Structural and functional response of river sediment microbial communities to environmental concentrations of copper and arsenic, alone or in mixture

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Ayanleh Mahamoud Ahmed[1,2], Emilie Lyautey[2], Aymeric Dabrin[1], Chloé Bonnineau[1], Josiane Gahou[1], Bernard Motte[1], Christophe Rosy[1], Bernadette Volat[1],Stéphane Pesce[1]

[1]Irstea, UR MALY, 5 rue de la Doua, BP32108, 69616 Villeurbanne Cedex, France
[2]CARRTEL, UMR INRA / USMB, Domaine Universitaire, 73376 Le Bourget-du-Lac Cedex, France
ayanleh.mahamoud-ahmed@univ-smb.fr
ayanleh.mahamoud-ahmed@irstea.fr

Introduction

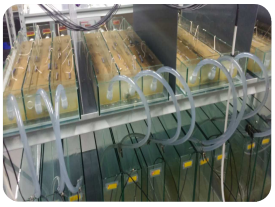
Sediments are an **essential** component of aquatic ecosystems in terms of **biodiversity** and **ecological functions**. They **receive** direct or indirect inputs from the water column or from the watershed including some **toxic** and **persistent** contaminants such as **metals**.

In sediments, **microbial communities** are major **players** in various **key** ecological functions (biogeochemical cycles). The **accumulation** of metals in sediments or their continuous input via the surface water can result in a **chronic exposure** of **benthic** microbial communities. It can impact microbial biodiversity thus leading to the **selection** of **tolerant species** and altering microbial functions. However there is a **lack** of **knowledge** about **ecotoxicological effects** of metals on **natural** sediment microbial communities.

In this context, this **microcosm study** investigated the effects **of environmental concentrations** of copper (**Cu**) and arsenic (**As**), **alone** or in **mixture** on **microbial communities** from **river sediment**. Microbial responses were evaluated in terms of **structure, functions,** and pollution induced community tolerance (**PICT**).

Material and Methods

Experimental design:



- uncontaminated sediments from the Ain River
- 12 artificial streams, 4 treatments:
  - **REF**: without metal
  - **Cu**: 40 mg Cu/kg
  - **As**: 40 mg As/kg
  - **Mix**: 40 mg Cu/kg + 40 mg As/kg
- 21 days, 4 sampling times (days 0, 7, 14, 21)

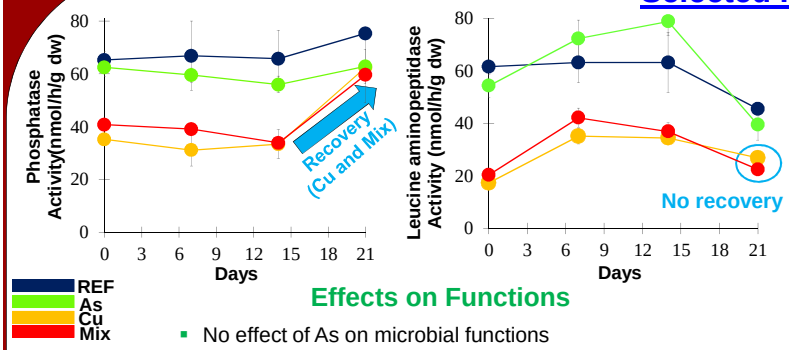
Microbial parameters:

- **Functions (C, N, P cycles)**: enzymatic and metabolic activities, genetic potential
- **Structure**: bacterial abundance (qPCR) and community composition (ARISA)
- **P**ollution **I**nduced **C**ommunity **T**olerance **(PICT)** measurements

Chemical analyses:

- **Cu and As concentrations** in sediments

Selected Results

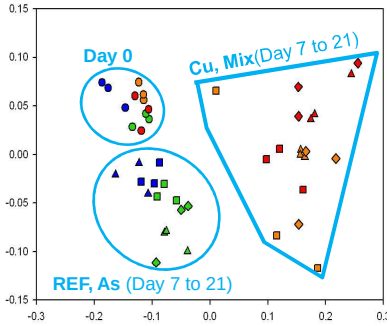


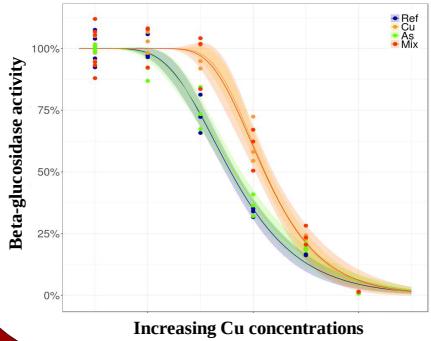
Effects on Functions

- No effect of As on microbial functions
- Fast and significant (Tukey test, $p < 0.05$) inhibition of phosphatase and leucine aminopeptidase under Cu and Mix exposure:
  - ✓ Phosphatase: recovery at 21 days
  - ✓ Leucine aminopeptidase: no recovery

Effects on Structure

- No effect of As on bacterial community composition (BCC)
- Significant changes of BCC from the first week of exposure to Cu and Mix (ANOSIM, $p < 0.05$)
- No recovery of BCC between day 7 and day 21





Pollution Induced Community Tolerance (after 21 days of exposure)

- No effect of As on community tolerance to Cu (i.e. no cotolerance)
- Significant increase of Cu tolerance on communities exposed for 21 days to Cu and Mix

Effective concentrations (EC) inhibiting 50% of beta-glucosidase activity after acute Cu exposure (4h)

	EC_{50} g/kg	Confidence Interval
REF	3.9	[2.8 ; 5.0]
As	4.1	[2.8 ; 5.4]
Cu	18.1	[12.6 ; 23.6]
Mix	10.7	[5.5 ; 16.0]

Conclusions

- **Environmental concentrations** of **As** had **undetectable** or very limited effect on microbial community **functions**, **structure** and **tolerance** induction.
- Environmental concentrations of **Cu** had **rapid** and **marked effects** on the **structure** and most of the measured **functions**.
- Most of the **mixture** effects were **similar** to individual effects of **Cu**.
- **No structural recovery** was observed and **functional recovery** at **day 21** was **dependent** of the **function tested** and the **exposure condition** (i.e. Cu or Mix).
- The **PICT response** (Cu tolerance under Cu and Mix exposure) was **consistent** with **bacterial community composition** changes.
- These findings **reveal** that **metals accumulation** in sediments can **impact** exposed **microbial communities** thus potentially **affecting** their **functional role** in **aquatic ecosystems**.

Perspectives

- **PICT:** these **first results** open perspectives for the application of PICT in the **sediment compartment** as a **biomotoring tool** for environmental risk assessment (protocols standardization and field validation under process).
- **Sediment microbial ecotoxicology**: further studies are needed to better understand the **ecotoxicological** impacts of contaminants on **natural sediment** communities and improve the **evaluation** of the **ecological quality** of sediments in a context of pollution.

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