - Acquisition of copper tolerance in microbial communities

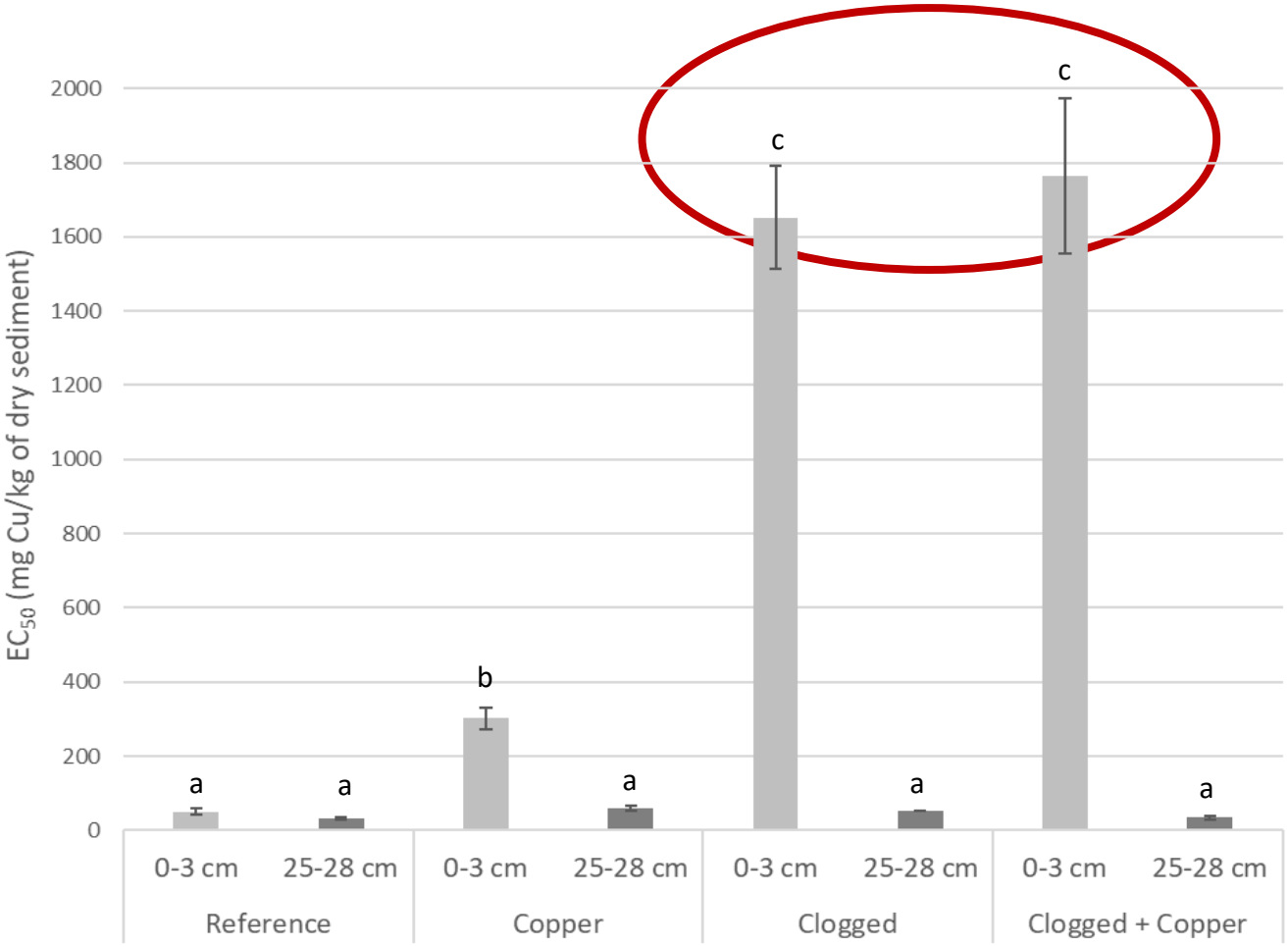


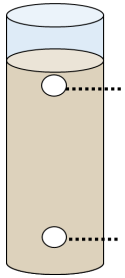




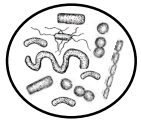
(Different letters indicate significant differences between two treatments)

