Effect of organic carbon sources and COD / sulfate ratios on the Innovative Integrated Reactor System for Simultaneous Removal of Carbon, Sulfur and Nitrogen and Elemental Sulfur Reclamation

Ye Yuan*, Chuan Chen*, Dezhi Sun, Cong Huang, Xijun Xu, Nanqi Ren, Aijie Wang*

*State Key Laboratory of Urban Water Resource and Environment, Harbin Institute of Technology, Harbin 150090, P. R. China. (E-mail: *yuanye_19840915@yahoo.cn*; *echo110244@126.com*; *waj0578@hit.edu.cn;sundezhi@bjfu.edu.cn*;)

Abstract

The paper investigated the effect of different carbon sources and COD / sulfate ratios on the innovative integrated reactor system for simultaneous removal of carbon, sulfur and nitrogen and elemental sulfur (S^0) reclamation. The system mainly consisted of an expanded granular sludge bed (EGSB) for sulfate reduction and organic carbon removal (SR-CR), an EGSB for autotrophic and heterotrophic denitrifying sulfide removal (A&H-DSR), a biological aerated filter for nitrification, and a sedimentation tank for sulfur reclamation (SR). Three carbon sources (lactate, molasses and starch) were examined. The experiments indicated that the sulfate can be fully reduced in the SR-CR unit when using the three carbon sources through adjusting the hydraulic retention time (HRT) and loading rate. Meanwhile, the A&H-DSR and AN unit also need to match the HRT and loading rate with the SR-CR unit according to the different Org-C/S^{2-}-S/NO^{3-}-N ratios by adjusting nitrification reflux ratio. Different Org-C/S^{2-}-S/NO^{3-}-N ratios will affect S^0 reclamation rate. Average 90% S^0 conversion rate was achieved in the A&H-DSR when using the lactate as the carbon source for influent of the CR-SR unit at HRT of 12h. Average 87% and 78% S^0 conversion rate were obtianed, respectively, when using molasses and starch as the carbon sources at HRT of 12h and 17 h. So, using lactate as the carbon source to study the influences of COD / sulfate ratios on the system. Influent sulfate concentration of the system was fixed to 1,500 mg/L and lactate was added to make COD/SO_4^{2-} =1.3:1, 1:1, 2:1. The influent COD/SO_4^{2-} ratio of 1.3 and the reflux ratio of 4.0 could provided optimum Org-C/S^{2-}-S/NO^{3-}-N ratio to the A&H-DSR reactor for obtaining maximum production of sulfur.

Keywords

Different carbon sources; COD/SO_4^{2-} ratio; sulfate reduction; autotrophic and heterotrophic denitrifying sulfide removal; nitrification; sulfur reclamation;

INTRODUCTION

Sulfate in the wastewater is first reduced to sulfide by Sulfate reducing bacteria (SRB) under anaerobic condition, and then the produced sulfide is oxidized by Sulfide oxidation bacteria (SOB) to elemental sulfur (S^0). The biotechnologically produced elemental sulfur suspension have colloidal characteristics that can be collected together(Janssen, Keizer and Lettinga 1994). If the produced elemental sulfur (S^0) is not received any dispose, it will be oxidized to sulfate again. Sulfate-laden organic wastewater from pharmaceutical industry, food fermentation and paper pulp. Such kind of wastewater usually contains high levels of sulfate, ammonia and carbon compounds, which can contaminate the receiving waters, endanger life, and cause eutrophication if it is not well treated before discharge (Cadena and Peters 1988; Bahambhani and Singh 1991; Chen et al. 2008a). Therefore, the study of the effect of different carbon sources and COD / sulfate ratios on this integrated reactor system is very significant. There's no such report on the effect of different carbon sources on S^0 reclamation.

