Investigation on the Application of Active Algal-bacterial Granular Sludge for Hexavalent Chromium Removal from Wastewater

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Abstract

Heavy metals (HMs) are regarded as a great challenge to wastewater treatment plants (WWTPs) due to their toxic effects on aquatic organisms and human beings. As one of the typical HMs, hexavalent chromium (Cr(VI)) has significant carcinogenic and mutagenic effects to humans. Among the various methods for HMs removal, biosorption is considered as a cost-effective and environmentally friendly process. Conventional bacterial aerobic granular sludge (AGS) system has been considered as a promising biotechnology for wastewater treatment, which is now frequently attempted for HMs removal tests. As a novel biotechnology, algal-bacterial AGS is expected to largely reduce operation costs due to much less consumption of carbon source and energy in comparison to the bacterial AGS process. However, to the best of our knowledge, still, very little information is available on the application of algal-bacterial AGS biomass as a biosorbent for Cr(VI) removal or recovery from wastewater. Moreover, in most of the previous studies for concerning HMs removal by AGS, microbial activity of AGS during the adsorption process was ignored, which is, however, critical to the reuse and recycles of HM loaded AGS and the interpretation of the underlying mechanisms.

In this study, mature bacterial or algal-bacterial granules were used for Cr(VI) removal from synthetic wastewater, in terms of both total Cr removal and Cr(VI) reduction. The algal-bacterial AGS was cultivated from mature bacterial AGS, and compared with the bacterial AGS in terms of Cr(VI) removal capacity, granular stability and metal content. Besides, the influences of environmental factors on Cr(VI) removal and the responses of algal-bacterial AGS were evaluated. Moreover, the underlying mechanisms were also studied by the means of chemical fractionation and microcharacterization. Major results can be summarized as follows.

(1) Batch tests revealed that Cr(VI) biosorption onto algal-bacterial AGS was highly pH dependent and the maximum Cr(VI) biosorption capacity of 51.0 mg g^{-1} occurred at pH 2. Compared to the conventional bacterial AGS, algal-bacterial AGS

demonstrated higher biosorption capacity (9.60 mg/g vs. 8.49 mg/g under the same test conditions; p=0.0014) and better granular stability, implying that algal-bacterial AGS can be more potentially utilized as a Cr(VI) removal and recovery biomaterial for the treatment of Cr(VI)-containing wastewater.

(2) Microbial activity and granular stability of algal-bacterial AGS were maintained after 6 h biosorption at an initial Cr(VI) concentration of 5 mg/L. The highest Cr(VI) reduction (99.3%) and total Cr removal (89.1%) were achieved within 6 h at pH 2 and 6, respectively. Metal cations enhanced Cr(VI) reduction but suppressed total Cr removal. In addition, the test natural organics promoted Cr(VI) removal, especially on Cr(VI) reduction; while salinity > 5 g/L severely inhibited both Cr(VI) reduction and total Cr removal.

(3) 85.1% of total Cr was removed by active algal-bacterial AGS after 6 h under pH 6 at an initial Cr(VI) concentration of 5 mg/L, which decreased dramatically to 29.6% when sterilized algal-bacterial AGS was used. Glucose promoted Cr(VI) removal by active AGS while no effect on sterilized one. Besides, total Cr removal via bacterial AGS was inhibited by 11.2% but maintained in the case of algal-bacterial AGS when antibiotic levofloxacin added. Extracellular polymeric substances (EPS) analysis showed that more soluble microbial products (SMP) and loosely bound EPS were secreted by algal-bacterial AGS under Cr(VI) exposure. Moreover, results from Cr distribution and fractionation revealed that around 17.3% of the loaded Cr was EPS bounded and 69.2% was intracellularly accumulated, 61.7% of loaded Cr was organic bound fraction, and totally around 90.5% of Cr was in an immobile form, indicating the safety of using algal-bacterial AGS for hazardous heavy metals removal.

Results from this research are expected to facilitate the utilization of algal-bacterial AGS with high efficiency for heavy metal remediation in the real world of wastewater treatment.

Key words: Algal-bacterial aerobic granular sludge; Bacterial aerobic granular sludge; Environmental factor; Chemical fractionation; Hexavalent chromium