Results - Acquisition of copper tolerance in microbial communities





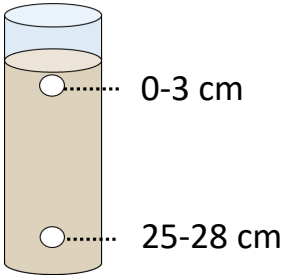
Sediment used for clogging was copper contaminated (30.19 mg Cu/kg in dry sediment)

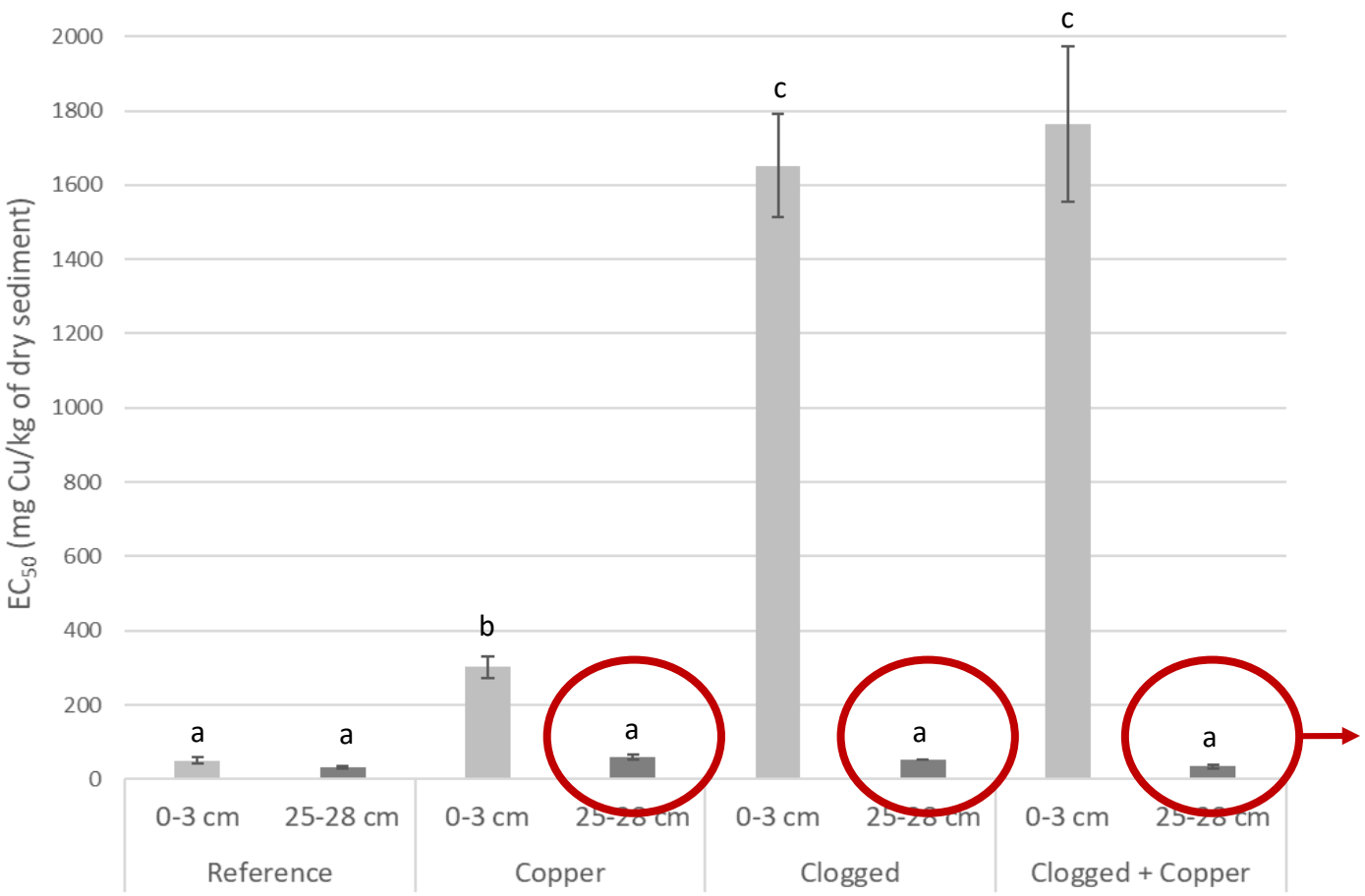


Already copper tolerant?

(Different letters indicate significant differences between two treatments)