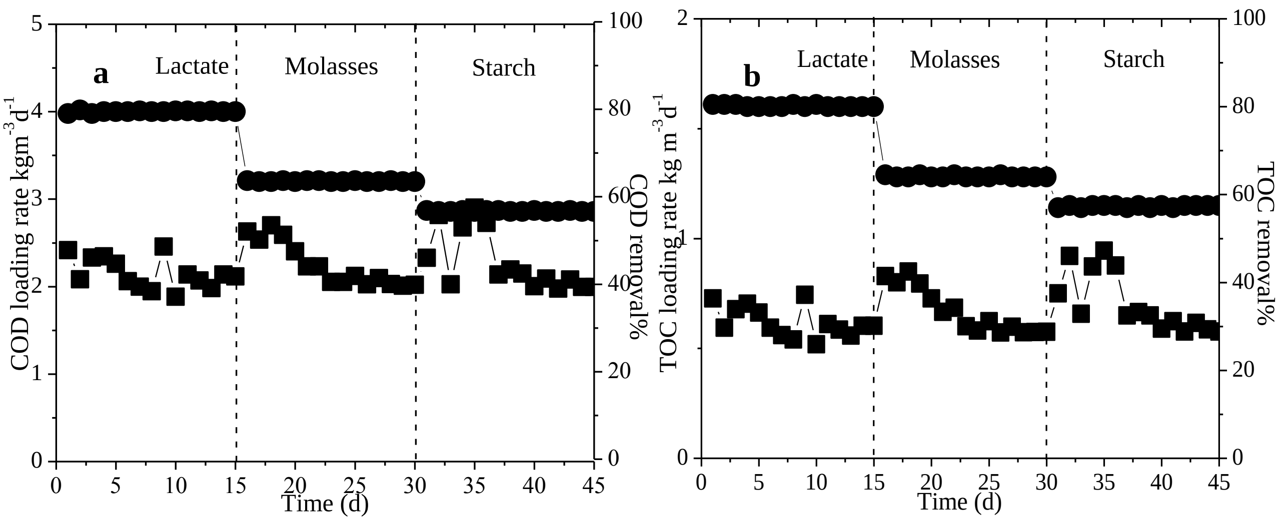
MATERIALS AND METHODS

The total dissolved sulfide ($H_2S_{(aq)}$, HS^- and S^{2-}), COD, TOC, suspended solids (SS) and volatile suspended solids (VSS) were determined according to standard methods (APHA, 2005).

RESULTS AND DISCUSSION

Operation of the integrated reactor system for simultaneous removal of carbon, sulfur and nitrogen. Operational parameters on production of elemental sulfur in the system were investigated, including COD/SO_4^{2-} ratios and hydraulic retention time (HRT) for SR-CR reactor, Org-C/S^{2-}-S/NO^{3-}-N ratios and HRT for A&H-DSR, ammonia concentrations and HTR for AN and reflux ratios between the A&H-DSR and AN reactor. The A&H-DSR reactor was connected to the SR-CR reactor at the optimum HRT of 12h. Meanwhile, the optimum reflux ratio of nitrification between A&H-DSR and AN was 4, under these conditions, SR-CR and AN reactor could provide optimum Org-C /S^{2-}-S/NO^{3-}-N ratio for realizing maximum S^0 conversion rate in the A&H-DSR reactor. Than, the system demonstrated 93% chemical oxygen demand (COD), 78% nitrogen and 93% sulfate removal efficiency. The average reclaimation rate of elemental sulfur (S^0) was 60%.

