

Anaerobic ammonium nitrogen oxidation and sulfate reduction in psychrophilic conditions

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Abstract

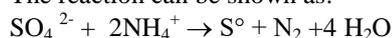
Investigations of simultaneous removal of ammonium and sulphate were carried out in anaerobic laboratory bioreactor - upflow anaerobic filter (UAF). The process was operated in psychrophilic conditions. Temperature was maintained constant at $20 \pm 2^\circ\text{C}$. Synthetic wastewater containing ammonium chloride and sulphate magnesium was used as the feed for the bioreactor in experiment. The concentration range of ammonium and sulphate in the wastewater were kept at $22\text{--}27 \text{ mgNH}_4\text{-N/L}$ and $80\text{--}130 \text{ mg SO}_4\text{-S/L}$, respectively. About 80% of the sulphate entering the reactor was removed from the liquid phase, of which 30% appears as S-S^{2-} in the effluent. During sulphate conversion were formation also $\text{S-H}_2\text{S}$ in the biogas and elemental S. Raman spectroscopy (RS) were performed to confirm the presence of sulphur in the sludge. Owing to the reduction sulphate and oxidation ammonium, about 20% nitrogen initially present in the influent was removed appearing as N_2 in the gas phase.

Keywords: ammonium and sulfate removal, reactor UAF, psychrophilic conditions

1. Introduction

In order to remove ammonium and sulfate in wastewater biological removal technologies are commonly used. Anaerobic ammonium oxidation (anammox) is biotechnology that uses ammonium oxidation into nitrogen gas under anoxic conditions with nitrite as electron acceptor.

Under anaerobic conditions sulfate can be used as terminal electron acceptor by sulfate - reducing bacteria that couple the oxidation of the substrate (organic or inorganic) to the reduction of sulfate to sulfide and toxic H_2S . The biological reaction (process), which produces molecular nitrogen and elemental sulfur using ammonium as the electron donor and sulfate as electron acceptor is called sulfate-dependent anaerobic ammonium oxidation. The reaction can be shown as:



The dominant technologies are sequential batch reactors (Laureni et al. 2015) and moving bed reactors, and the best-performing biomass forms: granular sludge and biofilms (Gilbert et al. 2015), as well as combinations of these technologies (Laureni et al. 2015). The optimum temperature for the anammox process and sulfate reduction is approximately $30\text{--}40^\circ\text{C}$ (Sobotka et al. 2016).

Based on the review of previous studies and achievements regarding the use of the nitrite process - anammox at low temperatures, it results that it is possible to effectively remove ammonium nitrogen from municipal sewage at a temperature of 15°C on a pilot scale (Ma et al. 2016, Trojanowicz et al. 2016, Taotao et al. 2015, Awata et al. 2015), and even 12°C on a laboratory scale (Laureni et al. 2015). Until now, the process of simultaneous removal of ammonium and sulphate in psychrophilic conditions remains unknown. In this study, the feasibility of the aforementioned process was tested using a upflow anaerobic filter for the treatment of synthetic wastewater in psychrophilic conditions.

2. Materials and Methods

The simultaneous ammonium and sulfate removal was explore in the reactor. The bioreactor was a reformative reactor from the up-flow anaerobic filter (UAF). UAF was constructed as plastic tube with 2,7 liters volume filled in with propylene rings on which a film of microorganisms had grown. The reactor was fed with the synthetic wastewater (Ma et al. 2012) using a peristaltic pump to maintain a constant flow rate.

The hydraulic retention time (HRT) kept was one to two days.

For the UAF reactors were used as the inoculums mixed seed culture of anoxic and activated sludge from a local treatment plant operated in a full scale.