Results - Acquisition of copper tolerance in microbial communities



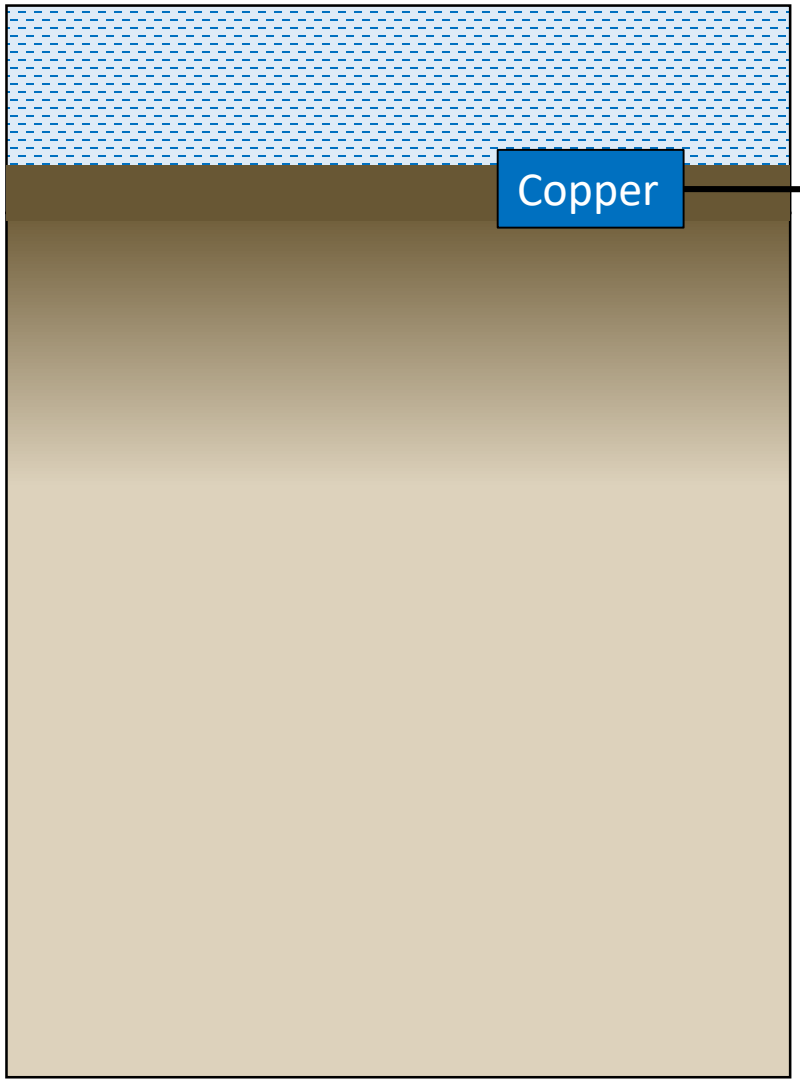


No diffusion of copper tolerance in deep zone

(Different letters indicate significant differences between two treatments)

Conclusions

What are the combined effects of copper contamination and clogging on microbial communities in the hyporheic zone?