Effects of different carbon sources on elemental sulfur conversion rates. Using the lactate-containing water as the influent of CR-SR unit, Org-C/S^{2-}-S ratio in the effluent of the SR-CR was nearly 1:1 at HRT of 12h and average 90% S^0 conversion rate was achieved in the A&H-DSR (Fig. 6). VFAs in the effluent mainly included acetic which accounted for 95% of total carbon. When the influent of CR-SR unit changed for molasses-containing water, the Org-C/S^{2-}-S ratio in the effluent of the SR-CR was kept at nearly 1:1 and average 87% S^0 conversion rate was gained in the A&H-DSR unit at HRT of 12h. The effluent of using molasses-containing water contained acetic, ethanol, propionic, butyric, valeric acid, and undegraded molasses, with the proportion of 80%, 2%, 6%, 4%, 1% and 7%, respectively. When the HRT was increased to 17 h, starch-containing water as the influent of SR-CR unit could be well treated to maintain the effluent at Org-C/S^{2-}-S ratio of 1:1, resulting in about 78% of S^0 conversion rate in the A&H-DSR. The main carbon source of effluent was acetic which made up 80 percent of the total VFAs, and ethanol, propionic, butyric, valeric acid, and undegraded starch accounted for 4%, 5%, 3%, 2% and 4%, respectively.



