Effects of ecological restoration on speciation and release of copper in lake sediments

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Abstract. The conclusion about the effect of macrophytes rhizosphere and mollusks bioturbation on morphology and mobility of heavy metals in the sediments is not entirely consistent. It is necessary to study further on influence mechanism of macrophytes growth and macrobenthos bioturbation on speciation and release of heavy metals in natural water body. This study intends to explore the influence mechanism of *Bellamya aeruginosa* (*Bel*) bioturbation and *Pontederia cordata* (*Pon*) growth on the speciation and release kinetics of Cu in sediment through construction of an aquatic organism-water-sediment system by indoor potted experiment. The results show that the particulate Cu in water of the control group and *Pon* treatment always maintain in lower level and the particulate Cu concentration in water of *Bel* treatment and *Pon+Bel* treatment appeared to a certain level of fluctuations at latter period. There was a significant positive correlation between the content of particulate Cu in water and the water turbidity. *Bellamya aeruginosa* bioturbation has not significantly affected the different speciation of heavy metals in surface sediments and the concentration of reducible Cu and Zn in the rhizosphere sediment was significantly lower than that in the control group.

1. Introduction

The rapid development of industry and agriculture has resulted in more and more heavy metal pollutants have been discharged into the aquatic environment [1]. Main of them were combined with particulate matter in water by adsorption, complexation, precipitation and other physical/chemical effects, then accumulated and enriched in the sediment, becoming an important accumulation base and potential pollution source [2]. In response to the disturbance of bioturbation, redox conditions change and the growth of macrophytes, the heavy metal in sediments may be released into the water column, causing potential threat to ecosystems and being toxic to the aquatic flora and fauna [3, 4].

At present, different ecological restoration measures including re-establishing the submerged macrophytes and repopulating mollusks were designed and employed in increasing numbers across the world. However, the conclusion about the effect of macrophytes and bioturbation on the morphology and mobility of heavy metals in the sediments is compatible and it is necessary to study further on influence mechanism of macrophytes growth and macrobenthos bioturbation on speciation and release of heavy metals in water body. This study intends to explore the influence mechanism of *Bellamya aeruginosa* bioturbation and *Pontederia cordata* growth on the speciation and release kinetics
of Cu in sediment through an indoor pot experiment of constructing an aquatic organism-water-sediment system.

2. Materials and methods
Twelve PVC barrels (d=30cm, h=40cm) were selected to carry out the experiment, and the upper layer of container filled with tap water (h=5 cm) and the sublayer was heavy metal pollution layer (h=30 cm, the design concentration of Cu was 100 mg/kg DW). The physical and chemical properties of sediment were as follows: cation exchange capacity (CEC) was 10.42±1.99meq/100g, organic matter (OM) was 8.25±0.34%, total organic carbon (TOC) was 4.57±0.18%, moisture content was 0.90±0.15%, and pH was 7.22±0.02.

The experiment was designed into three treatments, named *Pontederia cordata* treatment (*Pon*), *Bellamya aeruginosa* treatment (*Bel*), *Bellamya aeruginosa* and *Pontederia cordata* treatment (*Pon+Bel*) and one control treatment (Control), respectively, and there were three replicates for each treatment. The dosage of *Bellamya aeruginosa* was 1.72±0.01 kg/m²ww (wet weight) and the *Pontederia cordata* treatment was 2.41±0.21 kg/m²ww. All barrels were placed in the same condition (the average temperature was 22±3°C and light intensity was 92.5±3.2 μmol/s/m²).

Water samples were collected on 0d, 2d, 4d, 7d, 14d, 21d and 28d following start of treatment and the dissolved, particulate and total copper were determined. Sediment samples were collected on 0d and 28d after the experiment commenced and were divided into different layers of 0-2 cm, 2-5 cm and 5-8 cm and different copper forms were determined. Cu concentration was analyzed by ICP-MS. The experiments of sequential extraction procedure were carried out according to Community Bureau of Reference (BCR)'s scheme.

3. Results and discussion
The figure 1 shows that the particulate Cu concentration in water of all treatment showed a decreased tendency after the start of the experiment, due to the effect of natural sedimentation of the water and the effect of the *Bel*. The particulate Cu in the water column have shown the biggest reducing trend in *Bel* treatment and *Pon* treatment and the concentration of these two groups had reduced to 0.13±0.02 μg/L and 0.15±0.01μg/L on the second day. With the time goes on, the particulate Cu of the control group and *Pon* treatment always maintain in lower level. But the particulate Cu concentration in water of *Bel* treatment and *Pon+Bel* treatment appeared to a certain level of fluctuations at latter period, which are agree with the results by Ciutat and Boudou [5].

![Figure 1. Changes of particulate Cu concentration in water of different treatments](image-url)
During the study period, there was a significant positive correlation between the content of particulate Cu in water and the water turbidity \((Y=0.5449X-0.0876, R^2=0.988)\), as shown in figure 2. With the sedimentation of the particulate (natural sedimentation and biological action would accelerate sedimentation), the turbidity value of the water decreased, and the content of particulate heavy metal was also decreased. In addition, in the middle and late state of the experiment, the particulate Cu content in the water remained at a very low level under the normal state or the normal activities of the ring snail, and no significant sediment resuspension and release occurred and this was consistent with the previous study [6].

![Figure 2. Correlative analysis between particulate Cu concentration and the turbidity in water](image)

In this study, the bioturbation of *Bellamya aeruginosa* has not significantly affected the different speciation of heavy metals in surface sediments (data not shown), which may be related to the mode and intensity of bioturbation and the short experimental period. In the study period, the concentration of reducible Cu in the rhizosphere sediment (5-8 cm) was 73.06±1.87 mg/kg dw (dry weight), significantly lower than that in the control group \((P<0.05)\). The content of labile reduction Cu was 80.09±1.27 mg/kg dw. The content of Zn in sediments was similar to that of Cu \((P<0.05)\), that is, the content of rhizosphere sediment in the treatment group was significantly lower than that in the control group \((P<0.05)\).

| Fractions (5-8cm) | Cu (mg/kg dw) Control | Pon treatment | Zn (mg/kg dw) Control | Pon treatment |
|-------------------|---------------------|---------------|-----------------------|---------------|
| Acid extractable  | 11.22±2.02          | 13.60±3.28    | 46.13±1.16            | 53.08±1.21*   |
| Reducible         | 80.09±1.27          | 73.06±1.87*   | 68.78±2.85            | 58.66±1.12*   |
| Oxidizable        | 92.59±2.42          | 92.96±7.01    | 33.23±5.08            | 35.77±5.47    |
| Residual          | 25.21±1.30          | 23.74±1.25    | 29.62±2.69            | 30.04±3.04    |

Note: *represents the differences are significant \((P<0.05)\)

### Table 1. The effect of *Pontederia cordata* growth on the heavy metal speciation

**4. Conclusions**

During the experiment period, the particulate Cu in water of the control group and Pon treatment always maintained in lower level and the particulate Cu concentration in water of Bel treatment and Pon+Bel treatment appeared to a certain level of fluctuations at latter period. There was a significant positive
correlation between the content of particulate Cu in water and the water turbidity. The bioturbation of Bellamya aeruginosa has not significantly affected the different speciation of heavy metals in surface sediments and the concentration of reducible Cu and Zn in the rhizosphere sediment was significantly lower than that in the control group.

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