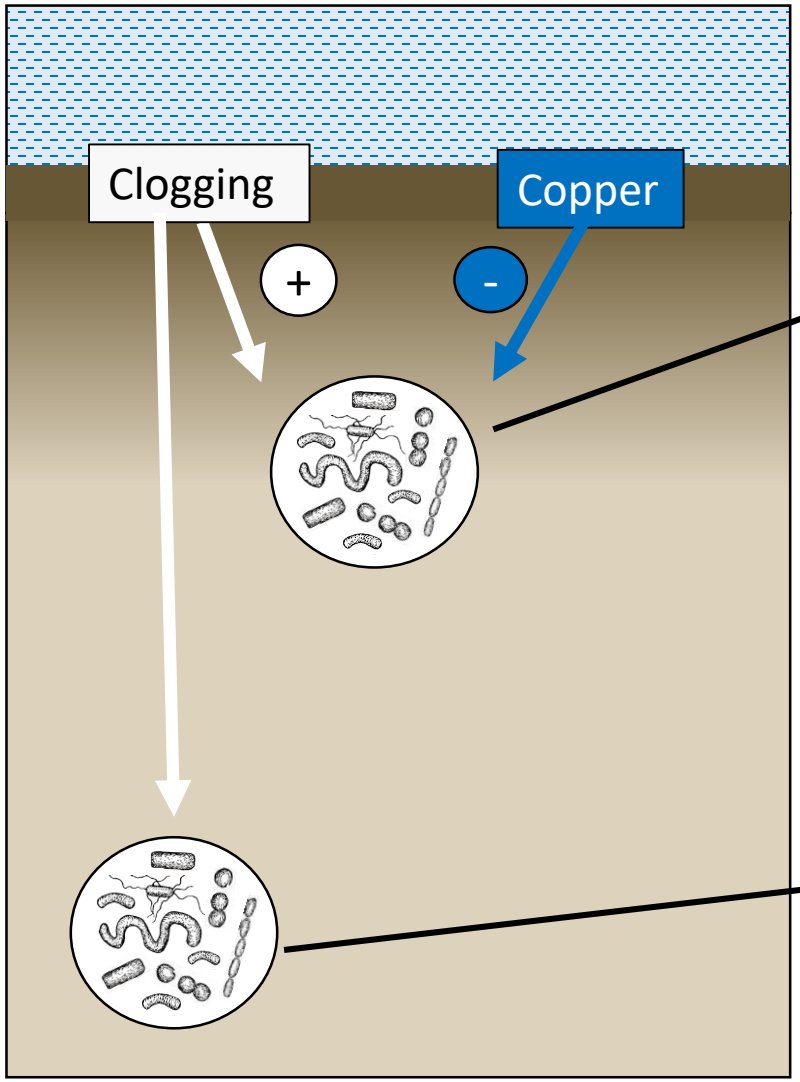


Hypothesis 1

Copper fixation in the first centimeters

Copper Fixation in the first centimeters with or without clogging

What are the combined effects of copper contamination and clogging on microbial communities in the hyporheic zone?



Hypothesis 2

- Antagonistic effects of copper and clogging on microbial functions
- Modification of microbial structure