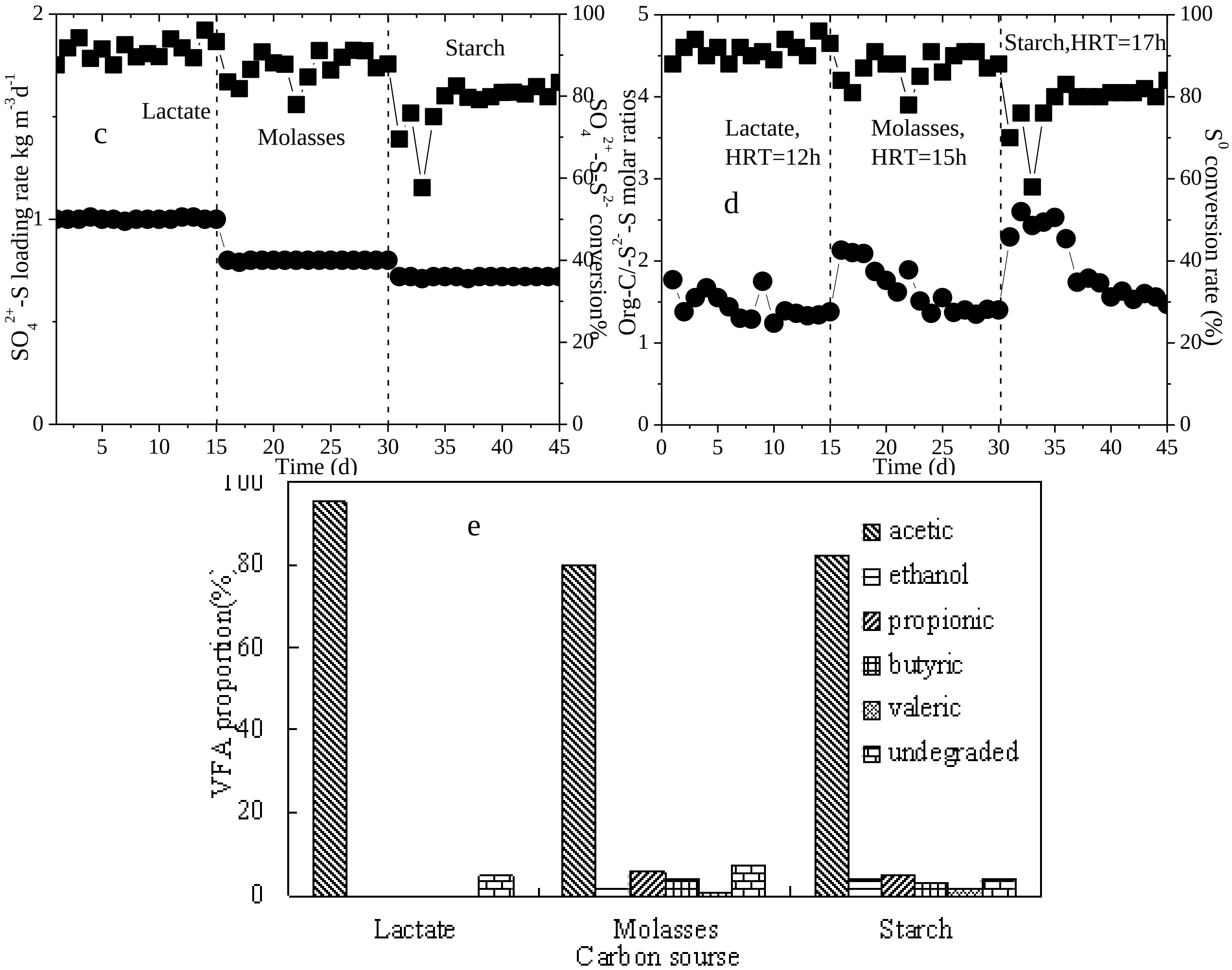


Figure 1. Performance of effects of different carbon soures on S^0 production rate. SR-CR: (a) COD Loading rate(●), COD Removal(■). (b) TOC Loading rate(●), TOC Removal(■). (c) SO_4^{2-}-S Loading rate(●), SO_4^{2-}-S→S^{2-} Conversion(■); A&H-DSR: Org-C/S^{2-}-S ratios(●) and S^0 production rate(■); (e) VFAs in the effluent of SR-CR unit.

Effects of different COD / SO_4^{2-} ratios on elemental sulfur conversion rates. Influent SO_4^{2-} concentration of the system was fixed to 1,500 mg/L, lactate was added to make COD/SO_4^{2-} =1.3:1, 1:1, 2:1 (Fig. 2). The system operated at optimum operation parameters described in part 1 above.

At COD/SO_4^{2-} ratio of 1.3:1, Org-C/S^{2-}-S ratio in the effluent of the SR-CR declined from 3.0 to 1.29, resulting in supporting optimum Org-C/S^{2-}-S ratio for average 90% of S^0 conversion rate in the A&H-DSR.

At COD/SO_4^{2-} ratio of 1:1, Org-C/S^{2-}-S ratios in the effluent of the SR-CR dropped to about 0.7, which could not provide sufficient organic carbon sources for denitrifying sulfide removal, leading to only 70% of S^0 conversion rate.

When the COD/SO_4^{2-} ratio increased to 2, Org-C/S^{2-}-S ratio in the effluent of the SR-CR was improved to about 3. The decreased S^{2-} concentration and increased Org-C concentration in the effluent of the SR-CR led to 30% of S^0 conversion rate in the A&H-DSR. Hence, the optimum COD/SO_4^{2-} ratio of 1.3:1 can provide appropriate Org-C / S^{2-}-S ratio for maximum S^0 conversion rate in the system.

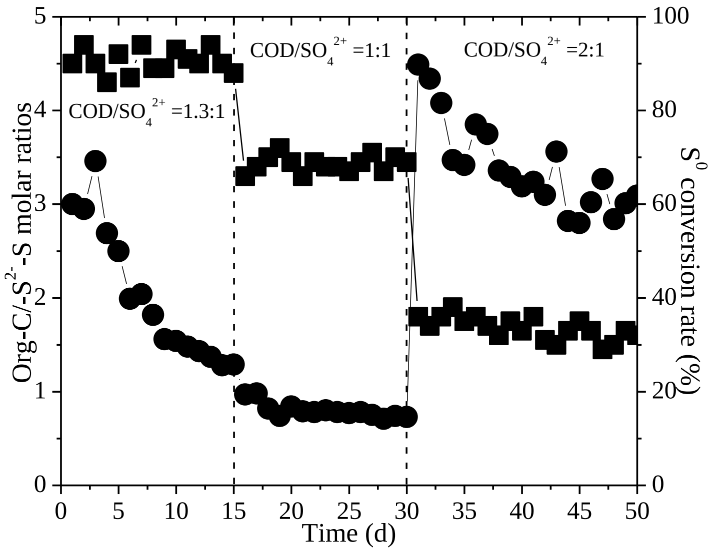


Figure2. Performance of effects of different COD/ SO_4^{2-} ratios on S^0 production rate. Org-C/S^{2-}-S ratios(●) and S^0 production rate(■).

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