Removal of eutrophication factors and heavy metal from a closed cultivation system using the macroalgae, *Gracilaria* sp. (Rhodophyta)

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Abstract In this study, the ability of macroalgae *Gracilaria* sp. of removing eutrophication factors and toxic heavy metals Al, Cr, and Zn in a closed cultivation system is reported. The results show that the concentration of the three heavy metals decreased significantly during the experimental period in an algal biomass dependent manner. The biofiltration capacity of the alga for Al, Cr, and Zn is 10.1%–72.6%, 52.5%–83.4% and 36.5%–91.7%, respectively. Using more materials resulted in stronger heavy metal removal. Additionally, the concentration of chl-a, TN, TP and DIN of water samples from aquariums involving large, medium, and small algal biomass cultivation increased first and then decreased during the experiment. COD value of all three groups decreased with time and displayed algal biomass dependency: more algae resulting in a greater COD value than those of less biomass. Furthermore, changes in COD reflect an obvious organic particles deprivation process of algae. This is the first report on heavy metal removal effect by *Gracilaria* species. The results suggest that macroalgae can be used as a biofilter for the treatment of nutrient-enriched or heavy-metal polluted water, to which an appropriate time range should be carefully determined.

Keyword: biofiltration; COD; eutrophication; *Gracilaria* sp.; heavy metal

1 INTRODUCTION

Eutrophication of aquatic systems becomes a serious issue during industrialization. In addition, toxic heavy metals in air, soil, and water are becoming a growing threat to humanity. For example, Cr may accumulate in the body after exposure to contaminated environments (Luo et al., 2008; Xu et al., 2008). Cr and As have been classified as priority pollutants by the United States Environmental Protection Agency (USEPA) with a carcinogenicity classification of A (human carcinogen) (USEPA, 1999; Pekey, 2006).

The rapid expansion of aquaculture has led to an excessive increase in eutrophication factors, especially nitrogen and phosphorous, in aquatic ecosystems (Beveridge, 1996). These factors generally originate from pond fertilization, feed and metabolic residues of cultivated animals. Hence, there is a great demand for non-polluting strategies that minimize the negative effects of this activity. The most practical and economical approach to reducing the concentration of eutrophication factors in aquaculture areas is to treat the effluent before it is discharged into the environment. Biological treatment of contaminated effluent using macroalgae for nutrient removal has the potential to successfully reduce the amount of toxic materials in the effluent prior to discharge (Chopin et al., 2001; Neori et al., 2004). A series of studies have demonstrated the potential beneficial effects of intensive culture of seaweed during wastewater treatment and bioremediation (Schramm, 1999; Chung et al., 2002; McVey et al., 2002). Among the species of seaweed commonly used, *Gracilaria* is one of the most important because of its high yields and commercially valuable extracts (Lapointe et al., 1978; Troell et al., 1999; Wang, 2002). In the present study, we examined the removal of eutrophication factors by

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applying macroalgae *Gracilaria* sp. in a closed cultivation system. In addition, we assessed the possible use of this species as a biofilter for the removal of Al, Cr, and Zn. The goal of this study was to monitor the dynamic changes in eutrophication factors and heavy metals in treated water within a limited time and to evaluate the potential of the species for bioremediation of coastal waters.

2 MATERIAL AND METHOD

2.1 Setting of *Gracilaria* sp. biomass scale

The algae were collected from the Jangseung coast in Chonnam Province, South Korea, in the intertidal zone during low tide periods. After collection, the macroalgae were transferred to the laboratory and immediately cleaned of epiphytes and encrusting organisms. Next, they were placed in a container filled with sea water until the start of the experiment. Three scales of algal biomass were set within different 50 cm×30 cm×30 cm aquariums containing 20 L of sea water and a holding rate based on the algal wet weight of 3:2:1 (Table 1 for details). All experiments were conducted under constant light (250 μmol/m²s), photoperiod (12:12 L:D cycle) and aeration at 20±2°C. Triplicate experiments were conducted under the same cultivation conditions.

<table>
<thead>
<tr>
<th>Item</th>
<th>Large (L)</th>
<th>Medium (M)</th>
<th>Small (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight (g)</td>
<td>170±1</td>
<td>107±1</td>
<td>54±1</td>
</tr>
<tr>
<td>Approximate holding rate on wet weight</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

2.2 Determination of COD

Water samples from three algal biomass groups were collected at 3, 5, 10, 24, 48, and 72 h. COD analysis was conducted using the sodium thiosulfate method according to the standard methods (APHA, AWWA and WPCF, 1980).

2.3 chl-α and N-P analysis in aquarium

Nutrient removal experiments were conducted on the three algal groups cultivated in seawater collected from a nearby marine animal farm. Water samples were collected after cultivation for 3, 12, 24, and 72 h for the determination of the chl-α, TN, TP, and DIN concentrations, which was conducted using an Automatic Analyzer of Water Quality (Micromac Total P and Total N, Italy). The experiment was initiated with the same starting concentration of chl-α (0.74 mg/L), TN (1 mg/L), TP (0.03 mg/L) and DIN (0.25 mg/L) as indicated in Figs.2 and 3.

2.4 Heavy metal analysis

Water samples of three biomass groups were collected for measurement of the concentration of Al, Cr, and Zn after 3, 12, 24, and 72 h of cultivation. All analyses were conducted using an Inductively Coupled Plasma Mass Spectrometer/ICP-MS (Perkin-Elmer). The experiment was initiated with the same starting concentration of Al (49.923 mg/ml), Cr (21.764 mg/ml) and Zn (13.581 mg/ml) as indicated in Fig.1.

3 RESULT

3.1 Removal of heavy metal

The concentration of three heavy metals, Al, Cr and Zn, decreased significantly during the experimental period, indicating that macroalgae have a high heavy metal removal capacity (Fig.1). Furthermore, the results revealed that this decrease

![Fig.1 Changes in the concentration of Al, Cr and Zn of tested groups containing different levels of algal biomass during the study period](image1)

L-Large biomass; M-Medium biomass; S-Small biomass

![Fig.2 Changes in the concentration of chl-α and TN of tested groups with different algal biomass during the study period](image2)