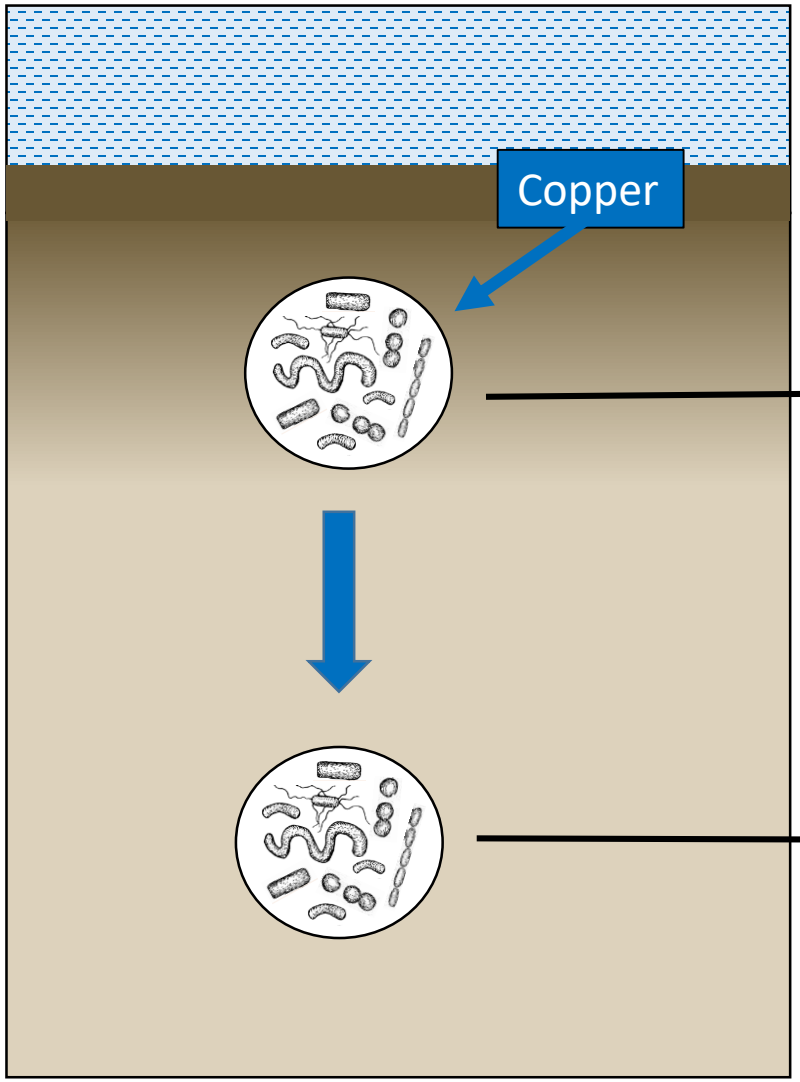
✓ Clogging strongly affects microbial functions (stimulation) and microbial structure

✓ Clogging reduces the copper effects on leucine aminopeptidase

- Only the effects of clogging on microbial functions and structure (development of anaerobic communities)

✓ No difference in microbial function and structure between treatments

What are the combined effects of copper contamination and clogging on microbial communities in the hyporheic zone?



Hypothesis 3

Copper tolerance in the first cm

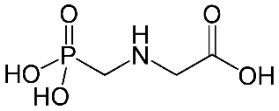
- ✓ Copper tolerance in the first cm of sediment exposed to "copper" treatment without clogging
- ✓ Microbial communities of clogging sediment already copper tolerant ?

Diffusion of copper tolerance in deep zone

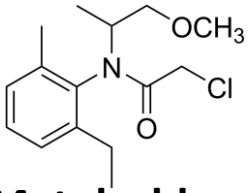
- ✓ No diffusion of copper tolerance
- ✓ Copper tolerance linked to copper distribution at a micro habitat level

Copper filtered in the first centimeters of the hyporheic sediments

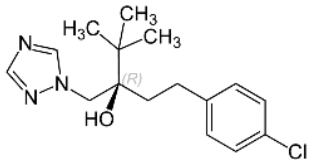
How clogging can modify the filter role of a more mobile contaminant ?



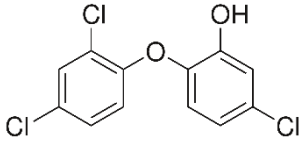
Glyphosate
(Herbicide)



Metolachlore
(Herbicide)



Tébuconazole
(Fongicide)



Triclosan
(Biocide)

- Organic contaminants
- Frequently found in streams
- Biodegradation by microorganisms