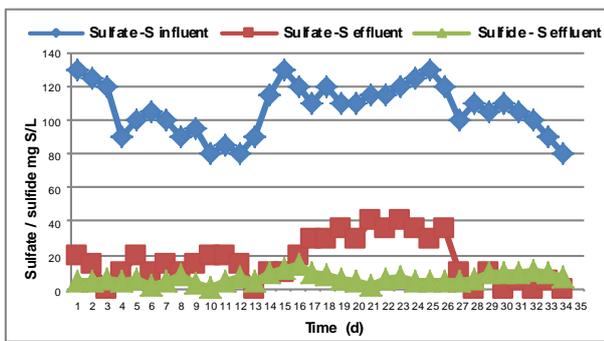
The analysis of pH, $\text{NH}_4^+\text{-N}$, SO_4^{2-} , S^{2-} , COD were measured according to standard methods (APHA, 2005). The volume of gas produced in the reactors was measured by water displacement method. Biogas composition (CH_4 , CO_2 , O_2 and H_2S) was analyzed daily, using a gas analyzer Gas Data GFM 416.

3. Results

The analysis of the nitrogen and sulphur compounds in the liquid and gas phases indicated simultaneous ammonium and sulphate removal in the reactor. After star-up and acclimatization of this process for 35 days, the average effluent concentrations of ammonium and sulphate were 20 and 18 mg/L, respectively.

The reactor performance in terms of sulfate and ammonium removal efficiencies is shown in Fig. 1.

(a)



(b)

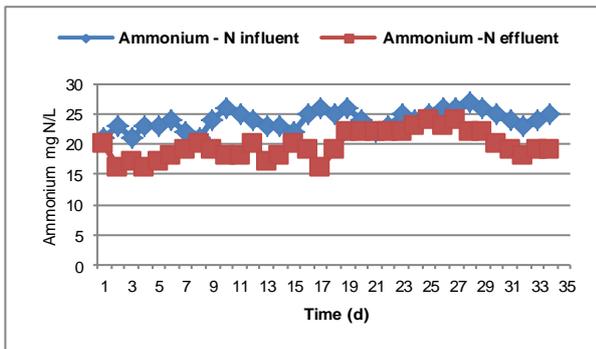


Fig 1. Changes of sulfate – S concentration (a), ammonium –N concentration (b) in the influent and effluent

During sulphate conversion were formation elemental S (Fig.2). The spectra obtained by Raman microscopy allowed to identify the sulfur present in the analyzed wastewater obtained as a result of sulfate reduction in the anaerobic process (Fig.3).

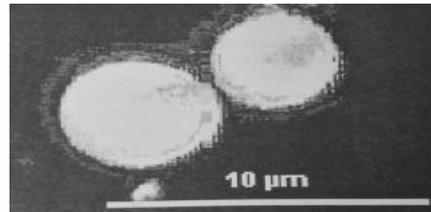


Fig. 2. Elementary sulfur of spore – dark field vision at 100 x increase

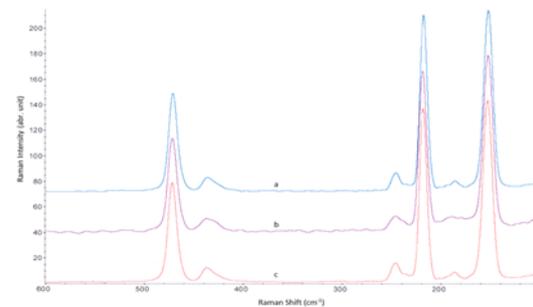


Fig.3. Raman spectroscopy of sulfur: (a) days 1-15, (b) days 16 – 35, (c) standard sample of sulfur

4. Conclusions

The simultaneous removal of ammonium and sulfate was started up successfully in the in this experiment by used sulfate as elektron akceptor. The analysis of the nitrogenous and sulphur compounds and the mass balances of these compounds in the liquid and gas phases indicated an evolution of nitrogen and sulphur in the reactor. About 80% of the sulphate entering the reactor was removed from the liquid phase, but in days 16-26 sulfate removal efficiency decrease. Only 20 % nitrogen initially present in the influent was removed. Low temperature (psychrophilic conditions) is associated with ammonium oxidation because negative impact on growth metabolism, enzyme activity and mass transfer rate.

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