Arsenic removal without thio-As formation in a sulfidogenic system driven by sulfur reducing bacteria under acidic condition

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ABSTRACT: Sulfidogenic treatment using sulfate-reducing bacteria has been used to remediate Acid Mine Drainage (AMD). With sulfide, As(III) can be precipitated as As_2S_3 . However, thio-arsenic formation with the pH increased by sulfate reduction, and results in the failure of As(III) removal. In this study, we proposed a novel sulfidogenic system driven by sulfur reducing bacteria (S^0RB), which worked under acidic condition to reduce elemental sulfur into sulfide without pH elevation. Then the acidic sulfide-rich effluent mixed with the arsenic-containing AMD to remove arsenic. In the long-term lab-scale test, S^0RB activities maintained for over 100 days under acidic condition (pH 4.3). Over 99% of the influent arsenic (10 mg L^{-1}) were removed by the acidic sulfide-rich solution. The results of batch tests show that, higher As removal rate can be obtained under lower pH conditions, under the same As-to-S molar ratio. The Eh-pH plot demonstrates that, sulfide production under acidic condition avoided the formation of thio-arsenic compounds (thio-As), ensuring the high removal efficiency of As(III) from AMD.

1 INTRODUCTION

Removal of trivalent arsenic is a major concern in the treatment of arsenic-contaminated acid mine drainage (AMD) due to its high toxicity. In recent years, as an attractive AMD treatment technology, sulfate-reducing bacteria (SRB) was used to remove As(III) due to the immobilization of arsenic through the reaction of H_2S with As(III) (Eq.1). However, sulfate reduction by SRB leads to a significant increase in pH (Eq.3), promoting the formation of dissolved thio-As (Eq.2) and resulting in inefficiency of arsenic removal (Johnston *et al.*, 2016). As an alternative, this study proposed a novel sulfidogenic process driven by sulfur-reducing bacteria (S^0RB) at acidic condition, to generated sulfide-rich solution with low pH to precipitate As(III) and avoid the formation of thio-As. In contrast to sulfate reduction, elemental sulfur reduction does not generate OH^- (Eq. 4), which ensures the acidic condition remains stable and control the formation of thio-As. Therefore, it is possible to efficiently remove As(III) from AMD by sulfidogenic process with S^0RB under acidic conditions. In our previous studies, high-rate sulfur reduction process under neutral and alkaline condition has been achieved (Sun *et al.*, 2017). However, sulfur reduction under acidic condition has not been tested yet, and the performance of As removal shall be investigated.

2 METHODS AND MATERIALS

In this study, we established a lab-scale sulfidogenic arsenic removal system including a sulfur reduction reactor (SRR) and an arsenic-sulfide precipitation tank. The effluent of the sulfur reduction reactor is mixed with arsenic-contaminated acid mine drainage at a volumetric ratio of 1:4 in the arsenic-sulfide precipitation tank. The sulfur reduction reactor was packed with sulfur lumps and fed with 600 mg C/d sodium acetate. The arsenic removal system operated continuously for more than 140 days. The influent pH of the sulfur reduction reactor gradually decreased from 7.2 to 4.0 within 40 days, then remained stable for 100 days. In addition, batch tests were also carried out to study the effect of pH and As/S molar ratio on arsenic removal.

3 RESULTS AND DISCUSSION

Long-term performances of the elemental sulfur reduction and arsenic removal system are shown in Figure 1. The effluent pH gradually decreased from 7.5 to 4.5, and S^0RB activities kept stable to produce 50–150 mg L^{-1} H_2S for arsenic removal. Under neutral condition, the efficiency of the As(III) removal was 60–80%, and then increased to more than 99% when the effluent pH decreased to 4.5. The results of

Figure 1. The performances of elemental sulfur reduction and arsenic removal system (a. the inlet and outlet pH and concentration of the effluent H₂S; b. the removal efficiency of arsenic in the arsenic and sulfur reaction tank).

Figure 2. The removal efficiency of arsenic S with As/S, and pH changes.

batch tests showed that the arsenic removal efficiency decreased with the increase in pH from 4.5 to 7.5 (Fig. 2). When the pH was 4.5, the efficiency reached more than 99% when As/S molar ratios were less than 0.35. The results of these batch tests were consistent with the performance of the sulfidogenic arsenic removal system. It explained the high efficiency of