Enhanced phosphorus removal from wastewater by growing deep-sea bacteria combined with basic oxygen furnace slag

Weizhi Zhou[a,b*], Zhaosong Huang[a], Cuiping Sun[a], Haixia Zhao[a],Yuzhong Zhang[b]
a School of Environmental Science and Engineering, Shandong University, Jinan 250100, China
b State Key Lab of Microbial Technology, Shandong University, Jinan 250100, China
*Corresponding author. Tel.:+86 531 88361383; fax: +86 531 88361383.
E-mail address: wzzhou@sdu.edu.cn

Abstract
The removal of phosphorus from wastewater to minimize eutrophication is important yet difficult. In this study, phosphorus removal was investigated by using the deep-sea bacterium Alteromonas 522-1 in combination with basic oxygen furnace slag (BOFS) to treat synthetic wastewater. The use of deep-sea bacteria showed a satisfactory phosphorus removal at phosphorus concentration below 20 mg/L, whilst at higher phosphorus concentrations, the removal performance was reduced. However, this challenge was solved by the combination of bacteria and BOFS80 (Bio-BOFS), which not only achieved a 21.83% and 15.43% higher removal than using bacteria or BOFS only when the phosphorus concentration above 20 mg/L, but also gave a solution pH value of 7.8～8 to meet the discharge requirement compared to the treatment with BOFS only (pH value over 9.5). Moreover, Bio-BOFS also had better sedimentation property, lower sludge production and better ability to alleviate cementing of BOFS. Further, the results of SEM-EDS, AFM and XRD indicated that phosphorus was removed due to the formation of phosphate crystalline on the bacterial surface in Bio-BOFS treatment. These results provided a promising strategy for the development of combined biological treatment and steel slag in wastewater treatment.

Keywords
Wastewater treatment; Deep-sea bacterium; Bio-BOFS; Phosphorus removal; Buffering of pH

Introduction

Phosphorus removal from water to minimize eutrophication is important yet difficult, whilst steel slag as one kind of bulk industrial solid waste can cause a series of environmental issues. Application of steel slag in phosphorus removal from water has significant environmental and economic significances. However, the high effluent pH and cementing of steel slag limit its industrial application.

Deep-sea microbes play a significant role in geochemical processes, and they can adapt in some extreme environments including high temperature, high pressure, hyper saline brines, and drainage waters ranging from acidic to strongly alkaline. Alteromonas 522-1, a deep-sea bacterium, could grow in alkaline environment and has the phosphorus removal ability at lower phosphorus concentration.

In this study, deep-sea bacteria with high phosphorus removal was screened and inoculated in wastewater containing BOFS. The effects of granular size and BOFS dosage, pH value, salinity and temperature on phosphorus removal in a bacteria and BOFS combined system were systematically investigated to optimize the process conditions. A range of characterization techniques including scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM-EDS), atomic force microscopy (AFM) and X-ray diffraction (XRD) analyses were performed to reveal the mechanism of enhanced phosphorus removal.

Methods and materials

Screening and identifying of the studied strain

Studied strain was screened from 72 strains in South China Sea provided by the State Key Laboratory of Microbial Technology, Shandong University, based on the removal efficiency (RE) of an initial phosphorus concentration of 20 mg/L from synthetic wastewater, and was identified by

16S rDNA analysis as previously described in literature.

Experimental setup

The morphology of the bacteria and BOFS was observed using a scanning electron microscope, equipped with an energy dispersive X-rayspectroscope for qualitative and semiquantitative analysis of chemical composition. And atomic force microscope was used to observe the morphology of the bacterial surface at the state of living. Then, the mineralogy of the bacterial samples was evaluated by X-ray diffraction using CuKα radiation. At last, particle size of BOFS only, BOFS after phosphorus removal and BOFS of Bio-BOFS was determined by a laser particle size analyzer to reveal the particle size distribution.

Results and discussion

Effect of physicochemical properties on phosphorus removal

The effects of BOFS dosages**,** pH, initial phosphorus concentration**,** salinity and temperature on phosphorus removal were shown in Fig. 1.

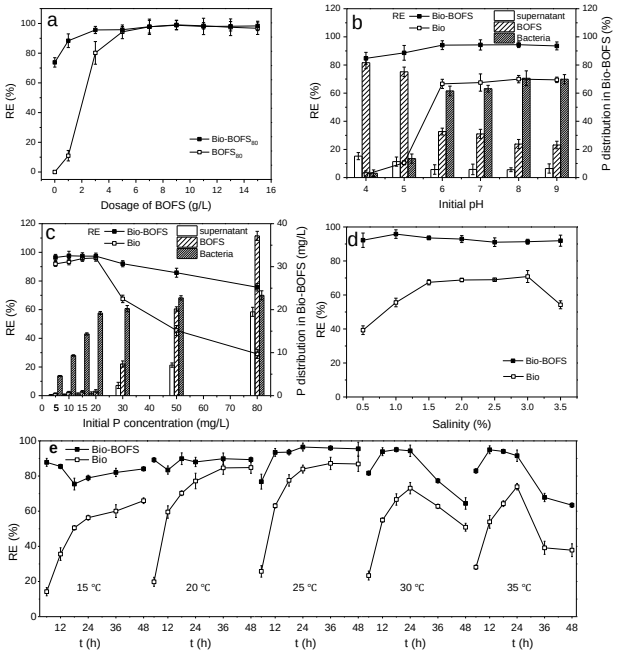

Fig. 1 Effects of (a) BOFS dosage; (b) initial pH; (c) initial phosphorus concentration; (d) salinity; and (e) temperature on the RE of phosphorus.

Conclusion

The combination of deep-sea bacterium *Alteromonas* 522-1 and BOFS demonstrated higher phosphorus removal than bacteria only and BOFS only at different conditions. The maximum phosphorus removal was obtained with the optimum initial pH (6∼9), P concentration (0∼40 mg/L), salinity (0.5∼3%), temperature (25 ^{o}C) and BOFS dosage (3 g/L). SEM and AFM results revealed the bacterial surface was very rough and surrounded by granular and crystalline substances. Collinsite and quartz were the main components of these crystals as confirmed by XRD. More specifically, the addition of bacteria not only prevented the cementing of BOFS by reducing the dosage and aggregating bacteria or/and EPS on its surface, but also slightly decreased the amount of sludge compared to Bio. Therefore, this study provided an efficient and feasible approach to remove phosphorus in wastewater.