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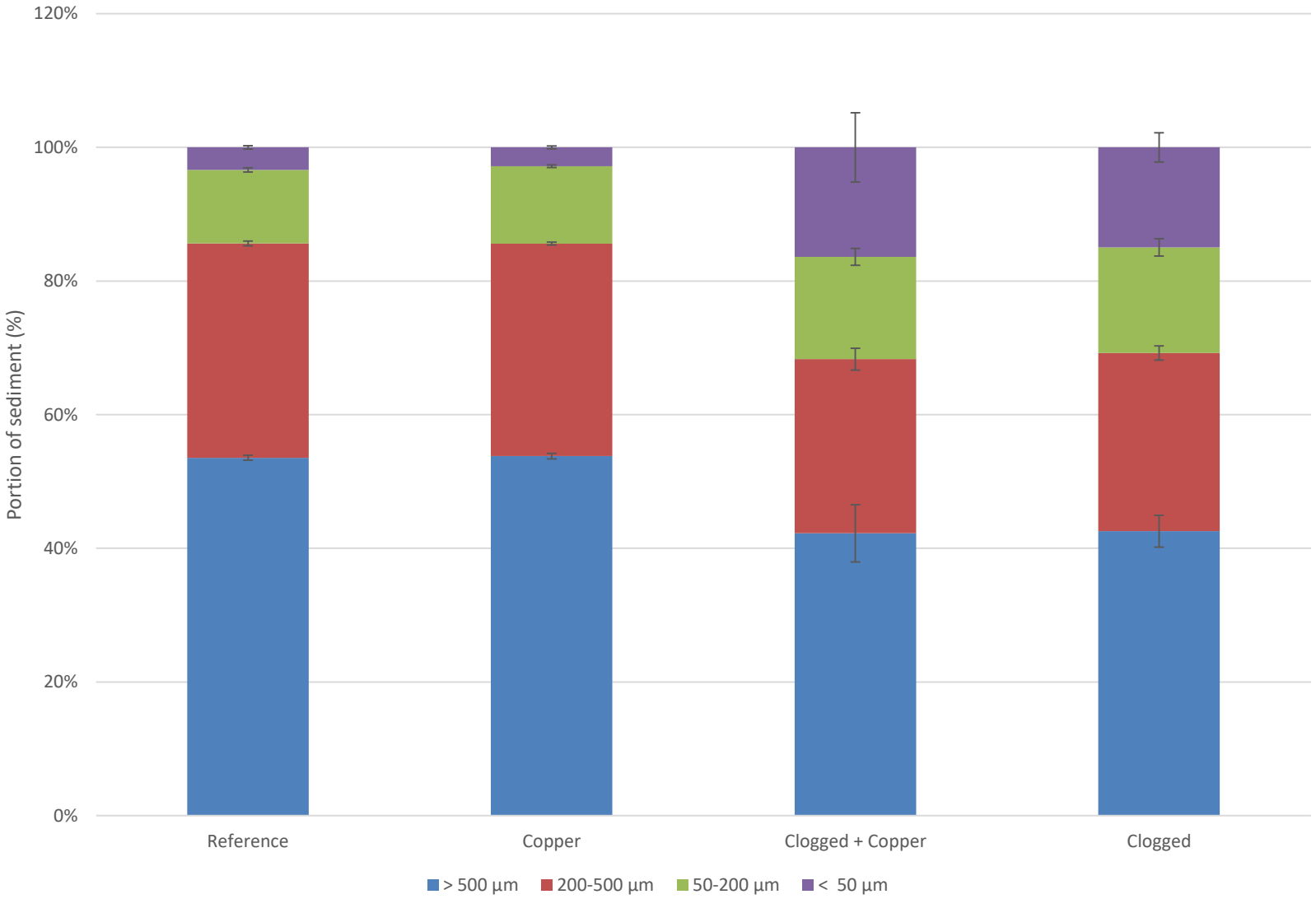
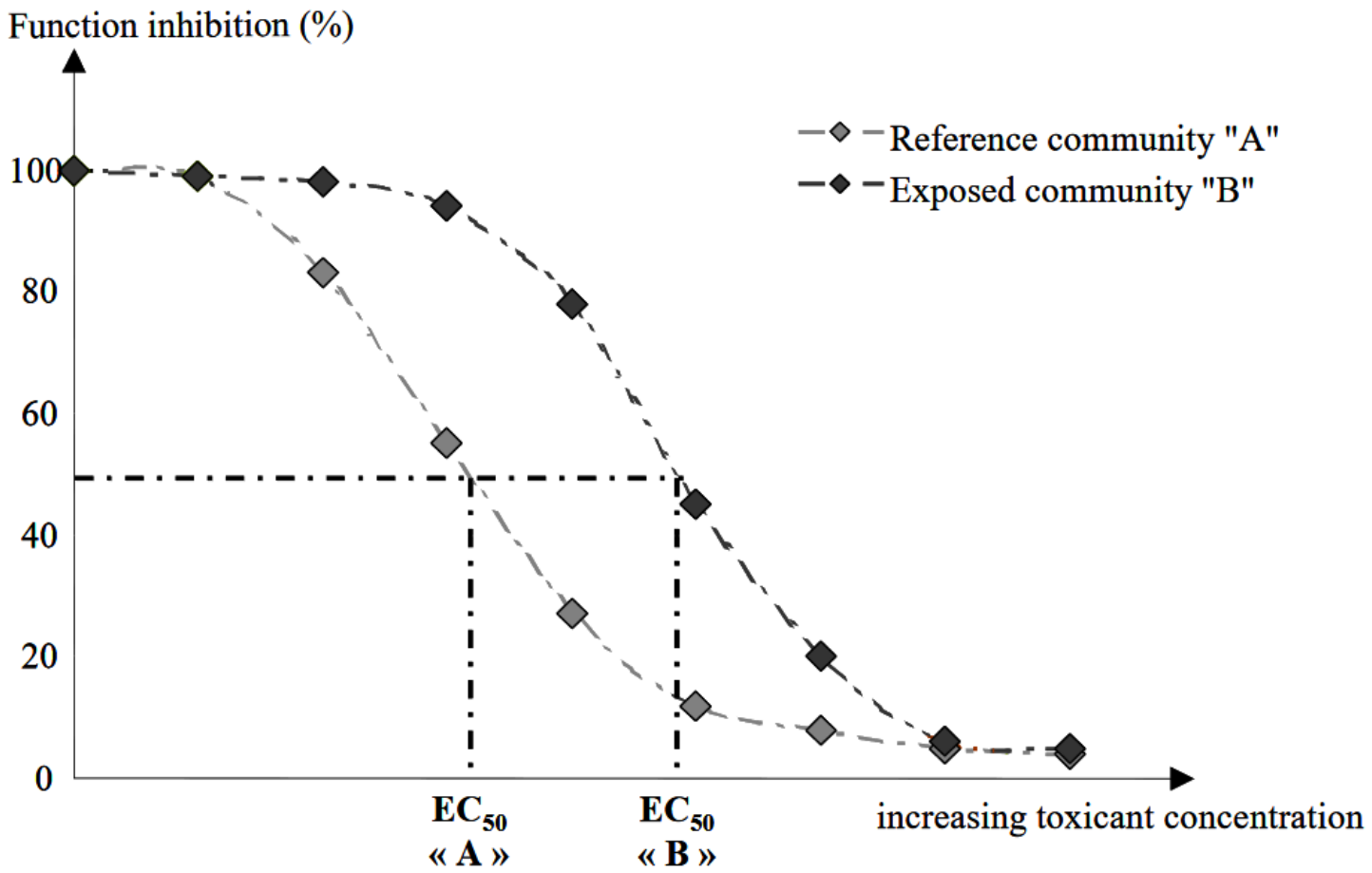
> Thank you for your attention !


120%
100%
80%
60%
40%
20%
0%
Portion of sediment (%)
Reference
Copper
Clogged + Copper
Clogged
> 500 µm
200-500 µm
50-200 µm
< 50 µm

PICT method



Tlili, A. (2013) – Rapport de thèse : Ecological significance of the induced tolerance of microbial communities in fluvial biofilms to anthropogenic contaminations